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Haptic nudges to influence cyclist behaviour – an experimental study

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1 ABSTRACT

2 Bicycle riders are over represented in fatal traffic accidents in Europe, and the trend is still on
3 the rise (European Commission, 2018). While most cycling accidents are defined as single
4 accidents, the outcome of an accident where a car or other heavy vehicle is involved is
5 naturally much more severe. A Swedish study found that eight of ten car-bicycle accidents
6 happen in intersection scenarios (Isaksson-Hellman & Werneke, 2017). If cyclists, as well as car
7 drivers, adapt their speed before intersections everyone has more time to spot each other and
8 to take evasive action, which should lead to a decrease in accidents.

9 Authorities around the world are putting up physical obstructions such as rumble stripes to
10 make cyclists slow down, but is this the right way to go? Previous studies have found smooth
11 surfaces to be a very important factor for cycling comfort, and vibrations to be highly disliked
12 (Ayachi et al., 2015; Bil et al., 2015; Stinson and Bhat, 2005; Torbic et al., 2003).

13 The core of the MeBeSafe project is to investigate whether nudging, i.e. non-forcing
14 measurements without demands on conscious interpretation, can be used to influence traffic
15 behaviour and suggest how these nudges should be designed. In the project, both visual and
16 haptic nudges have been developed and tested. This paper reports on an experimental study
17 with 16 participants, 19-75 years of age, that was carried out with six different haptic nudges.
18 The nudges consisted of modified surface softness and roughness as well as dimensional

19 modifications. Results indicate that most haptic nudges have very little effect on speed and
20 those with larger effect are generally disliked. This suggests that building physical obstructions
21 for cyclists may not be the correct way forward, although results from cycling workshops
22 performed in the project suggests that haptic nudges might be a good choice if one wants to
23 nudge cyclist to change trajectory. If one wants to affect bicyclists' speed, visual nudges are
24 likely to be a more constructive route for cities to take.

25

26 **Keywords:** nudging, traffic safety measures, transportation, bicycle safety, behavioural
27 economics,

28 **1 INTRODUCTION**

29 Eight percent of those killed on EU roads are riding a bicycle, but only two percent of the
30 travelled passenger-kilometres are made on bikes. (European Commission, 2017; European
31 Commission, 2018; Steenberghen et al., 2017). Moreover, cyclist road fatalities are on the rise
32 (European Commission, 2018). A Swedish study found that eight out of ten car-bicycle
33 accidents happen in intersection scenarios, and in the majority of these accidents, the car
34 drivers had failed to spot the cyclist before the collision (Isaksson-Hellman & Werneke, 2017).
35 Re-designed intersections, and auto-brake systems in cars are examples of solutions to
36 increase safety in these situations. Another solution is to decrease the speed of cars, bicycles
37 and other vehicles before intersections. This gives everyone more time to spot each other as
38 well as shortening stopping distances.

39

40 A common way to slow down both car drivers and cyclists are speed bumps and rumble strips.
41 Vibrations of any kind are however found highly uncomfortable when cycling, and smooth
42 surfaces is one of the most important factors for cycling comfort (Ayachi et al., 2015; Bíl et al.,

43 2015; Stinson and Bhat, 2005; Torbic et al., 2003). Furthermore, speed bumps have been found
44 to have very little effect on cyclists' speed (e.g. Ljungblad, 2017). As the European Union's
45 official cycling strategy states that bicycle use should grow with 50% in ten years while still
46 cutting the amount of deaths in half, it is highly important to find speed-altering measures that
47 are both acceptable by bicyclists and actually work (ECF, 2019).

48

49 MeBeSafe is an EU-funded project under the Horizon 2020 banner that aims to change traffic
50 behaviour by nudging. Nudging was first described by Thaler and Sunstein (2008) and is a way
51 of predictably altering people's behaviour on a subconscious plane without forbidding any
52 options. It can be described as more or less a gentle push in the right direction. MeBeSafe has
53 previously explored visual nudges as a way to affect cyclists with promising results. This study
54 however investigates if any type of haptic alterations to the road surface could change
55 behaviour and still be accepted by cyclists. To achieve this, much more subtle changes of the
56 ground than what is currently used were tried, as this was considered essential to get
57 acceptance.

