

## The relative effects of road markings on cycle stability

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### **ABSTRACT**

Participants completed 1600 trials over 20 objects on an instrumented racing cycle. Recordings of lateral acceleration and handle bar angle were combined to form a single measure of instability and compared to recordings of normal riding over smooth asphalt. New techniques to control for learning effects were used within an experimental procedure that controlled for the angle and speed of the cyclist. Sixteen of the objects including rough ground, a round utility access cover, oversized thermoplastic lines (7mm thick), and an audio-tactile line show significant effects on the stability of cycles. Traditional chlorinated rubber lines, one thermoplastic line, and a waterborne line show no significant impact on cycling. Relative assessment of the effect of the objects on cycle stability is reported and the validity and reliability of the method is discussed.

Key Words: Bicycle, line markings, objects, road markings, safety, stability

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## **1 INTRODUCTION**

Munster et al. (2001) found that 28% of cyclists injured in cycle-only accidents attribute the event to road features. The most common single road feature cited was loose gravel (34%), while a grouping of surface irregularities (e.g., potholes and uneven surfaces) was frequently cited (39%). Cycle-only accidents have also been associated with thermoplastic line markings (Munster et al., 2000). However, apart from a few investigations on the effect of road markings (i.e., Munster et al., 1999; Plant, 1995) and milled in rumble strips (i.e., Outcalt, 2001; Torbic et al., 2001), there has been little research conducted on the effect of objects on cycle stability.

Munster et al. (1999) investigated the effects of thermoplastic lines on cycle stability with tests conducted by riding over thermoplastic lines at an approach angle of between 0 and 10%. The physical effects of the line on cycle stability were subjectively assessed by the cyclists and appraised by an observer. No detectable effect on cycle stability was found with thermoplastic line markings below 2.1 mm. Effects were found for markings around 4 mm, and consistently observed for markings above 7 mm in height.

Plant (1995) investigated the effects of thermoplastic audio-tactile markings on cycle stability with tests conducted by riding over the lines at an approach angle of between 5 and 20°. The effect of the markings on the subjective impressions of comfort and handling were measured. Plant (1995) concluded that such markings should not cover areas that cyclists are likely to cross.

Many types of road marking exist and are used in different road contexts. For example, profiled thermoplastics are designed for wet weather and structured

markings are designed for snow. Some markings contain glass beads of different sizes (and with different modes of application) to increase retroreflectivity for improved visibility. These markings may also have calcite added to compensate for the apparent increase in slipperiness due to the glass beads.

Methods used to investigate cycle stability typically rely on the subjective impressions of actual cyclists (Bucko & Khorashadi, 2001). Cycle stability has been evaluated by verbal reports of cyclists' perceptions and by observation of cycling (e.g., Munster et al., 1999). These approaches lack precision and introduce a potential bias into the results because the cyclists may evaluate the risk of instability by their impression of the object rather than its effect on their riding.

A few researchers have used electronic equipment to measure the effect of objects on cycles and motorcycles (Martinez, 1977; Bayer & Nels, 1987; Outcalt, 2001; Torbic et al., 2001). Physical measures used have included handlebar torque, handlebar angle, vertical acceleration, and lateral acceleration. Of the studies that have used physical measures, one found too much "noise" in the measurements from two thirds of the trials to analyse (Torbic et al., 2001), two used the subjective experience of riders to make conclusions instead of the physical measures (Martinez, 1977; Outcalt, 2001), and one failed to find any effect of the object studied (Bayer & Nels, 1987). Indeed Bucko and Khorashadi (2001) state that the subjective experience of the rider is more useful than physical measures. In the present study, subjective and physical measures will both be collected. Handlebar angle and lateral acceleration are measured because either or both of these will be affected if stability is compromised (Jones, 1970).

Because cycle stability is a dynamic process involving environment, cycle, and cyclist, the effect of objects on cycle stability is best studied with actual cyclists riding over objects. However, using human participants introduces confounding factors that need to be controlled. Participants might compensate for the effect of an object or improve their ability to ride over the test lines with repeated experience. In this case the true effects on cycle stability are masked in experimentation through learning and anticipation effects. The results from such a study would underestimate the effect of an object on cycle stability and not generalise to a population of riders encountering the object for the first time.

