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1 **The light is red: uncertainty behaviours displayed by pedestrians during illegal road**
2 **crossing**

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37 **ABSTRACT**

38

39 Road accidents involving pedestrians are a reality of urban life. Pedestrian risk is now
40 well known and documented from the perspective of drivers. However, pedestrian behaviour
41 plays a central role in road accidents, notably in terms of illegal road crossing at signalized
42 intersections. This study focuses on pedestrians crossing illegally at a signal light, and
43 specifically investigates *uncertainty behaviour*, also referred to as *hesitation*, which occurs
44 when a pedestrian slows down or stops his/her crossing movement then (1) abandons the
45 crossing by returning to the kerb or (2) accelerates to cross the road more quickly. We sought
46 to understand the causes of this behaviour in France and Japan, two countries where
47 interesting differences have already been demonstrated in the way pedestrians behave. The
48 results show a longer period of uncertainty for pedestrians in Japan compared to France.
49 Japanese pedestrians also hesitated longer when they were alone. This study demonstrates a
50 tendency to speed up if there are a number of pedestrians already crossing the road, but
51 abandoning behaviours were more frequently observed than acceleration. This study confirms
52 that pedestrians may miscalculate the moment to cross and hesitate when they realise that they
53 have made a mistake, thus increasing the risk of an accident. These results could help to find
54 solutions that prevent illegal and dangerous road-crossing behaviours.

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58 **KEYWORDS:** illegal road-crossing; pedestrian; uncertainty; hesitation; decision-making;
59 culture

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70 INTRODUCTION

71 In 1896, Bridget Driscoll was killed by a motor vehicle during a demonstration in the
72 United Kingdom; her death is the first recorded case of pedestrian road fatality (Porter, 1998).
73 The number of road traffic accidents has since continued to rise, with pedestrians representing
74 22% of world road traffic death (World Health Organization, 2015, WHO/NMH/NVI/15.6).
75 Despite the efforts made by governments to enhance road safety practices, there are still too
76 many accidents involving pedestrians, most of which occur in urban agglomerations. In
77 France, collisions with pedestrians represent 14% of lethal road accidents, and 67% of these
78 deaths occur in the urban environment (ONISR, French Observatory of Road Safety, 2017).
79 These deaths are all the more unacceptable given their largely predictable and preventable
80 nature. Indeed, risks to pedestrians are now well known and documented in terms of driver
81 behaviour (for speeding, see the review by Rosén et al., 2011; for drink driving see Hingson
82 and Winter, 2003) to road infrastructures (see Bunn et al., 2003; Hamed, 2001) and vehicle
83 design (see Desapriya et al., 2010).

84 Another key factor of pedestrian safety is the behaviour of the pedestrians. Zhuang and
85 Wu (2011) showed that 66% of pedestrians crossing outside signalized intersections in China
86 did not check for oncoming vehicles before crossing, and 16.1% did not even do so whilst
87 crossing. Among pedestrians who saw an approaching vehicle after stepping off the kerb,
88 40.6% stopped crossing, 11.4% stepped backwards and 31.9% accelerated to complete the
89 crossing. In this example, more than 40% of pedestrians demonstrated uncertainty behaviours.
90 The authors observed many instances where pedestrians were using cell phones or listening to
91 music while walking or even while crossing roads. The risky pedestrian behaviour described
92 in this case is also problematic in the context of illegal road-crossings at signalized
93 intersections (Diaz, 2002; Preusser et al., 2002; Evans and Norman, 1998; Evans and Norman,
94 2003; Rosenbloom, 2009; King et al., 2009; Xu et al., 2013).

95 Pedestrian behaviours vary according to the socio-demographic traits of individuals.
96 Men show more risky behaviours than women, who display more compliance and conformity
97 (Osman, 1982; Granié, 2011). These behaviours can also vary according to countries and
98 social conventions (Sueur et al., 2013). For instance, French pedestrians crossed against the
99 red light much more often than their Japanese counterparts (41.9% vs 2.1%) (Pelé et al.,
100 2017). As unsafe behaviours, pedestrian infractions can be classified as either errors or
101 violations (Reason, 1990). While an error is unintentional and associated with individual
102 information, violation is deliberate and associated with social factors (Reason, 1990). Social
103 information (gained from surrounding people) is an important factor in collective human

104 phenomena and followership (Faria et al., 2010; Boos et al., 2014). For instance, Dyer and
105 colleagues (2009) showed that a small percentage of informed individuals (5%) was sufficient
106 to guide a larger group of uninformed people to a target place. At a signalised intersection,
107 some pedestrians do not check the light colour but simply follow when other pedestrians have
108 already started to cross (Pelé et al., 2019). Trusting wrong or unreliable information and
109 following someone who is crossing without first checking the light colour (personal
110 information) leads to an increased risk of accidents and injuries (Rosenbloom, 2009). Indeed,
111 a conflict between these two types of information (social vs personal) may lead the pedestrian
112 to change his/her behaviour while already crossing. Our study focuses on this specific
113 behavioural change in pedestrians crossing illegally at a signal light. We have called this
114 *uncertainty behaviour* (also referred to as *hesitation*). We define this specific behaviour as the
115 moment the pedestrian slows down or stops his/her crossing movement then either (1)
116 abandons the crossing by turning back to the kerb or (2) accelerates to cross more quickly.
117 Both of these reactions are potentially dangerous for the pedestrian, who may be hit by
118 vehicles driving on inner or outer road lanes.