58 **2 METHOD**

59 In order to gain insight into which haptic nudges could be manufactured and used, two
60 workshops were organised in Sweden and the Netherlands. A number of cycling experts were
61 invited to come up with ideas on how to make bicyclists decrease their speed before an
62 intersection by haptic measures in the ground. In the Netherlands, the issue of changing
63 trajectory (for instance nudging cyclists to the right when cycling slow and to the left when
64 going faster, or steering to the left to make it possible for cyclists coming from the right to
65 enter your bike lane) by the same means was also touched upon.

66

67 For booth workshops separately, the results were categorised into relevant categories.
68 Evaluation criteria were formed, and the nudge categories were voted upon. Each nudge
69 deemed to have potential was built and tested in a one month long iterative nudge-
70 prototyping session. The nudges were tried out and modified until they were found to give a
71 clear haptic experience without any significant discomfort. In total, six different nudges were
72 designed.

73

74 The nudges were then tested on cyclists for evaluation of appreciation and effects on speed.
75 Participants were recruited via targeted ads and groups in social media and via direct ads on
76 bikes around the city of Gothenburg. Potential participants were asked to fill in a questionnaire
77 on cycling behaviour, and those cycling at least weekly were invited to book a time slot for a
78 test. Three days of tests were set up and booked in case one had to be cancelled due to
79 weather. This actually happened and 16 people participated in the test.

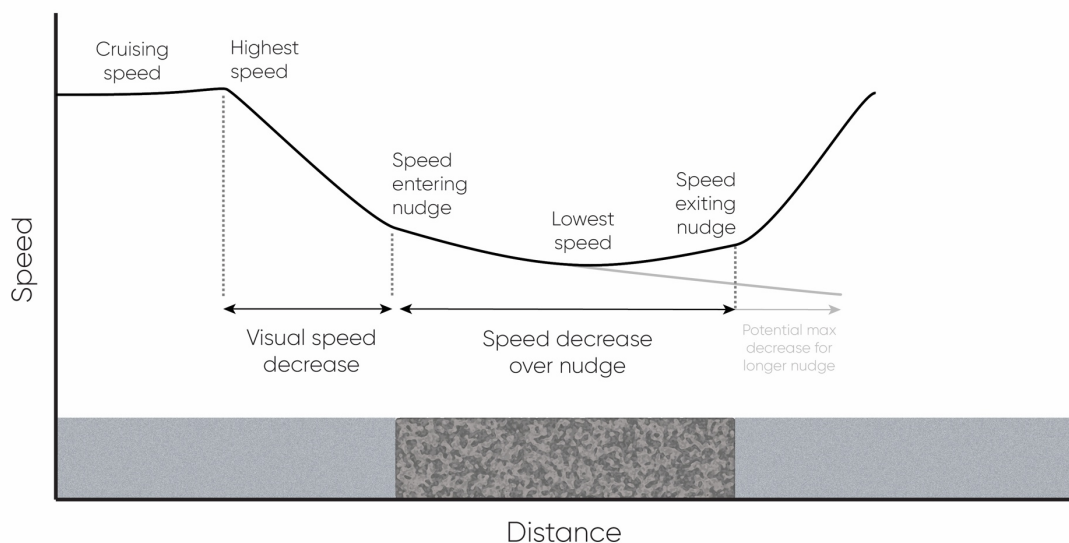
80

81 The test was conducted in a desolate area of the Gothenburg harbour, where old ferry queuing
82 lanes provided tracks for the test. While previous tests on visual nudges had been made in real
83 traffic, the novelty of the haptic nudges and the potential hazard they might constitute made it
84 important not to expose too many unaware cyclists to them. The nudges were placed in the
85 lanes, with enough space to reach cruising speed before the nudge and after. The ordering of
86 the different nudges was mixed between the days.

87

88 The participants brought their own bike and were told to bike over the nudges and try to bike
89 as normal as possible. Their bikes were equipped with a *Garmin Virb Ultra* GPS equipped
90 camera, taking up videos of the tests and logging speed and position with high accuracy at 10
91 Hz. After the test, the participants were probed for their experience when cycling over the

92 nudges and they filled in Likert type appreciation scales from -2 to 2 and asked to rank the
93 nudges.
94
95 The speed and position data were extracted from the Garmin Virb manually and plotted.
96 Several speeds were noted, including the highest speed before the nudge, the speed when
97 entering the nudge, the lowest speed within the nudge and the speed directly after the nudge
98 (Figure 1). This allowed to capture what part of the expected speed decrease was due to the
99 participant reacting to seeing the nudge and which effect the haptics of the nudge had on
100 speed. All measurements were calculated based on decrease in percent, to make them
101 independent of different initial speeds.