The present study uses physical and subjective measures, within a procedure designed to control for confounding factors, to establish the relative effects of road markings and common road objects on cycle stability. Effects on cycle stability are examined relative to a smooth asphalt surface and an audio-tactile line.

## **2 METHOD**

### **3.1 PARTICIPANTS**

Seventeen participants were involved in a within subjects repeated measures design. Six of the participants rode over all 20 objects 12 times, and completed a number of trials over blank asphalt to establish a baseline of riding behaviour. These six participants were paid for their time and were selected because they did not usually cycle. Eleven participants were experienced cyclists, recruited through cycling groups, who volunteered their time and rode over a selection of road markings. Table 1 shows the median days cycled per week, median kilometres cycled per week on sealed roads, median speed when cycling on sealed roads, number of males and

females, median age, median height, and median weight for the two groups of participants.

### **3.2 MATERIALS**

Apart from the 20 objects and their attendant characteristics (as outlined in Table 2 with selected line markings shown in Figures 1, 2, and 3), the most important equipment used in this study was the instrumented racing cycle. A racing cycle is considered the most vulnerable of cycle types presently using the road network (Plant, 1995). The instrumented cycle had general purpose racing tyres of dimension 700 x 22/23C<sup>1</sup> and these were inflated to approximately 70 psi. Attached to the frame and steering pinion was a potentiometer to measure the angle of steering every 1/10 of a second. An accelerometer was mounted under the seat to measure lateral acceleration every 1/10 of a second. The cycle also carried a speedometer to assist the cyclist, though cycle speed was measured externally using two laser trip beams (Beam 1 and 3, Figure 4). A logger on the cycle recorded the main measures, and these were synchronised to the point of cycle contact with the object by a single trip beam (Beam 2, Figure 4) placed over the object and linked to a telemetric device. In this way measures of handle bar activity and lateral acceleration were recorded and matched to the position of the cycle.

FIGURES 1,2, 3, and 4 here

Two other pieces of equipment were required: a laser mounted to the frame of the cycle and a target board. The laser was similar to those that might be used in high quality laser pointers, and visible at a distance of 70 metres when reflected on the

target board. To assist visibility of the laser in bright daylight conditions the target board was covered with reflective material, the same as that used for road signage. Cyclists could also choose to wear special glasses to enhance the visibility of the laser.

### **3.3 PROCEDURE**

Munster et al. (1999) and Plant (1995) have noted that the angle of approach of road markings is a factor in cycle stability, with narrower angles appearing to increase the effect of a line on cycle stability. In the present study, cyclists were guided to lines at a 5° angle using cones, and this angle was maintained during the cyclists approach by aiming a cycle-mounted visible laser at a target board (see Figures 4 and 5).

Cyclists were guided to the other obstacles at a 90° angle.

FIGURE 5 here

The presence of water often decreases grip and this may adversely affect cycle stability. With the exception of the loose gravel, all objects were cycled over when wet as in Munster et al. (1999). Water was applied to the objects and to 2 m of the cycle path in front of the objects, prior to each participant starting to ride the course, so that the greatest effect that the object would have on cycle stability could be established.

Participants were asked to do three tasks designed to prevent a learning effect and to distract attention from the object. These tasks were intended to simulate real cycling actions, such as those required to check traffic when merging and those used

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<sup>1</sup> Tyre dimensions: 700 = circumference, 22 = 622mm inner diameter, 23 = 623 mm

to come to a quick stop. At the end of each completed trial a judge determined whether the participant “passed” or “failed” the task, and this was told to the participant to maintain a standard of task performance.

The three tasks were as follows:

(1) Target: after breaking the first laser beam cyclists were instructed to keep the frame-mounted laser pointer on the target board. A pass was scored if the laser was visibly on the target board when the cycle was just prior to contact with the object (i.e., laser beam 2).

(2) Lookback: after breaking the first laser beam cyclists were instructed to look back and report the time indicated by a large clock held by the experimenter. On each trial the experimenter changed the position of the clock hands. A pass was scored if the time given by the participant matched that on the clock card.