119 To our knowledge, this is the first study to investigate the factors (sociodemographic
120 and environmental) affecting uncertainty behaviour. This specific behaviour is a clear signal
121 that the pedestrian has misevaluated the situation, and it deserves in-depth analysis. We also
122 sought to identify any factors that could affect the abandon and acceleration rates observed in
123 pedestrians. This was achieved by studying the behaviours of pedestrians crossing streets in
124 two different countries: Japan and France. We have already demonstrated interesting
125 differences in the way pedestrians behave in these two countries (Sueur et al., 2013; Pelé et
126 al., 2017). First, there was a higher frequency of infractions in France than in Japan. In view
127 of this finding, we predict a greater relative number of uncertainty behaviours in French
128 pedestrians. Women and the elderly are expected to show more uncertainty behaviours and
129 the longest uncertainty times in comparison to other categories of pedestrians when crossing
130 at the red light. Indeed, women appear to focus more on the behaviour of other pedestrians at
131 the time of crossing (i.e. prioritizing social information) (Tom and Granié, 2011) while older
132 pedestrians (> 65 years old) appear to prioritize their course of travel over other
133 environmental information (Tapiro et al., 2016a). Men and the youngest pedestrians are
134 expected to accelerate after hesitation. At a pedestrian crossing red light, combining the
135 number of pedestrians already crossing with the pedestrian departure order (rank) should
136 increase the rate of illegal crossings and subsequently the rate of uncertainty behaviours, as
137 pedestrians show mimetic process and trust in social information (Faria et al., 2010; Bode et

138 al., 2015). We also expect any pedestrians who are using their phones or accompanied by
139 another person to show more uncertainty behaviours than other pedestrians, as these factors
140 are known as distractors (Neider et al., 2010; Tapiro et al., 2016b; Tapiro et al., 2018).
141 Moreover, the probability of abandoning instead of accelerating should increase with the
142 number of lanes on the road, as the risk and the perception of risk increase with the crossing
143 distance.

144

145 **MATERIALS & METHODS**

146 **Study sites**

147 Pedestrians were observed at three sites in Strasbourg, France and at four sites in
148 Nagoya, Japan (see details in Table 1). On each site, the speed of vehicles was limited to
149 50km/h. The speed of pedestrians when crossing the road was estimated by scoring the speed
150 of 20 random pedestrians at each site. It was not significantly different from one site to
151 another (permutation test for independent samples: $\max T=2.22$, $p=0.168$). At some sites,
152 vehicles approaching the intersections were allowed to enter the road despite the green light
153 for pedestrians; these drivers were aware that crossing pedestrians had priority and drove
154 much more slowly than vehicles that were heading straight on. However, the driver of an
155 approaching vehicle may be less careful if pedestrians cross at a red light, as the former has
156 the right of way. Pedestrians therefore run a much higher risk of being injured when crossing
157 at a red light. There was no button for pedestrians to trigger the green light at any of the sites.

158

159 **Data scores**

160 Data were scored over a six-day period for each site, for one hour per day during
161 working days and between 12:00 and 17:00 to ensure that data included different groups of
162 pedestrians (workers, families with children, retirees, etc.) but also excluded movements
163 generated by social events (tourism, festivals, concerts, etc.). Observation time then varied
164 within locations to get a wider pool of pedestrians. This scoring duration is sufficient to
165 provide a large dataset (Faria et al., 2010; Sueur et al., 2013; Yannis et al., 2013). A video
166 camera was set up in order to score the light colour in locations that were chosen to ensure
167 that crossing pedestrians were visible at all times. We used the behavioural sampling method
168 (Altmann, 1974) to score the behaviours of pedestrians in one direction only, i.e. those
169 recorded by the camera. Pedestrians were not informed about the purpose of the study to
170 avoid any modification of their behaviour. As both cities are touristic, pedestrians are
171 accustomed to seeing tourists taking pictures or videos. Our camera was placed on the other

172 side of the road to the starting point of pedestrians. It was not placed directly in front of the
173 crosswalk but was located slightly to one side to make it less of a distraction for pedestrians
174 before and during crossing. None of the pedestrians who noticed the camera changed their
175 direction. To avoid influencing pedestrian behaviour, we purposely did not take any other
176 equipment such as counters or pocket PCs. Any observations of road-crossing that were
177 hampered by a visual obstacle (i.e. a car or a truck in front of the video camera) and the
178 observations occurring immediately before and after it were removed from the analyses. We
179 also removed data in which cyclists and tourists were among the pedestrians. We
180 differentiated tourists from citizens without difficulty, as they were mostly in large groups
181 accompanied by a guide, or carried specific equipment (camera or travel guide) and could be
182 dressed differently to local citizens.