102
103 **Figure 1.** An example of a speed curve with different speeds measured

104
105 Data were compiled and compared in Matlab with two-sample t-tests, under the hypothesis
106 that one is lower than the other and that the variance is not necessarily equal. P-values under
107 0.05 were considered relevant. The distances between the steps in the Likert scales were
108 considered equal, and the results were considered to be parametric.

109

110 **3 RESULTS**

111 The results are divided into type of nudges, test group, effect on speed, and cyclist ratings.

112

113 **3.1 Types of nudges**

114 The workshops identified several ways of affecting cyclists by haptic modifications of the
115 ground. These were summarised into Modified surface structure, such as shaggy or rugged
116 surface, Modified surface properties, such as soft or spongy surface, or Dimensional
117 modifications, such as bumps, stripes, slopes, or grooves. From a large number of potential
118 nudges built in the prototyping session, six haptic nudges were chosen for use in the actual
119 trial. They were a Soft Surface, a Spongy Surface, a Rough Surface, an array of Soft Stripes, an
120 upwards Slope and a Soft bump (Figure 2). They first four are based on the idea of sending a
121 brief signal to the cyclist that something changes, which could potentially decrease their speed
122 and make them more attentive. The Slope is supposed to incline upwards before an
123 intersection and then incline downwards afterwards, and will therefore by itself remove
124 kinetic energy and therefore speed on the way up, but will give it back on the way down. The
125 Soft bump is based on the traditionally used idea of having to slow down to cross it
126 comfortably, but using a somewhat more comfortable version than regularly used. This would
127 act as a comparison with more ordinary measures, yet still more comfortable.

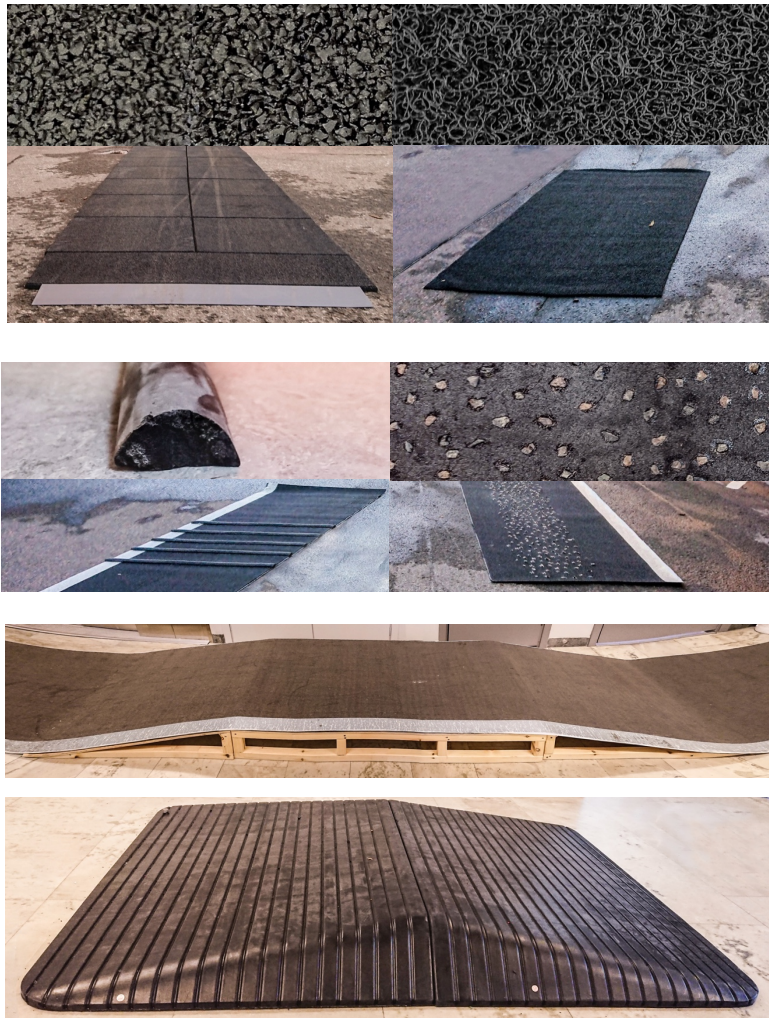


Figure 2. The haptic nudges used in the test. From top and left to right, Soft surface, Spongy Surface, Soft Stripes, Rugged surface, Slope and Soft bump.