(3) Brake: after breaking the first laser beam participants were told “Brake”. They were instructed that this meant to come to a complete stop, and place one foot on the ground. They were also told that they would only have a short period of time to stop, so it was important to respond when the instruction “brake” was given. A pass was scored if the cycle braked on or before contact with object (i.e. laser beam 2).

A complete trial required the cyclist to ride from the start position at speed aiming the laser pointer at the target board (in case of a request to ‘target’), cross through the laser trip beams (to record speed and the time that the object was hit), perform the task requested, traverse the object, and return to the start position. After each trial

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outer diameter, C = continental racing tyre.

the riders were asked for a subjective evaluation of the influence of the object on ride stability: “On a scale of 0-10 (with 0 being not noticeable and 10 being caused dangerous instability) how much effect did the object have on your ride stability?” The entire procedure constituted a completed trial.

Each participant had 12 trials of the object, three trials with each task and three with no task. There were 20 randomised orders in which the tasks were presented. An order of task presentation for each of the 12 trials over an object was randomly selected from the 20 orders prior to the participant riding. To obtain before and after measures for each trial, the data from the physical recordings of the instrumented cycle 1.5s before and after object contact were selected. These data were then averaged for the three trials of each task.

### **3 RESULTS**

#### **3.1 CALCULATION OF THE COMBINED MEASURE OF CYCLE STABILITY**

The data collection method used here permits separate analysis of four measures: the average handle bar position, the average lateral acceleration, the range of handle bar position, and the range of lateral acceleration<sup>2</sup>. Such an analysis would not give an assessment of the overall effect of an object on cycle stability and hence not enable objects to be ranked in terms of their effect on cycle stability. To do so requires these measures to be combined into one measure of cycle stability.

When cycling on a level piece of even asphalt, such as before the object, a cycle can be assumed to be in a normal and stable state. The relative contribution of the four measures to cycle performance under this stable state can be ascertained by forcing

the derivation of one factor using a principal components factor analysis and looking at the factor coefficients of the measures. These factor coefficients can be used to combine the measures taken before the object into one measure of cycle stability. Assuming that the four measures contribute the same degree to cycle performance in an unstable state as they do in a stable state, the factor coefficients from before the object can also be used to combine the measures after the object into one measure of cycle stability.

The factor coefficients from a principal component analysis performed on the before object data are shown in Table 3. The before object data was regressed against the after object data for each measure to obtain residuals free of variance due to differences before the object. The residuals for each measure were then multiplied by their respective coefficient and the results were added together to obtain the combined measure.

### **3.2 COMPARISON OF THE EFFECT OF OBJECTS WITH BASELINE**

Table 4 shows the results of univariate Analysis of Variance (ANOVA) comparing the combined measure for each object with that from the baseline condition. It can be seen that 16 of the 20 objects resulted in a significantly higher mean of the combined measure compared with baseline. The means are ordered by the difference between the baseline and object means from negative to positive. A negative number indicates that an object has an adverse effect on stability. It can be seen that line markings are ranked below the other objects. It can also be seen that although the 7 mm high line markings create some of the greatest instability in comparison to other

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<sup>2</sup> Analysis of the effects of objects on individual measures has been performed and is available from the authors on request.

line markings, 3 mm and 3.5 mm high lines also appear to create considerable instability. Instability does not appear to be a simple function of height.

### **3.3 COMPARISON OF THE EFFECT OF ROADMARKINGS WITH AUDIO TACTILE LINE**

Table 5 shows comparisons for the combined measure with each line marking compared to the audio-tactile line, and is ordered by the difference between this line and the individual line markings from negative to positive. A negative number indicates that a line marking causes more instability than the audio-tactile line. Rough ground, the round utility access cover, domes, and loose gravel create more instability than the audio-tactile line. The conventional paints (waterborne paint lines 15 and 2, and the chlorinated rubber line) cause less instability than the audio-tactile line. The remaining obstacles cause a similar level of instability to the audio-tactile line.