183

184 **Research ethics**

185 This study only involves anonymous observations and anonymous data scores. We
186 followed the ethical guidelines for research of both countries and received ethical approval
187 from both the Institut Pluridisciplinaire Hubert Curien, Strasbourg, France and the Primate
188 Research Institute, Kyoto University, Japan to conduct our observations. As all data were
189 anonymous, focal individuals were given sequential numerical identities according to the day
190 of observation, the crossing concerned and the time of the road crossing. To avoid influencing
191 pedestrians, the experimenters did not approach them. However, pedestrians had the
192 opportunity to learn about the study by an informative medium in their language (French or
193 Japanese) if requested after seeing the camera. If they wished to do so, they also had the
194 possibility to obtain an email address and phone number to contact the corresponding author
195 at a later date. Neither of the two Japanese pedestrians nor the three French ones who asked
196 for information refused to participate in the study.

197

198 **Data analyses**

199 Uncertainty behaviours were analysed from video recordings by two teams of two
200 coders (AR with AD and MJ with KB, each team coding for French and Japanese videos),
201 using BORIS software (Friard and Gamba, 2016) and demonstrating all coder reliability of
202 80%. We only scored and analysed uncertainty behaviours observed at the red light on
203 pedestrian crossings. However, in order to have a rate of uncertainty behaviour per illegal
204 road-crossings, we also scored the number of illegal road-crossings behaviours in France and
205 in Japan, regardless of the occurrence of uncertainty behaviour.

206 We defined the start of a crossing as the moment the pedestrian lifted one of his/her
207 feet to cross. The *uncertainty behaviour* was defined as the moment the pedestrian stopped
208 his/her crossing movement, or slowed down. This hesitation was then followed by one of two
209 possible behaviours, i.e. scenario 1, the abandon of the road crossing, which is characterized
210 by returning to the kerb, or scenario 2, acceleration, characterized by an acceleration of the
211 crossing movement (Figure 1). These two possible behaviours following hesitation will
212 hereafter be referred to as “subsequent behaviours”. We never observed a pedestrian who
213 continued to cross at the same speed after hesitating, with speed estimated according to the
214 number of steps per second.

215 Using these behavioural sequences, we defined *uncertainty time* as the time comprised
216 between the beginning of the uncertainty behaviour and the beginning of the following
217 behaviour (abandon or acceleration).

218 To determine the environmental and sociodemographic factors affecting uncertainty
219 behaviour and its possible consecutive behaviours, we scored the following variables for each
220 focal pedestrian:

- 221 - gender (male or female),
- 222 - age, estimated at 10-year intervals from 0–9, 10–19 [. . .] to 70–89.
- 223 - country (France or Japan),
- 224 - the number of lanes to be crossed,
- 225 - whether or not the focal pedestrian was using their phone,
- 226 - whether or not the pedestrian was accompanied (i.e. the pedestrian was talking with another
227 person or walking very closely and synchronously with her/him, arriving at the road and
228 crossing it at the same time),
- 229 - the total number of pedestrians involved in the road-crossing event,
- 230 - the departure order of pedestrians, where the first pedestrian to leave is ranked as 1, the
231 second as 2, and so on. No uncertainty behaviour was noted after the sixth rank.

232

233 **Statistical analyses**

234 We first used chi-square tests to assess differences between countries and between
235 genders. To evaluate the effect of age on uncertainty, we calculated the percentage of
236 uncertainty behaviours (i.e. pedestrians as one behaviour per pedestrian) in each age category.
237 Two samples were used for this purpose: (1) a random sample of 1,278 pedestrians (N=551
238 for France and N=727 for Japan, with 2x10 minutes scorings for each site on two different
239 videos) and (2) our sample of 118 pedestrians crossing at the red light and showing

240 uncertainty in each country (N=80 for France and N=38 for Japan, see details for each site in
241 Table 1). For each sample, we divided the number of individuals per age category by the total
242 number of uncertainty behaviours (*100). We then calculated the differences between the two
243 percentages in each age category: negative values indicated that fewer individuals showed
244 uncertainty behaviours than the average for a given age category, while positive values
245 indicated that more individuals showed uncertainty behaviours than the average. A
246 Kolmogorov-Smirnov test was realised to compare the distributions of the hesitation
247 frequency according to departure order. For this test, the mean departure order rank \pm
248 standard deviation per uncertainty behaviours is given per country.

249 A generalized linear model (GLM) was used to test the influence of the independent
250 variables on our response variables. We first analysed the uncertainty time using a Gamma
251 law (link = log) with the following independent variables: the age and the gender of the
252 hesitating pedestrian, whether s/he was using a phone, whether s/he was accompanied by at
253 least one other person, the country, the number of lanes, the number of waiting pedestrians,
254 the order of pedestrian departure, the [country*gender] interaction and the
255 [country*accompanied] interaction. Another possible biological and viable interaction would
256 have been [country*age], but this was not tested due to insufficient data per age category. We
257 then analysed the probability of abandon or acceleration using a Binomial law (abandon noted
258 as 1, acceleration noted as 0) and with the following dependent variables: the age and the
259 gender of the hesitating pedestrian, whether s/he was using a phone, whether s/he was
260 accompanied by at least one other person, the country, the number of lanes, the number of
261 waiting pedestrians and the order of pedestrian departure. For each GLM, we ran multi-model
262 inferences to rank candidate models according to (i) their respective Akaike information
263 criterion after correction for small sample sizes (AICc) and (ii) normalized Akaike weights
264 (AICw) (Burnham and Anderson, 2004). $\Delta AICc$ is the difference in AICc between a given
265 model and the model with the lowest AICc. AICw indicates the probability that a given model
266 will be the best among candidate models (Burnham and Anderson, 2004; Burnham et al.,
267 2011; Johnson and Omland, 2004).

