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Different risk thresholds in pedestrian road crossing behaviour: A comparison of French and Japanese approaches

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ABSTRACT

When crossing the road, pedestrians have to make a trade-off between saving time and avoiding any risk of injuries. Here, we studied how culture influences an individual's perception of risks when crossing a street, using survival analysis. This study is the first to use this analysis to assess cognitive mechanisms and optimality of decisions underlying road crossing behaviour. We observed pedestrian behaviour in two city centres: Inuyama (Japan) and Strasbourg (France). In each city, observations were made at a safe site consisting of a crosswalk and a street light and at an unsafe site (i.e. no crosswalk or street light). At the unsafe site, we measured the time needed by a pedestrian to take a decision (T_{dec}). During T_{dec}, a pedestrian estimates whether he can (T_{safe}) or cannot (T_{risk}) cross the road. Using survival analysis, we studied the distributions of these three time variables and showed that French pedestrians took more risks than Japanese pedestrians, and that males took more risks than females, but only in Japan. More studies would considerably broaden our understanding on how culture may affect decision-making processes under risky circumstances.

1. Introduction

Animals, including humans, have to deal with environmental and social factors every day in order to maximise their fitness. The way an individual behaves may enhance its fitness with regards to a specific factor, but may at the same time decrease fitness regarding another (McNamara and Houston, 1996; Bogacz, 2007). Most previous research assessed whether choices made by individuals are rational in terms of decision optimality (Bogacz, 2007; Pelé et al., 2010). Indeed, making the right decision entails collecting social or non-social (Dall et al., 2005) information about all possible outcomes; yet the time available to collect such information is often limited (Franks et al., 2003). Threshold responses may underlie optimal decisions and can be formalised by the diffusion model by which the speed of decision-making is optimised to meet the required accuracy (Bogacz, 2007). The diffusion model stipulates that a choice should be made as soon as the difference between the evidence supporting the winning alternative and the evidence supporting the losing alternative exceeds a threshold. The diffusion model implements an optimal test called the sequential probability ratio test (SPRT) which optimises the speed of decision-making for a required accuracy (and a required risk). These specific mechanisms were successfully found in insects when choosing the best new nest (Franks et al., 2003), in fishes when facing predators (Ward et al., 2008), and in primates when moving collectively (Sueur et al., 2011).

Human road crossing behaviour could easily illustrate the diffusion model. Indeed, when crossing a street, individuals need to trade between saving time and avoiding any risk of injuries (Faria et al., 2010). This compromise directly depends not only on the traffic but also on the presence of traffic lights (Aoyagi et al., 2011; Guo et al., 2012; Havard and Willis, 2012). Crossing at sites where there is no pedestrian crossing, or crossing against the red light, results in a higher chance of road accident injury (Yang et al., 2006). In a study on Australian pedestrians, King et al. (2009) showed that crossing against the lights exhibited a crash risk eight times than crossing legally at signalised intersections. When considering sex of pedestrians, it appears that males seem to take more risks when crossing than females (Holland and Hill, 2007; Rosenbloom, 2009; Faria et al., 2010). Young and old individuals seem to commit also more road crossing violations than middle age people (Holland and Hill, 2007; Sullman et al., 2012). Groups or presence of people at the curb might also influence in a right or wrong way crossing behaviour of pedestrians (Rosenbloom, 2009; Faria et al., 2010). However, we have very little data concerning how the country's traditions of

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individuals could influence their perception of risks when crossing the road (Markus and Kitayama, 1991). Influence of cultures and especially of Asian and Western cultures was already studied concerning decision and risk assessment in international marketing (Tse et al., 1988) with Western cultures considered as having lower uncertainty aversion, lower tolerance for hierarchical relationships, and higher individualism than Asian cultures (Lee et al., 2011; Mihet, 2012). However no study was done on influence of cultures on pedestrian behaviour. Only one study on the tendency to cross on a red light showed that Ultra-Orthodox pedestrians committed more violations than secular pedestrians did (Rosenbloom et al., 2008). To our knowledge, the mechanisms underlying individuals' decision to cross have yet to be described. Pedestrians should evaluate the chance to cross or risk of injuries by determining whether the gap between two vehicles is big enough to cross. This is called the gap acceptance theory (Brewer et al., 2006; Zhuang and Wu, 2011b). Looking at vehicles before crossing the road is the most frequently mentioned safe behaviour that was practiced by the pedestrians. Some models tried to explain crossing behaviours and this gap or decision time at marked or unmarked roadway but did not assess precisely the mechanism underlying decision-making to cross (Zhuang and Wu, 2011a; Papadimitriou, 2012). Here, we studied the behaviours of pedestrians when crossing streets in two different countries: Japan and France, representing respectively Asian and Western cultures. We analysed the distributions of different decision times and expected to find a quorum-threshold process underlying pedestrians' decision-making. Indeed, crossing the street implies a risk depending on the car speed and the time to cross. Then, we should find a time threshold under which pedestrians would not cross the street. We also expected to highlight differences according to sex and age, as well as some differences between pedestrian behaviour between the two sites, as Japanese citizens are known to be more respectful of rules than their French counterparts (Benedict, 2005). Moreover, as Western cultures are more risk-prone and have a lower uncertainty aversion (Lee et al., 2011; Mihet, 2012), the time threshold should be lower in French pedestrians than in Japanese ones, meaning that French pedestrians cross the streets quickly and by evaluating in a shorter time distance with cars compared to Japanese citizens. This study is the first to use this survival analysis to assess optimality of decisions underlying road crossing behaviours between two different cultures.