128
129

130

131 3.2 Test group

132 The test group consisted of 16 participants aged 19-75, with an average age of 41. 75% were
133 men and 25% were women. 69% of them used the bike every day. A skew towards a larger
134 share of men generally partaking in more dangerous behaviour was found in the sample. As
135 the tests took place in mid-winter, it was believed to be an effect of more seasoned cyclists
136 being out on the roads.

137

138 3.3 Effects on speed

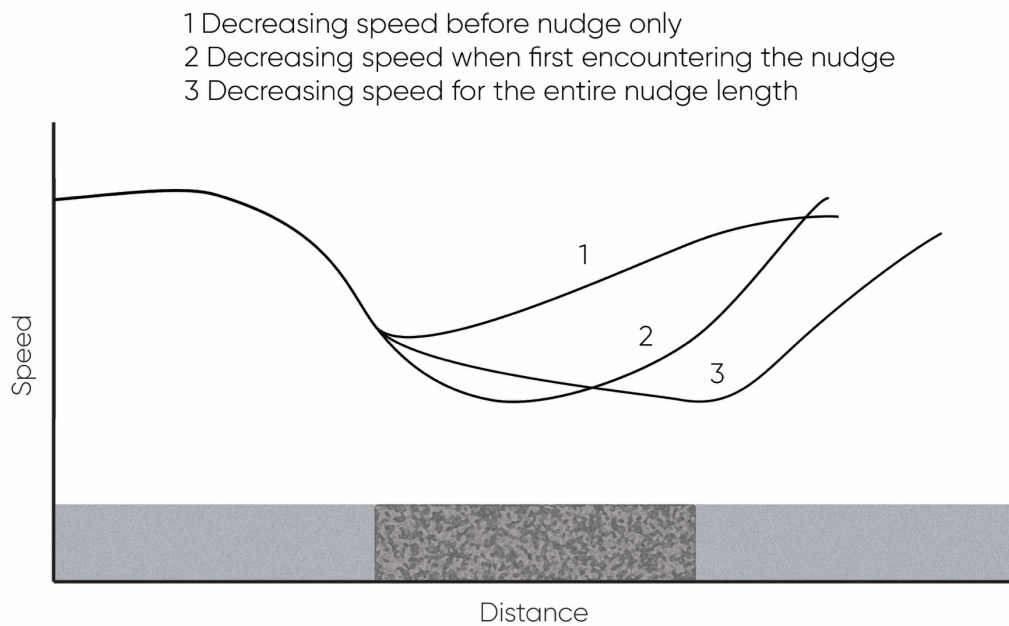
139 The total speed decrease measured for each nudge is the difference between the highest
140 speed before the nudge and the lowest speed during the nudge. This measurement includes a
141 solely visual part, i.e. the effect on speed due to the how the participants perceived the look of
142 the nudge. This effect is somewhat dependent on the rough design of the nudges and would
143 not persist to the same degree in the real world. The visual part stands for more than half of
144 the total speed decrease for the Soft Bump, but only 15-20% for Soft Surface and Spongy
145 Surfaces.

146

147 The most interesting measurement is the speed decrease over the nudge, comparing the
148 speed when entering the nudge with the speed when exiting the nudge. In many cases, the
149 lowest speed was however not reached at the end of the nudge. Speed curves are therefore
150 necessary to analyse to understand the effects of the nudges

151

152 If the nudges worked as intended the behaviour of the test persons would be to slow down
153 when encountering the nudge and then continue with a reduced speed. This was however a
154 very uncommon behaviour (Figure 3, graph 2).



155

156 **Figure 3:** Different types of speed behaviour before and over the nudge

157

158 A much more common behaviour was that the participants slowed down in advance of the
 159 nudge and then continued at that speed or even increased speed during the nudge (Figure 3,
 160 graph 1). In general, the reason for this behaviour was that the nudge looked worse than it was
 161 and it's reasonable to believe that the participants wouldn't slow down as much (or at all) on a
 162 second encounter with the same nudge.