268 All models were considered, from the null model (0 variable) to the full models (all
269 tested variables). Models were ranked and compared according to their AICc, with the lowest
270 AICc indicating the best model. Models with a difference of AICc ($\Delta AICc$) <4 were
271 considered equally possible candidates and their statistics (estimate, z-score and p-value) were
272 averaged according to Bartoń's method (2013). The null model was also included as a
273 possible candidate but was never among the models with lowest AICc. Averaged model

274 coefficients were obtained for models with a $\Delta AICc < 4$. Model inference and averaging were
275 carried out with the R package ‘MuMIn’ (Bartoń, 2013).

276 A Pearson correlation test was used to assess whether the relative number of abandons
277 and accelerations increased or decreased significantly according to the pedestrian’s departure
278 order (this analysis was carried out until the sixth rank, as no pedestrians were observed
279 hesitating after this rank order).

280 Statistical analyses were performed using Rstudio 1.0.143 (Team RStudio, 2015) and
281 the significance level was set at 0.05.

282

283 **RESULTS**

284 **a) Factors affecting uncertainty behaviour**

285 We observed 80 uncertainty behaviours for 1,464 infractions at Strasbourg (i.e.
286 5.46%) whilst 38 uncertainty behaviours were observed for 369 infractions at Nagoya
287 (10.29%), which is different ($\chi^2=11.4$, $p<0.001$). The gender of the pedestrian had no effect
288 on the likelihood of hesitating while crossing against a red light in either country ($\chi^2<0.48$,
289 $p>0.490$). For the age variable, a zig-zag product on the likelihood of hesitating was observed
290 on the graph for Japanese pedestrians. This is probably due to the small dataset with
291 uncertainty behaviours. The age graph for French pedestrians seemed more coherent, with the
292 highest number of uncertainty behaviours recorded for 20-year-old pedestrians and the lowest
293 for their 60-year-old counterparts (Figure 2). The tendency to hesitate (K-s test, $W = 6074$, p -
294 value = 0.06178) was observed in the first pedestrians to cross the road in France
295 (average \pm stdv=1.8 \pm 1.2), whilst the same tendency was shown by pedestrians following
296 individuals who had already started crossing in Japan (average \pm stdv=2.2 \pm 1.6). We observed
297 ten hesitating individuals using their phones (8.4% of hesitating individuals), which is no
298 higher than the rate of individuals using their phones whilst crossing at a red pedestrian light
299 (8.6%).

300 The uncertainty time GLM showed that this dependent variable is influenced by the
301 country (Table 2, $z=2.134$, $p=0.033$), by being accompanied ($z=2.526$, $p=0.012$) and by the
302 [country*accompanied] interaction ($z=2.087$, $p=0.037$). Uncertainty time appears to be longer
303 in Japan, and longer when the pedestrian is alone in both countries, but more importantly this
304 last effect is enhanced in Japan (i.e. a stronger effect was observed in Japan, with longer
305 uncertainty times when alone). Other factors (see Table 2) did not affect the time of
306 uncertainty.

307

308 **b) Factors affecting subsequent behaviours**

309 After the 118 scored uncertainty behaviours, pedestrians showed 90 abandons (76.3%)
310 and 28 accelerations (23.7%). Abandoning a crossing therefore appears then more probable
311 than accelerating. Surprisingly, the percentage of accelerations is higher in Japan compared to
312 France (34.2% and 18.7%, respectively). The GLM for the types of subsequent behaviours
313 (abandoning or accelerating, Table 3) showed that only the number of lanes [2x1] is
314 significant ($z=3.445$, $p=0.001$): the abandon rate increased with the number of lanes, whilst
315 the acceleration rate decreased (Figure 3). Due to our small sample size, we did not obtain a
316 significant effect for [2x2] and [2x3] lanes (where only abandon behaviours were observed).
317 Concerning the departure order ($z=1.682$, $p=0.093$), a Spearman correlation test on the
318 percentage of abandons/accelerations according to the pedestrian departure order revealed that
319 the relative number of abandons decreases with the departure order, whilst the relative
320 number of accelerations increases ($\rho_{\text{abandon}}=-0.86$, $\rho_{\text{acceleration}}=0.86$, $p=0.026$, Figure 4).

322 **DISCUSSION**

323 This study highlights the factors influencing the uncertainty behaviour of pedestrians
324 crossing against the red light and the subsequent behaviours, namely abandoning or
325 accelerating the crossing. Japanese citizens are known to respect social rules more than
326 French or even western citizens (Benedict, 2005; Komiya, 1999; Markus and Kitayama, 1991;
327 Ito, 1989). These cultural differences are not explained by differences in environmental
328 factors but rather by the emergence of social conventions (Centolla and Baronchelli, 2015). A
329 previous study showed that only 2.1% of crossings at signalized intersections are illegal in
330 Japan, compared to 41.9% in France (Pelé et al., 2017). However, only 5% of French
331 pedestrians showed uncertainty behaviours when crossing against the red light, compared to
332 10% of the Japanese pedestrians. It is important to note that it was impossible to carry out
333 observations of a road with 3*2 lanes in Strasbourg to compare with our observations in
334 Nagoya. This limitation could decrease the ratio of illegal crossings and the ratio of
335 uncertainty behaviours in Japan compared to France.

