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Numerosity heuristic in route choice based on the presence of traffic lights

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ABSTRACT

We analyzed how the presence of traffic lights, as a cause of time loss, is taken into account by drivers in planning their route through urban areas. Our hypothesis was that routes with fewer traffic lights are preferred even if the probability of having to stop at those lights is high and the waiting time at the red light is long. We carried out a questionnaire-based study in which car drivers ($n = 194$) chose the route they preferred from pairs of hypothetical itineraries. The binary dependent variable was the type of route chosen: either a route containing fewer lights at which being forced to stop was highly probable, or a route containing more lights at which being forced to stop was far less probable. We found that the number of traffic lights was the preferred criterion, and that this preference could sometimes induce non-optimal route choices. Red- and green-light durations were also used as choice criteria. However, manipulation checks showed that participants did not estimate the probability of being forced to wait vs. being able to go through the light. We concluded that they estimated a threshold of acceptable waiting time at red lights depending on the number of traffic lights along the itinerary.

1. Introduction

We are all so impatient that we believe there is often time to gain and especially not a minute to lose. When we are behind the wheel, this belief influences our choice of speed (Delhomme, 2002; Letirand & Delhomme, 2003, 2005, 2006; Rothengatter, 1988). Several studies have shown that car drivers overestimate the time gained by driving at high speeds (Peer, 2010; Svenson, 2008, 2009), and that biased estimates of a journey's mean speed are more predictive of route choice than objective estimates (Svenson, Eriksson, Salo, & Peters, 2011). In urban areas, however, car drivers generally have to deal with many interactions between different types of road users (trucks, motorcycles, cyclists, pedestrians, etc.) who are protected to various degrees and are moving at different speeds. Drivers cannot go too fast when their attentional resources are allocated to managing such interactions (Summala, 1997). In these circumstances, elements that can make a driver slow down or even stop have a substantial impact on travel time, which is why traffic lights are often considered by car drivers as a potential cause of time loss (Palat & Delhomme, 2012; Porter & Berry, 2001). It follows that drivers take traffic lights into account when planning their routes (Papinsky, Scott, & Doherty, 2009). Apparently, however, they do not necessarily use traffic-light information properly when choosing an itinerary.

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The information to be taken into account by drivers who wish to optimize their travel time includes the number of lights they will encounter on their way and the duration of red and green lights (yellow-light duration is fixed at 3 s in built-up areas in France: Ministère de l'Ecologie, de l'Energie, du Développement Durable et de la Mer, 2009). These pieces of information are usually available, although to various degrees of precision, for known itineraries. Every time a driver comes across a traffic light, it is likely that he/she will have to stop if the light is yellow or red. Knowing yellow-, red-, and green-light durations makes it possible to estimate the probability of having to stop at a traffic light. In fact, the three light colors delineate two periods in the cycle of a traffic light (Le Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques, 2008): a period during which approaching vehicles have to stop before the intersection (yellow and red lights) and a period during which approaching vehicles are authorized to go through the intersection (green light). When the two periods are equal in length, the probability of having to stop at the traffic light is 50%. In reality, though, the yellow- and red-light duration is not always equal to the green-light duration, especially at intersections where the roads differ in size. When the red-light duration is longer than the green-light duration, the probability of having to stop at the traffic light increases, as does the average waiting time at the red light. Interestingly, red- and green-light durations are predictive of red-light running. In a study on car drivers' aggressive behavior (Shinar, 1998), the number of red-light violations was positively correlated with red-light duration, whereas it was negatively correlated with green-light duration.

Several criteria that could save time can be taken into account in choosing a route. Many car drivers consider the presence of traffic lights. The number of lights to be driven through during the trip, as well as the probability of having to stop at those lights (derived from red- and green-light durations) are important pieces of information. The driver should attach equal importance to both, and consider them simultaneously when estimating possible travel times. However, probability remains a relatively complex abstract concept for an average person even though in today's France, as well as in other industrialized countries, basics of probability theory are in the high school program (Ministère de l'Education nationale, 2011). Overwhelmed by information in everyday life, people routinely tend to engage in minimal cognitive processing when judging or making a decision (Fiske & Taylor, 1984). Hence, decisions where probability judgments seem crucial are often biased because of heuristics used instead of probability estimations (Gilovich, Griffin, & Kahneman, 2002; Sutherland, 1992).

One such heuristic makes drivers pay more attention to the number of lights along an itinerary, especially when they allocate few cognitive resources to choosing a route. It is the *numerosity heuristic*, illustrated by Pelham, Sumarta, and Myaskovsky (1994). In their Study 4, an imaginary scenario was presented to students. A soldier had to choose between two minefields. There were fewer mines on the first minefield but the probability that they would explode was quite high. On the second minefield, there were more mines but the probability that they explode was lower. It was possible to estimate the probability that one could safely cross the first and the second minefields, 33% and 35%, respectively. The participants skipped the calculation and chose the first minefield.

The possibility of focusing on number while overlooking other important criteria can be found in many common decision-making situations. Before taking the wheel or while already driving in a car, drivers often face similar dilemmas involving a choice between alternative routes. There are more traffic lights on certain itineraries than on others, but the probability of having to stop at the lights also varies across lights. It is plausible that drivers choosing a route with fewer traffic lights make the same mistake as the participants of the study described above. However, there are some important differences between the minefield problem and the route-choosing problem. The former is about a single success/failure probability in a complex repetitive-event situation, whereas the latter is motivated by the desire to avoid time loss caused by a number of stops more or less likely to occur. Route selection based on this last criterion can be modeled by the binomial distribution (the number of successes in a sequence of n independent Bernoulli experiments). In both cases, exact computations are quite difficult for a layperson. But the consideration of probabilities of single events can lead to correct decisions, especially for simple problems where the probability across the concerned events remains constant. In this case, there is a preference for using numerosity as a selection criterion rather than the probability of occurrence of a single event in a series.

The tendency to attach more importance to number can be explained within the framework of *Cognitive-Experiential Self-Theory* (CEST, Epstein, 1994). CEST is a *dual-process theory* (for a review, see Chaiken & Trope, 1999) and implies two modes of information processing: cognitive and experiential. The primacy of information on numerosity over probability judgments could be due to the preponderance of experiential information processing (EIP) in everyday life. Compared to cognitive information processing (CIP), EIP is influenced by emotions and past experiences. It is superficial, holistic, concrete, and proceeds by associations. Applying EIP is spontaneous and usually unconscious, contrary to applying CIP, which needs conscious mental effort. The two modes of information processing are not incompatible, but can result in conflicting tendencies. For instance, reasoned behavior often gives way to emotion-driven impulsive behavior in everyday life.

The *ratio bias* paradigm (Kirkpatrick & Epstein, 1992) perfectly illustrates the conflict resulting from these two types of information processing. Participants in the Kirkpatrick and Epstein experiment could win money if they drew a winning ticket out of two bowls. The proportion of winning tickets was the same in each bowl, but one bowl contained more tickets than the other. The majority of the participants preferred to draw from the bowl where there were more tickets, i.e., where winning tickets were more numerous. The most astonishing finding was that the participants were aware of the irrationality of their behavior, yet incapable of ignoring numerosity. The bias was observed even when the proportion of winning tickets was lower in the bowl containing a greater absolute number (Denes-Raj & Epstein, 1994). If drivers really do base their route choice on the number of lights rather than on probabilities of stopping on each light, the *ratio bias* might help in understanding the cognitive underpinnings of this preference.