### **3.4 EFFECTS OF OBJECT TYPE ON PARTICIPANT RATING**

Table 6 shows the results of ANOVAs for the participant rating of each object compared with that of baseline, ordered by the difference between the baseline and object means from negative to positive. A negative number indicates that an object had an adverse effect on participants' rating of stability. Across all objects, participant ratings and the combined measure were moderately correlated ( $r(498) = .488, p < .05$ ). The rankings of objects by the combined measure and the participant ratings were strongly correlated ( $r_s(20) = .880, p < .05$ ).

### **3.5 EFFECTS OF PHYSICAL CHARACTERISTICS ON CYCLE STABILITY**

The physical characteristics of all the road markings were regressed stepwise against the combined measure to find out the relative effects of the characteristics on stability. The BPN ( $t(372) = 1.183, p > .05$ ), the presence or absence of beads ( $t(372) = -1.444, p > .05$ ), and the presence or absence of calcite ( $t(372) = 1.635, p > .05$ ) did not account for a significant amount of the variance of the combined measure. Height accounted for a significant amount of the variance ( $t(372) = 5.085, p < .05$ ). A similar regression was performed for the thermoplastic road markings only (lines 6, 8, 1, 10, 7, 11, and 3), and again height was the only measure to account for a significant amount of the variance ( $t(163) = 2.366, p < .05$ ).

### **3.6 EFFECTS OF TASKS ON CYCLE STABILITY**

An ANOVA found that the combined measure differed significantly across tasks ( $F(3, 492) = 5.942, p < .05$ ). A Games-Howell post-hoc showed that the braking ( $M_{Diff} = .0891, p < .05$ ) and look back ( $M_{Diff} = .0514, p < .05$ ) tasks produced more instability than the no-task condition. There was no significant difference between the no-task and target task conditions ( $M_{Diff} = .0313, p > .05$ ), or between the braking and look back task conditions ( $M_{Diff} = .0337, p > .05$ ).

### **3.7 RELIABILITY OF RESULTS ACROSS PAID PARTICIPANTS**

The data analysis above was performed on the aggregate data from the six paid participants. The objects were also ranked by their effect on the combined measure for each individual participant, with the degree of consistency between participant rankings indicating reliability. A Friedman test found no significant difference in rankings for the combined measure across participants ( $\chi^2(19) = 1.861, p > .05$ ).

Individual rankings strongly correlated with the rankings of the aggregate measure  $\bar{r}_s$  ( $r = .828$ ,  $SD = .064$ ) and with each other ( $\bar{r}_s = .699$ ,  $SD = .09$ ).

### **3.8 ANGLE OF APPROACH**

The angle of approach to road markings was planned to be 58°. If participants maintained this angle of approach then the cycle laser should have been on the target board for trials where there was no task and where the task was to target the laser on the board. Paid participants' lasers were on the target board in 88.5% of these trials.

### **3.9 GENERALISATION TO EXPERIENCED CYCLISTS**

Experienced cyclists rode over objects 5, 6, 14, and the baseline. ANOVAs found no significant difference between paid and experienced participants for the combined measure ( $F(1, 188) = .120$ ,  $p > .05$ ) or for the subjective rating ( $F(1, 189) = 3.749$ ,  $p > .05$ ). There was no significant interaction between participant type and object type for the combined measure ( $F(3, 188) = 2.395$ ,  $p > .05$ ) or the subjective rating ( $F(3, 189) = 1.702$ ,  $p > .05$ ).

## **4 DISCUSSION**

This study aimed to establish a reliable and valid method for investigating the effect of different objects on cycle stability. The physical measures collected generated clear and orderly differences between objects. That physical measures are useful here contrasts with the literature on bicycle and motorcycle stability (e.g., Torbic et al., 2001; Bayer & Nels, 1987; Bucko & Khorashadi, 2001; Martinez, 1977; Outcalt, 2001). It is likely that the use of repeated measures design, as well as the

investigation of object effects relative to a baseline were important improvements in methodology. Distraction tasks are commonly used to interfere with the performance of learnt behaviour (e.g., Strayer & Johnston, 2001; Weerdesteyn et al., 2003).

The use of tasks to prevent interference from learning effects, and the use of a bike mounted laser to achieve high consistency of angle of approach may also have helped to obtain clear differences between objects.