336 The uncertainty time is also longer in Nagoya (Japan, 1.55 ± 1.45 s) than in Strasbourg
337 (France, 1.22 ± 0.97 s). These two elements –higher rate and longer time in Japan - lead us to
338 suggest that Japanese pedestrians who crossed illegally mostly did so by following other
339 pedestrians. Indeed, hesitating seems to occur in Japan when a pedestrian follows others
340 already crossing against the red light (rather than due to inattention from using their phone,
341 see explanations below) then realises the misevaluation. Pelé et al. (2017) have already

342 described this phenomenon in Japanese pedestrians. Indeed, pedestrians show a strong
343 mimetism by following social information when they cross the road, sometimes inadvertently
344 crossing against the red light (Faria, 2010; Pelé et al., 2017). This could explain why surprised
345 pedestrians hesitate when they realise that they are crossing illegally. The information they
346 obtain after starting to cross might be personal (by checking the light colour or seeing a car
347 arriving) or social (noticing that other pedestrians do not cross). These conclusions may be
348 confirmed by the fact that accompanied pedestrians in Japan showed a lower uncertainty time
349 than pedestrians who crossed alone: the accompanied pedestrian could be therefore helped by
350 social information. These results and previous findings (Pelé et al., 2017) confirm a strong
351 inter-country difference in the causes of illegal road-crossings and the causes of uncertainty
352 behaviour. Pelé et al. (2017) showed that whilst most pedestrians deliberately cross against
353 the red light in France, they appear to do so accidentally in Japan.

354 Many studies have shown an age and gender effect on crossing behaviours (Tom and
355 Granié, 2011; Holland and Hill, 2007; Oxley et al., 1997). However, no such effects were
356 observed in our study for the uncertainty behaviour rate, or for the uncertainty time and its
357 possible subsequent behaviours. We suggest that this absence of effect may be due to two
358 consecutive indirect filters resulting from our hesitating pedestrian population and linked to
359 the data set: we studied uncertainty behaviours in a population of individuals who showed
360 such behaviours (compared to those who did not show them). In turn, this population was part
361 of a larger population of individuals: those crossing at a red light (compared to those who
362 crossed at the green light). We assume that these two consecutive filters resulting from our
363 dataset could lead us to solely observe pedestrians presenting a certain level of risk taking.
364 For instance, women and/or elderly pedestrians, known to take fewer risks than men or
365 adolescents (Sueur et al., 2013; Faralla et al., 2013; Wilson and Dally, 1985) did not cross at
366 the red light or rarely did so, thus could bias the dataset and providing non-significant results
367 for age and/or sex effect on uncertainty. We also expected men to display more accelerations
368 than women, but this gender effect does not appear to be statistically significant, again
369 probably due to the aforementioned filtering. We checked this filtering hypothesis in our
370 dataset: this was checked with Japan pedestrians but not with French ones. Indeed, we
371 observed a change in gender-ratio between total crossings and illegal crossings and between
372 illegal crossings and uncertainty behaviours in Japan but this was not the case with France
373 (see Table 4). Considering a possible age effect, we expected more uncertainty behaviours
374 from the youngest (10-year-old) and oldest (more than 60-year-old) pedestrians than in other
375 age categories. However, the results were inconsistent in Japan (Figure 2a) and were

376 unexpected in France (Figure 2b), with 20-year-old French pedestrians showing the highest
377 rate of uncertainty behaviours and 60-year-old pedestrians displaying the lowest rate of
378 uncertainty behaviours. This result may be explained by our low sample size, but we cannot
379 exclude the possible effect of decreasing cognitive abilities with age (Brown and Ott, 2004;
380 Farias et al., 2005; Iosa et al., 2014; Salthouse, 1996), responsible for a lack of reaction or
381 absence of uncertainty behaviour in the elderly when in risky situations (Holland and Hill,
382 2007; Oxley et al., 1997).

383 Whilst we did not observe an effect of environmental variables on the uncertainty
384 time, we did observe an effect on the probability of an acceleration or abandon behaviour
385 after uncertainty. A higher number of lanes resulted in a decrease in the probability that a
386 pedestrian would accelerate and an increase in the probability that they would abandon the
387 crossing. Only abandon scenarios were displayed by pedestrians illegally crossing roads with
388 six lanes (three lanes in each direction). As the number of lanes increases, the number of
389 vehicles and subsequently the risk of accidents increases. Thereby, abandoning the crossing
390 appears to be a safer behaviour for pedestrians than accelerating. Indeed, we decrease our
391 perception abilities when rushing, and we thus increase the probability of an error of
392 judgement. This processing-speed theory (Salthouse, 1996) - where accuracy of decisions
393 decreases with speed (Pelé and Sueur, 2013; Nagengast et al., 2011; Sueur and Pelé, 2015) -
394 has been well demonstrated for driving speed but can also be confirmed in pedestrians (Aarts
395 and Schagen, 2006; Kloeden et al., 2002; Kloeden et al., 2001).