2. Materials and methods

We observed pedestrian behaviour in the city centre of Inuyama, Japan from April to May 2011 and at Strasbourg, France from October to November 2011. The exact coordinates of the observed sites are respectively N 35°22.928′ E 136°57.057′ and N 48°35.099′ E 7°44.876′. Observations of pedestrian behaviour were made at sites which were safe (i.e. with pedestrian crossing and traffic lights) or unsafe (i.e. without pedestrian crossing or traffic lights) but which had to be crossed if pedestrians wished to continue their route. For both cities, safe and unsafe sites were on the same road, approximately 100 m apart (see Figs S1 and S2 in ESM). Observations were made between 01:00 PM and 02:00 PM when pedestrian volume was high. In each city, road traffic was two-way for both sites and we observed the pedestrian behaviour regardless of which pavement they set out from. We only observed pedestrians crossing the road alone (i.e. excluding couples or groups) in order to be certain that we were measuring their individual decision to cross (Faria et al., 2010). We analysed 12 days of observations in Inuyama and in Strasbourg. Traffic (number of cars during 10 min) was identical in both cities (Mann–Whitney test: $U = 16$, $P = 0.818$, $N_{\text{Inuyama}} = N_{\text{Strasbourg}} = 12$, $M_{\text{Inuyama}} = 93.01 \pm 11.73$, $M_{\text{Strasbourg}} = 95.17 \pm 14.25$). It was also identical at both sites at the observation time at Inuyama (Mann–Whitney test: $U = 8.5$, $P = 0.421$, $N_{\text{safe}} = N_{\text{unsafe}} = 6$, $M_{\text{safe}} = 86.20 \pm 14.06$, $M_{\text{unsafe}} = 93 \pm 12.94$) and at Strasbourg (Mann–Whitney test: $U = 15.5$, $P = 0.699$, $N_{\text{safe}} = N_{\text{unsafe}} = 6$, $M_{\text{safe}} = 92.67 \pm 11.29$, $M_{\text{unsafe}} = 95.17 \pm 14.24$) with a speed limit of 50 km/h. Similarly, the duration of the pedestrian traffic lights were the same in France and Japan: green for 30 s and red for 1 m, 30 s. The road width is the same (8 m) and pedestrians have the same sight line (about 100 m on each side) in both cities. We obtained 245 observations of pedestrians in Inuyama (135 females, 110 males) and 315 in Strasbourg (152 females, 163 males) divided into seven age classes from 10 to 70 years old.

We used a Chi square test to compare the proportion of individuals crossing the road against the red light in Inuyama and Strasbourg. We scored different events when a pedestrian crossed the road at the unsafe site (see Fig. 1). These different events enabled us to measure three parameters: T_{dec}, T_{safe} and T_{risk}. T_{dec} is the time needed by a pedestrian to take a decision. During T_{dec}, a pedestrian estimates whether he can (T_{safe}) or cannot (T_{risk}) cross the road. T_{safe} is the time a pedestrian estimates necessary to cross the road safely whilst T_{risk} is the crossing time a pedestrian estimates to represent a risk. T_{safe} and T_{risk} depend directly on the distance between the pedestrian and the next approaching vehicle, are linked to traffic density and might also be influenced by culture.

Using survival analysis (Miller et al., 1981; Klein and Goel, 1992), we studied the distributions of these three time variables. We used curve estimation tests first to analyse which type of function these distributions followed: linear (meaning that probability of crossing depends directly on time, whatever the distance of the next car), exponential (probability of crossing is time-constant) or sigmoid function (probability of crossing depends on a time threshold directly correlated to the distance with the next car) (Petit et al., 2009; Sueur and Deneubourg, 2011; Sueur et al., 2011). We then compared the time distributions between cities and genders (for each city) using a Student test and a Levene test. Data was transformed for the last two tests in order to ensure that they fitted linear functions (see ESM). Finally, we assessed whether each variable differed according to age using Kruskal–Wallis test. Analyses were performed in SPSS 17.00, with α set at 0.05.

3. Results

When crossing at the safe site, pedestrians at Inuyama broke the rule (crossing against the red light) in only 6.9% of cases whilst pedestrians at Strasbourg did so in 67% of cases (Chi square test on absolute frequency: $\chi^2 = 320.327$; df = 1; $P < 0.0001$). At the unsafe site, the distribution of decision times T_{dec} best fitted with an exponential curve for both Inuyama ($R^2 = 0.96$, $F_{1,2} = 46.78$, $P = 0.021$, $y = 0.747e^{-0.734x}$, Fig. 2a; see Table S1 for all tested functions) and for Strasbourg ($R^2 = 0.99$, $F_{1,5} = 381.56$, $P < 0.0001$, $y = 0.978e^{-1.01x}$, Fig. 2a). This distribution of decision times T_{dec} did not differ between Inuyama and Strasbourg (Levene test: $F = 1.659$, $P = 0.211$; Student test: $t = -1.168$, df = 22; $P = 0.255$, Fig. 2b). Time estimation for the absence of risk for crossing T_{safe} best followed a sigmoid distribution for Inuyama ($R^2 = 0.99$, $F_{1,26} = 3289$, $P < 0.0001$, $y = 1/(1 + (x/16)^{2.5})$, Fig. 2c, Table S2) and Strasbourg ($R^2 = 1.00$, $F_{1,30} = 8048$, $P < 0.0001$, $y = 1/(1 + (x/9)^3)$, Fig. 2c). This distribution of T_{safe} differed between Inuyama and Strasbourg with a threshold S (mean estimation) of 16 s in Inuyama and 9 s in Strasbourg (Levene test: $F = 0.796$, $P = 0.376$; Student test: $t = -3.285$, df = 52, $P = 0.002$, Fig. 2d).

Analyses showed that T_{safe} did not significantly differ between sex and age classes in either city (see Table 1) but males tended to differ from females in Inuyama with a threshold S of 11 s