Strong correlations were found between the rankings for the combined measure and the subjective measures of the different objects. Research suggests that verbal reports are made more accurate by the presence of physical measuring apparatus. This is true whether the apparatus measures anything or not because the perceived capacity of the physical measure to detect subjective bias reduces its occurrence (Jones & Sigall, 1971). The accuracy of the subjective measures in the present study is likely to have been improved by the collection of physical measures, explaining differences between findings here and those of previous research (e.g., Munster, et al., 1999) that relied mainly on the subjective impressions of the cyclists.

The data from each paid participant can be regarded as separate replications of the same experiment. Analysis revealed that the results were consistent across paid participants, suggesting that the results are highly replicable. In addition, no difference was found between the results for the paid participants and the results for the sample of experienced cyclists, suggesting that the results are reliable over a range of individual differences between cyclists. Such participant reliability forms part of the assessment of the generality of the results. Further enhancing the generality of the results was the use of tasks analogous to on road cycling, such as the braking and looking back tasks. These tasks generated instability above that of the 'no-task

condition' increasing the sensitivity of the measures to detecting differences between objects.

Amongst the road markings, four types did not create a detectable instability relative to baseline. These were a 2 mm thermoplastic line with no beads or calcite, waterborne paints lines of .2 mm and .5 mm in height (one with large glass beads and calcite, and one without beads and calcite), and a .2 mm chlorinated rubber line. Because these lines create no more instability than asphalt they do not represent a hazard to cyclists.

All objects were compared to the audio-tactile line, an object thought to cause significant hazard to cyclists. Rough ground, the round utility access cover, domes, and loose gravel created more instability than the audio-tactile line, and twelve other objects were found to create a similar level of instability to the audio-tactile line. These latter objects include commonly used line markings, which suggest that changes might be made to standards that guide road marking practices.

Better management of the potential hazard road markings pose to cyclists can occur through alteration of existing standards covering road marking materials and practices. For example, the space left available to cyclists could be increased to reduce the need to cross the object (see Bachman, 2001), inserting crossing point gaps into the road marking (see Moeur, 2000) and providing a warning to cyclists that the object exists, so that cyclists can actively manage crossing the object (Outcalt, 2001). The first two practices decrease the exposure of cyclists to the road markings. However, there will be circumstances such as parked cars, debris, and intersections that force cyclists to cross road markings when they may not be in a position to

negotiate any known increased risk to their safety from the road marking. Providing a non-hazardous road marking would overcome these limitations.

The only physical factor we found to account for a significant amount of variance in cycle stability was the height of the object. However, because a line marking of as low as .5 mm can induce a similar level of cycle instability to an audio-tactile line, regulating line markings by height cannot ensure cyclist safety. Testing of line markings, and other objects placed in cyclist's path, for effects on cycle stability could be undertaken to identify road markings that pose no risk to cyclists. Testing might take into account a broader range of factors such as the effect of different rider characteristics (e.g., age and weight) and riding variables (e.g., speed, angle of incidence, and turning when encountering the object), so that the standards address the most vulnerable cyclists and riskiest circumstances cyclists experience.

One disadvantage with the present method is the inability to assess the degree of risk associated with a particular object when an objects' effect differs significantly from that of baseline asphalt. To assess the degree of risk for such objects would require the relationship between the combined measure and the probability of accident to be quantified. The risk to participants precluded this in the present study. However, further experiments may develop the method to ensure participant safety and quantify this risk.

## **5 CONCLUSIONS**

The method used here establishes the relative physical effects different objects have on cycle stability and seems robust under statistical assessment. Commonly used road markings were not significantly different from audio-tactile lines that are considered by independent investigations to represent a hazard to cyclists. The

height of the line marking influenced cycle stability, but not enough to enable specifications based on height to ensure cyclist safety. Future work is necessary to establish the effects on cycle stability of the full range of road objects, and to establish a relationship between the combined measured of cycle stability and the probability of accident. Such research will enable precise specifications to be developed for the design and maintenance of cycle-safe environments.