396 Our results also show that the probability of abandoning decreases with the departure
397 order of the pedestrian (i.e. with the number of pedestrians who have already crossed or
398 started crossing) while the probability to accelerate increases. This mimetic effect is due to
399 conformity bias (Cialdini and Goldstein, 2004), and increases the risk of being injured or
400 killed. Referred to as “sheep” or “herd” behaviour, this copying behaviour is well known in
401 human beings in domains such as financial markets, fashion, purchasing or crowd behaviour
402 (Banerjee, 1992; Bikhchandani et al., 1992; Chen, 2008; Hirshleifer et al., 2003; Mawson,
403 2005; Raafat et al., 2009). It seems to be deeply rooted in human behaviour due to the
404 gregariousness and sociality of the human species, and can be observed in many other social
405 animal species (Couzin and Krause, 2003; King and Sueur, 2011; Krause and Ruxton, 2002).
406 However, it may also reflect a sense of safety in numbers; car drivers are more likely to see a
407 group and are hence more likely to slow down or stop, even if they have right of way (Harrell,
408 1991; Rosenbloom, 2009).

409 Finally, contrary to what we expected and what has been described in the literature
410 (McKnight and McKnight, 1993; Neider et al., 2010; Strayer et al., 2003), we did not observe
411 a decrease in attention when pedestrians were using a phone. Only ten hesitating individuals
412 were observed using their phone (8.4% of the sample size). This does not seem no higher than
413 the rate of individuals using a phone whilst crossing against the red light (8.6%), and these
414 pedestrians did not show a higher uncertainty time than other pedestrians. The rate recorded
415 in our study is lower than the 20% of distracted pedestrians found by Bungum and colleagues
416 (2005). Again, this result may be due to the low sample size caused by the double filtering
417 (see above).

418 Overall, combined with the findings of previous studies (Pelé et al., 2017), these
419 results indicate the existence of two categories of rule breakers among pedestrians, namely
420 those who deliberately do so (as described in Pelé et al. 2017) and those who do so
421 inadvertently (shown here through uncertainty behaviour). This second category appears to
422 represent the most vulnerable pedestrians, because they seem to misevaluate a safety crossing.
423 Additional signals could be set up to provide more adequate protection of pedestrians at
424 accident-prone intersections. Sound signals have already been set up to help impaired or blind
425 people (Tauchi et al., 2000; Tauchi et al., 1998). In our case, we could imagine less pleasant
426 signals such as the new water spray systems that surprised rule-breaking pedestrians in
427 China's Hubei Province (BBC News). Further research will then be needed to measure the
428 success rate of such innovative systems in saving lives.

429

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586 **TABLES**

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588 Table 1: Details concerning the studied sites in Strasbourg (France) and Nagoya (Japan). A
 589 total of 80 and 38 uncertainty behaviours were observed in France and in Japan, respectively,
 590 on the lines “Number of uncertainty behaviours counted during 6 hours of observation”.

591 Pictures of the different intersections are available in the Supplementary Material section of
 592 Pelé et al. 2017, via this link: <https://doi.org/10.6084/m9.figshare.c.3677176.v1>

Strasbourg-France				
Sites	Train Station	Pont des Corbeaux	Place Broglie	
Coordinates	48.584474, 7.736135	48.579509, 7.750745	48.584559, 7.748628	
Number of lanes in each direction	1	2	1	
Mean pedestrian flow per hour	667	612	850	
Mean road-crossing speed (m.s ⁻¹)	0.96±0.05	1.11±0.29	1.01±0.16	
Data collection dates	02/07-07/07/2014	01/10-25/10/2014	15/02-09/03/2015	
Number of uncertainty behaviours counted during 6 hours of observation	36	23	21	
Percentage of illegal crossings	58.29%	32.92%	44.02%	
Nagoya-Japan				
Sites	Train Station	Maruei	Excelco	Osu-Kannon
Coordinates	35.170824, 136.884328	35.168638, 136.905740	35.166891, 136.907284	35.159316, 136.901697
Number of lanes in each direction	3	one-way street	1	1
Mean pedestrian flow per hour	480	645	869	814
Mean road-crossing speed (m.s ⁻¹)	1.10±0.22	1.15±0.21	0.98±0.21	1.07±0.18
Data collection dates	13/06-05/07/2011	27/01-05/02/2015		
Number of uncertainty behaviours counted during 6 hours of observation	3	15	4	16
Percentage of illegal crossing	8.34%	14.53%	2.11%	8.86%

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597 Table 2: Results of the model selection (see statistical analyses section) with the uncertainty
 598 time (in seconds) as a dependent variable. Considering the number of lanes, the reference
 599 chosen is [1x1].