163

164 There were also nudges where the participants slowed down during the whole length of the
 165 nudge (Figure 3, graph 3). While slowing down cyclists is the intention behind the nudge this
 166 behaviour comes with the price of cyclists' acceptance. For the soft surface there is e.g. a clear
 167 correlation between the participant accepting the nudge and describing the nudge as
 168 comfortable on one hand and not slowing down continuously on the other. Similarly, to slow
 169 down through the whole distance of the rough surface nudge was correlated with the nudge
 170 being ranked less positive (Average -1,4 compared to +1, $p=0.0260$) and less comfortable
 171 (Average -0,86 compared to +0,83, $p=0.0333$). Those mentioning they were afraid of the

172 nudge, found it “evil” or, just disliked it, all slowed down continuously. Furthermore, those
173 decreasing speed continuously over the soft bump seemed more likely to talk about the bump
174 as dangerous.

175

176 The results on speed decrease are surprisingly similar for Soft Surface, Rugged Surface, and
177 Spongy surface. Only the slope has a considerably larger effect, if it is built sloping up before
178 an intersection and down afterwards. See Table 1 for a summary on the potential effects on
179 speed. The very similar effect on speed for all different types of measures suggest that the
180 speed decrease may be connected to the fact that something changes on the ground that
181 demands attention. I.e., speed may be decreased due to distraction, which is not optimal.

182

183 **Table 1.** The maximum potential speed reducing effect of the haptic nudges

Slope	15%
Rough, Soft & Spongy surfaces	<7%
Bump & Soft stripes (can't be extended)	4-5%

184

185 The potential maximal effect is however unlikely to be reached for Rough, Soft or Spongy
186 surfaces in real life, as large shares of cyclists seem to decrease speed at first only to
187 increase it again later. The speed curves for Rough Surface indicates larger potential for
188 speed decrease over time, but it also seems the decrease is dependent on cyclists finding
189 the nudge dangerous, which would most likely not be the case in real life.

190 **3.3 Cyclist ratings**

191 The cyclists rated the nudges in terms of general Appreciation, Comfort, Safety, Security and
192 Non-intrusiveness from scales to -2 to +2. The ratings of safety and security were merged as
193 “perceived as safe”, and general appreciation, comfort, and non-intrusiveness were merged
194 to the variable “acceptance” (Crombach’s alpha 0,95 and 0,82 respectively). The ratings
195 were coherent, in that Soft surface, Rubber strips and Spongy surface are perceived as safe,

196 accepted by the participants and not perceived to lower speed. Rough surface was neutral,
 197 while Slopes and bumps was perceived as lowering speed, but also unsafe and not accepted
 198 by the participants. See Table 2 below for a summary of the ratings.

199 **Table 2.** The results from Likert ratings on the nudges (mean values -2 to +2)

	Perceived to lower speed	Perceived as safe	Accepted by the participants
Soft surface	-0,94	1,06	0,94
Slope	0,81	-0,5	-0,79
Rough surface	-0,44	0,03	-0,04
Soft bump	1,19	-0,25	-0,92
Spongy surface	-1,31	0,88	0,56
Soft stripes	-0,63	0,97	0,54

200

201 The cyclists were asked if they would accept the nudges on real cycling lanes, and the
 202 acceptances ranges from 81% to 25%. The follows the same pattern that was established in
 203 the Likert type ratings above.

204

205 **Table 3.** The number of cyclists who would accept each nudge on a real cycling lane.

Acceptance of nudge on real cycling lanes

Soft surface	81%
Rubber stripes	81%
Spongy surface	69%
Rough surface	63%
Slope	44%
Bump	25%

206

207

208 The cyclists also stated what they would do if encountering the nudge on a real cycling lane
 209 and a significant share stated that they would cycle around the obstacle or take another
 210 route altogether for bumps and rugged surface. Even for soft stripes the number is

211 surprisingly high, and based on the participant's statements it would be much higher for
212 ordinary rumble stripes.