## **ACKNOWLEDGEMENTS**

This research was funded by Transfund New Zealand (Project No 715). We would like to thank Vince Dravitzki, Richard Jackett, Shirley Potter, Diana Munster, and Fergus Tate.

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## **FIGURE CAPTIONS**

Figure 1. The audio-tactile marking.

Figure 2. The structured marking.

Figure 3. A thermoplastic marking.

Figure 4. Cycle course layout for road markings. Lines 1, 2 and 3 indicate the approximate positions of the laser trip beams. Course layout was similar for other objects with the exception that beam 2 was adjacent to beams 1 and 3 and the angle of incidence with the objects was 90°.

Figure 5. View towards the target board of a cyclist approaching a line marking. The logger, telemetry device, and accelerometer can be seen on the back of the cycle. The lasers are in between white sandbags.



**TABLES**

Table 1. Median days cycled per week, median kilometres (km) cycled per week, median speed when cycling in kilometres per hour (kph), number of males and females, median age in years, median height in centimetres (cm), and median weight in kilograms (kg) for paid and experienced participants.

	Paid	Experienced
Median days cycled per week	0	3
Median km per week	0.5	45
Median speed (kph)	18	28
Number of males	3	9
Number of females	3	2
Median age	20	45
Median height (cm)	175	170
Median weight (kg)	65	75

Table 2. The objects tested in the experiment. For the road markings (objects 1 to 15<sup>a</sup>) a measure of skid resistance (BPN<sup>b</sup>) the height in millimetres (mm), bead type, presence of calcite, and type of line are given. For the other objects (16 to 20) relevant dimensions are given.

Object	BPN	Height	Bead	Calcite	Line
	72	Baseline asphalt with no line			
1	58	3.5	Large beads	Yes	Thermoplastic
2	59	.5	Large beads	Yes	Waterborne Paint
3	63	2	None	No	Thermoplastic
4	52	.5	Large beads	No	Waterborne Paint
5	46	.2	None	No	Chlorinated Rubber
6	67	7	None	No	Thermoplastic
7	54	3	Dropon	Yes	Thermoplastic
8	70	3.5	None	No	Thermoplastic
9	50	.5	Dropon	No	Waterborne Paint
10	57	7	Dropon	Yes	Thermoplastic
11	58	4.5	Dropon	Yes	Thermoplastic
12	68	3	Dropon	No	Structured Marking
13	91	N/a	None	No	Profiled Thermoplastic
14	59	N/a	None	No	Audio-tactile
15	41	.2	None	No	Waterborne Paint
16	Round utility access cover: 580 mm in diameter with rings 60 mm in height				
17	Rough ground: 1005 mm long x 800 mm wide x 8 mm deep				
18	Gravel: 1550 mm long x 800 mm wide x 7 mm high, Grade 4 seal chip				
19	Retroreflective raised pavement markers (rrpms): 102 mm square x 19mm high				
20	Domes: 106 mm in diameter x 22.5 mm high				

<sup>a</sup> Line markings were laid, in accordance with standard practice, to be 100 mm wide, with the exception of line 3, which was laid to be 200 mm wide.

<sup>b</sup> British Pendulum Number measures the skid resistance. Lower numbers indicate less resistance to skidding or greater slipperiness.

Table 3. Component score coefficients from principal component analysis for average handle bar position, average acceleration of cycle, range of acceleration of cycle, and range of handle bar position collected before the objects.

Component	Coefficient
Average handle bar position	-.458
Average acceleration of cycle	.386
Range of acceleration of cycle	.427
Range of handle bar position	.348

Table 4. ANOVA comparisons for the combined measure, with each object compared to baseline. Shown is the difference when each mean is subtracted from baseline, the standard error, and significance. Objects are ordered by mean difference from negative to positive.