Independent variables	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
(Intercept)	0.869	0.281	0.284	3.064	0.002
Accompanied [Yes]	-0.733	0.288	0.290	2.526	0.012
Country [France]	-0.629	0.292	0.295	2.134	0.033
Accompanied [Yes]* Country [France]	0.660	0.313	0.316	2.087	0.037
Number of waiting pedestrians	-0.014	0.014	0.014	1.033	0.302
Gender [Man]	-0.105	0.191	0.193	0.543	0.587
Number of lanes [2x1]	0.368	0.286	0.289	1.275	0.202
Number of lanes [2x2]	0.478	0.323	0.326	1.465	0.143
Number of lanes [2x3]	-0.224	0.487	0.493	0.455	0.649
Using a phone [Yes]	-0.157	0.260	0.263	0.595	0.552
Age	-0.003	0.005	0.005	0.547	0.584
Departure Order	-0.005	0.054	0.054	0.099	0.921
Gender [Man]*Country [France]	-0.200	0.303	0.306	0.652	0.514

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603 Table 3: Results of the model selection (see statistical analyses section) with the type of
 604 behaviour following uncertainty as dependent variable (abandon = 1, acceleration = 0).

Independent variables	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)
(Intercept)	-0.574	1.067	1.075	0.534	0.593
Number of lanes [2x1]	2.882	0.829	0.837	3.445	0.001
Number of lanes [2x2]	0.625	0.874	0.883	0.708	0.479
Number of lanes [2x3]	17.015	1377.357	1392.471	0.012	0.990
Departure Order	-0.303	0.178	0.180	1.682	0.093
Age	0.023	0.018	0.018	1.273	0.203
Gender [Man]	0.648	0.550	0.556	1.166	0.244
Number of waiting pedestrians	-0.054	0.050	0.051	1.072	0.284
Country [France]	0.670	0.832	0.841	0.797	0.425
Using a phone [Yes]	0.490	0.984	0.995	0.492	0.623
Accompanied [Yes]	-0.179	0.558	0.563	0.319	0.750

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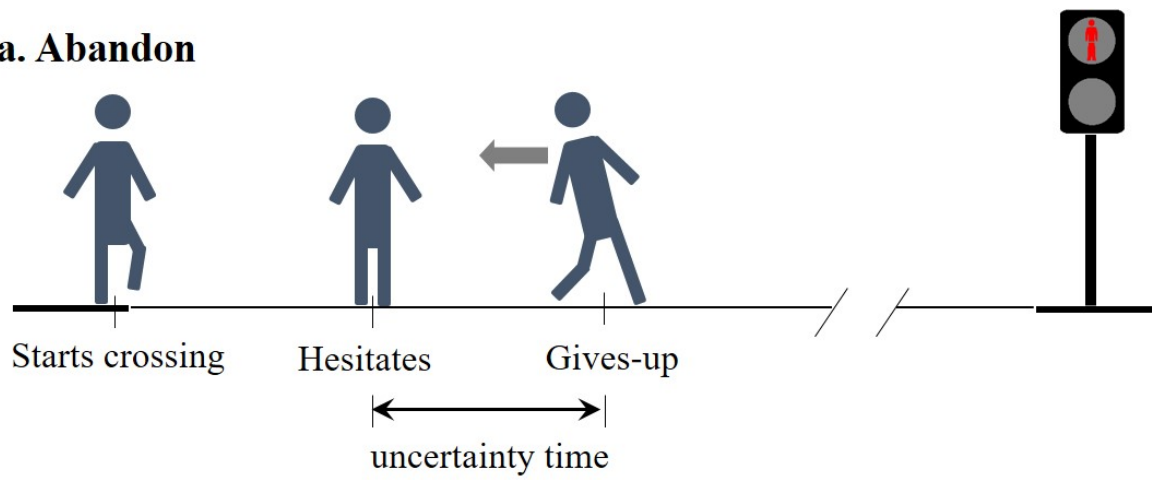
622 Table 4: Relative percentage of men and women in France and Japan according to the total
623 crossing (at red and green light), the illegal crossing (red light) and the uncertainty
624 behaviours.

		Total crossing	Illegal crossing	Uncertainty behaviours
France	Men	44.4	44.4	46.25
	Women	55.6	55.5	53.75
Japan	Men	42.2	59	42.1
	Women	57.7	41	57.9