213

214 **4 DISCUSSION**

215 The nudges that were most appreciated, namely Soft surface, Soft stripes and Spongy surface,
216 had rather low effects. Furthermore, the speed curves indicate that the effect will fade away
217 rather quickly, as the speed decreases mainly seem to be first-time reactions to reaching an
218 unknown material. Soft and Spongy surfaces were appreciated for their softness, which was
219 both comfortable when cycling and could reduce the severity of falling accidents. However, it
220 was also believed to potentially decrease speed on its own. This is exactly what was found by
221 Wallqvist et al. (2017), in a study on rubber surfaces. The Soft stripes nudge was in contrast
222 mostly appreciated because they were relatively better than ordinary rumble stripes; they
223 were not really believed to be good on their own. However, no one of the participants
224 connected them to speed reduction at all.

225

226 The Rough surface was created by gluing gravel to an asphalt surface, and the appearance was
227 quite harsh (some participants described it as "evil looking"). It is possible that a rough surface
228 made by using coarser gravel while making the asphalt would have been less evil-looking, but
229 it would also likely decrease the haptic experience and thereby the effect. As stated earlier,
230 the slope was the solution with the highest potential in reducing speed if the uphill slope had
231 continued for a longer distance. As this solution would require either submerging all cycling
232 lanes or raising all intersections by quite a bit, it can't be argued as a very practical solution.

233

234 The bump tested was found to be both highly disliked and without any significant effect on
235 speed. The bump was still preferred to regular speed bumps, as it had safe slopes towards the

236 side and was somewhat more comfortable due to the rubber. The geometry was however
237 similar to an ordinary bump, and there is no reason to believe that an ordinary bump could
238 decrease speed any more.

239

240 None of the haptic nudges seem to work on a subconscious level. A classic nudge should alter
241 behaviour without affecting the conscious mind, although so-called Type 2 nudges can appeal
242 to consciousness. The nudges have remarkably similar effect on speed, which indicates that
243 the effect is due to the distraction of something happening. They are likely taking away
244 attention from traffic, making the cycling more dangerous. The haptic experiences were made
245 as strong as possible without being “uncomfortable”, but they were still clearly felt and
246 recognised. Even subtler changes in surface may act subconsciously, but the effect on speed is
247 then likely to be negligible.

248

249 It therefore seems that there is little potential in affecting cyclist speeds with haptic nudges.
250 An issue was however raised in one of the workshops regarding trajectory. It would be possible
251 to use some of the materials used in the haptic nudges, such as the rough surface, in an
252 overtaking lane on a cycling road; if there is a problem with cyclists overtaking others in a
253 dangerous manner. In this way, cyclists would not have to encounter the uncomfortable
254 material if they do not want to. While it would still be possible to overtake others, it would
255 steer cyclists into not doing it. Similarly, haptic measures could be used to “narrow” down the
256 useful part of lane, which has been found to affect speed in previous studies.

257

258 One limitation of the study is that the nudges were implemented on a straight road without
259 any intersections. It is plausible that the absence of a perceived danger the nudges more

260 difficult to interpret and that the effects consequently are somewhat less than could be
261 expected in real traffic situations.

262 Visual nudges have been tried on cyclists in a previous MeBeSafe study (Karlsson et al. 2019),
263 with much better results than the haptic nudges. 93 test persons cycling in real traffic were
264 shown to reduce speed significantly even if the cyclists did not notice the nudges. I.e. they
265 work on a subconscious level. They were found to lead to equal speed reductions no matter
266 how much the cyclists use to slow down, and they decrease speed for all types of cyclists.

267 Completely flat transverse stripes getting gradually closer, or linearly narrowing down the lane,
268 were found to decrease speed by 13% more than what was done in baseline conditions before
269 intersections. Transverse stripes would also not significantly decrease the attention to traffic.

270 In these trials, only 3 of 93 participants stated that they preferred haptic measures, while the
271 visual ones were universally approved. In fact, most participants spontaneously mentioned
272 how pleased they were that the nudges were not haptic. It therefore seems that visual nudging
273 is a much better way to affect speed than haptic.

274

275 **5 CONCLUSIONS**

276 Haptic nudges were in this study found to have little effect on speed. Moreover, the haptic
277 nudges with the largest effect were also the least appreciated by the cyclists. Appreciation of
278 haptic nudges is furthermore very varied between cyclists, and there was no haptic nudge
279 tested that was universally accepted. Consequently, we argue that visual nudges have a much
280 higher potential for reducing cyclists' speed as they are universally approved, work for all types
281 of cyclists, and are much easier to implement.

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