N	Type	Height	Beads	Calcite	BPN	$M_{Diff}$	$SE$
17	Rough Ground					-.462***	.039
16	Round Utility Access Cover					-.231***	.024
20	Domes	22.5				-.230***	.034
18	Loose Gravel					-.212***	.031
19	Rrmps	19				-.189***	.042
6	Thermoplastic	7	None	No	67	-.179***	.035
1	Thermoplastic	3.5	Large beads	Yes	58	-.120***	.028
10	Thermoplastic	7	Dropon	Yes	57	-.118**	.039
14	Audio Tactile		None	No	59	-.104**	.034
7	Thermoplastic	3	Dropon	Yes	54	-.103**	.034
11	Thermoplastic	4.5	Dropon	Yes	58	-.100*	.041
9	Waterborne Paint	.5	Dropon	No	50	-.099***	.024
8	Thermoplastic	3.5	None	No	70	-.076*	.033
12	Structured Marking	3	Dropon	No	68	-.066**	.019
13	Profiled Thermoplastic		None	No	91	-.062*	.024
4	Waterborne Paint	.5	Large beads	No	52	-.062*	.026
3	Thermoplastic	2	None	No	63	-.026	.027
15	Waterborne Paint	.2	None	No	41	-.012	.017
2	Waterborne Paint	.5	Large beads	Yes	59	.032	.016
5	Chlorinated Rubber	.2	None	No	46	.039	.021

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

Table 5. ANOVA comparisons for the combined measure, with each object compared to the audio-tactile line. Shown is the difference when each mean is subtracted from the audio-tactile line, the standard error, and significance.

N	Type	Height	Beads	Calcite	BPN	$M_{Diff}$	$SE$
17	Rough Ground					-.358***	.05
16	Round Utility Access Cover					-.127**	.039
20	Domes	22.5				-.127*	.048
18	Loose Gravel					-.108*	.044
19	Rrmps	19				-.086	.051
6	Thermoplastic	7	None	No	67	-.075	.046
1	Thermoplastic	3.5	Large beads	Yes	58	-.016	.042
10	Thermoplastic	7	Dropon	Yes	57	-.014	.05
7	Thermoplastic	3	Dropon	Yes	54	.000	.046
11	Thermoplastic	4.5	Dropon	Yes	58	.004	.051
9	Waterborne Paint	.5	Dropon	No	50	.004	.039
8	Thermoplastic	3.5	None	No	70	.027	.045
12	Structured Marking	3	Dropon	No	68	.038	.036
13	Profiled Thermoplastic		None	No	91	.042	.039
4	Waterborne Paint	.5	Large beads	No	52	.042	.04
3	Thermoplastic	2	None	No	63	.077	.043
15	Waterborne Paint	.2	None	No	41	.092*	.035
	Baseline Asphalt				72	.104**	.034
2	Waterborne Paint	.5	Large beads	Yes	59	.136***	.035
5	Chlorinated Rubber	.2	None	No	46	.142***	.037

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

Table 6. ANOVAs for the mean participant rating of each object compared with baseline. Shown is the difference when each mean is subtracted from baseline, the standard error, and significance.

N	Type	Height	Beads	Calcite	BPN	M <sub>Diff</sub>	SE
17	Rough Ground					-2.503***	.231
19	Rrpms	19				-2.285***	.219
16	Round Utility Access Cover					-2.111***	.247
18	Loose Gravel					-2.111***	.253
20	Domes	22.5				-1.825***	.217
10	Thermoplastic	7	Dropon	Yes	57	-1.444**	.467
14	Audio-tactile		None	No	59	-1.347***	.348
11	Thermoplastic	4.5	Dropon	Yes	58	-1.306**	.443
1	Thermoplastic	3.5	Large beads	Yes	58	-1.292**	.415
8	Thermoplastic	3.5	None	No	70	-1.097**	.383
6	Thermoplastic	7	None	No	67	-1.083**	.344
7	Thermoplastic	3	Dropon	Yes	54	-1.042*	.408
13	Profiled Thermoplastic		None	No	91	-.917**	.311
15	Waterborne Paint	.2	None	No	41	-.705*	.347
3	Thermoplastic	2	None	No	63	-.658*	.314
9	Waterborne Paint	.5	Dropon	No	50	-0.556	.316
5	Chlorinated Rubber	.2	None	No	46	-0.5	.264
12	Structured Marking	3	Dropon	No	68	-0.486	.259
4	Waterborne Paint	.5	Large beads	No	52	-0.278	.185
2	Waterborne Paint	.5	Large beads	Yes	59	-0.111	.139

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$