Modeling multiple meanings of mental maps

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Abstract

In this paper, the "mental map" concept is positioned with regard to individual travel behavior to start with. Based on Ogden and Richards' triangle of meaning (1966) distinct thoughts, referents and symbols originating from different scientific disciplines are identified and explained. Furthermore, this research addresses the use and relevance of these constructs to understand and model individual travel demand, and specifies them using two computational models, i.e. Bayesian Inference Networks (BIN) and Fuzzy Cognitive Maps (FCM).

The mental map is commonly used to represent the internal knowledge base of a living data processor, i.e. notions and know-how in the mind concerning a certain issue or question. Most often, this concept is related to geographical or spatial aspects - hence the use of the "map" metaphor (Kuipers, 1982) - but distinct interpretations exist in different scientific fields.

Ever since behavioral psychologist Tolman (1948) first put forward the original synonym "cognitive map", this concept has been studied, adopted and adapted in various disciplines such as cognitive psychology, behavioral geography, computer science, engineering, neuropsychology, etc. For instance, our analysis of 305 references generated by entering the search term "mental map*" in the ISI Web of Knowledge (Thomson Scientific, 2008) shows that present sources can be assigned to 83 different subject areas. Inevitably, this has led to the attachment of multiple meanings to the concept and a proliferation of related terms such as: "(spatial) mental model", "mental representation", "cognitive image", "cognitive collage", "mind map", etc.

Because of mental map's varying contents and applications across different contexts and conditions, as well as its lack of a fixed and precise meaning, it has become an outstanding example of a fuzzy concept. But using such ill defined constructs may lead to misunderstanding and misinterpretation. Moreover, its vagueness and ambiguity can hinder computational implementation. Although the mental map and its intuitive, virtual definitions might be sufficiently clear and self-explaining to use in human communication, definitions for the reconstruction of a knowledge universe require a far-reaching process of formalization in which mathematical logic plays a key role (Lucardie, 1994). During this process, the meaning of a concept often appears to become less clear.

This is exactly what happened to the mental map concept in the travel demand research community to date. Clearly, the expression will be intuitively understood by most travel behavior researchers. However, there is no generally accepted definition in this field - each author basically defines the notion closely to the task at hand -, let alone a universally applied method to take the concept into account in computational applications such as travel demand models. Still its importance to understand travel behavior is widely recognized (Chorus & Timmermans, forthcoming; Hannes, Janssens, & Wets, 2008). Moreover, in theoretical travel demand modeling descriptions the mental map is mentioned as a distinct behavioral factor, e.g. (Arentze & Timmermans, 2000; Salvini & Miller, 2005). However, measurement of this construct and putting the concept into operation in actual forecasting models
proves to be problematic (Golledge & G?rling, 2004), to say the least, partly due to its fuzzy nature. This paper seeks to resolve both the definition and the computation problem.

Ogden and Richards' scheme (1966) is used to disentangle mental maps' multiple meanings. Herein, two major areas of research relevant to travel demand modeling are indicated and discussed in detail: spatial cognition and decision making. First of all, since travel involves movement in space and time, there is an obvious spatial component to the execution of travel plans. Thus, individual's perception and comprehension of geographical space is a key factor to understand travel behavior; the mental map is human's spatial knowledge base, incomplete and biased, regularly updated by travel experiences and foundation of various travel decisions at the same time (Weston & Handy, 2004). This brings us to the second notion of the mental map stemming from decision theory and human reasoning: it conveys the mental representation of a decision problem; a temporarily generated mental model in someone's thought process including relevant choice factors and decision rules (Johnson-Laird, 2004). As planning and executing activity schedules involves different choices such as destination, travel mode and route choices, spatial knowledge is anchored in this broader, general decision process. Both meanings of the mental map, i.e. representation of individual's spatial knowledge and mental model of the personal thought process related to travel decisions, are crucial to comprehend individual's travel behavior.

In addition, relevance and use of both constructs to model individual travel demand are addressed, and two potentially valuable computational models are proposed and implemented: Bayesian Inference Networks and Fuzzy Cognitive Maps. Both models are primarily conceived as an individual mental model of decision problems involved in daily activity and travel scheduling, embedding spatial cognitive factors. Location choice, travel mode choice and activity timing decisions are related to contextual, instrumental and psychological choice factors. This way, a decision network is drawn, including the valuation of constituent parts and the specification of applied choice rules.

Although both models serve a similar purpose in representing the mental map of a decision problem, they differ with regard to basic theorem, network representation and parameter types that can be taken into account. BIN rely on Bayesian probability theory (Winkler, 1972). For its compilation, decision nodes, chance nodes and utility nodes have to be defined and structured in a decision network and several parameters have to be estimated. Chance node values are based on conditional probabilistic assessments, while utility nodes and calculated decisions are deterministic. FCM on the other hand, combine the robust properties of fuzzy logic and neural networks (Kosko, 1986). Here, knowledge is typically represented in a symbolic manner and states, processes, policies, events, values and inputs are related in an analogous manner. For both model implementations, a real life numerical example based on a structured interview protocol is provided (Kusumastuti et al., 2008). These two models are compared and opportunities and drawbacks of both approaches are listed in conclusion.

References