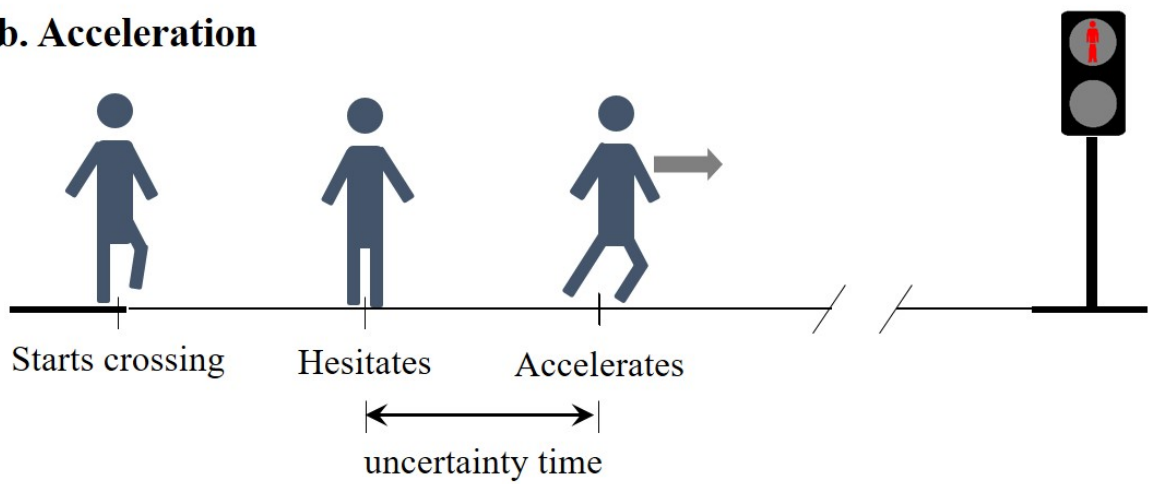
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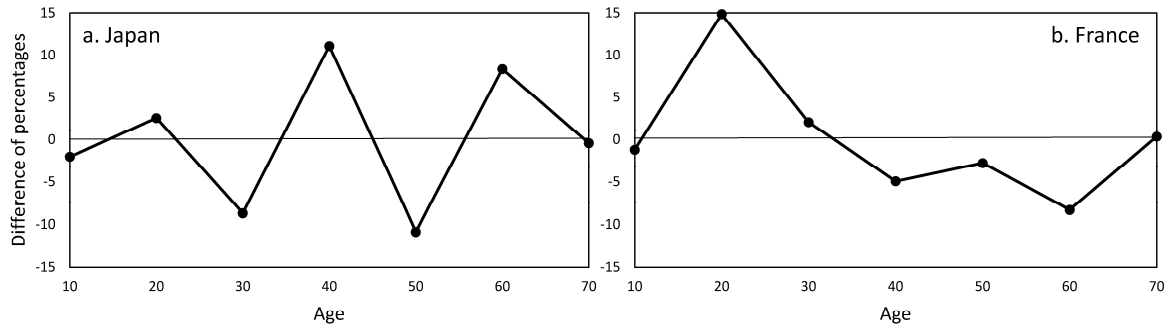
a. Abandon



b. Acceleration



630 Figure 1: Temporal scheme of the different behaviours scored in this study.



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644 Figure 2: Differences in the percentages of 118 pedestrians showing uncertainty behaviours
 645 (N= 80 for France and N= 38 for Japan) and 1,278 pedestrians of a sample size (N=551 for
 646 France and N= 727 for Japan) in a. Japan and b. France. Positive values showed that more
 647 pedestrians in a given age category showed uncertainty behaviour than expected; negative
 648 values showed that fewer pedestrians in a given age category showed uncertainty behaviour
 649 than expected.

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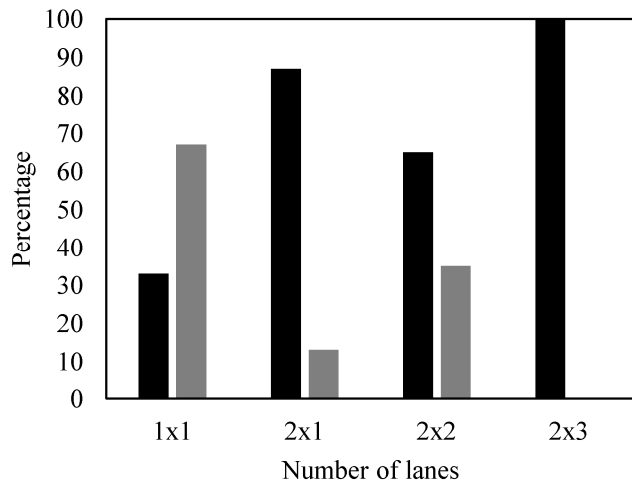
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672 Figure 3: Percentage of abandons (black bars) and accelerations (grey bars) according to the
 673 number of lanes.

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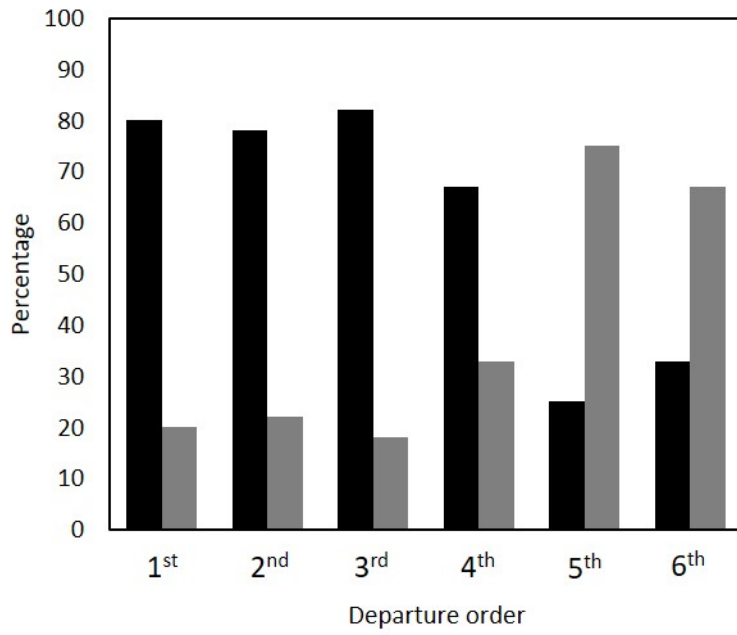
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696 Figure 4: Rate of abandonment (black bars) and acceleration (grey bars) according to the
697 departure order of the pedestrian.

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