



# Understanding monthly variability in human activity spaces: A twelve-month study using mobile phone call detail records



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## ABSTRACT

Human activity-travel behaviour (ATB) is a complex pattern of paths and activities in space and time. Studies indicate that ATB is the construction of daily habitual, weekly, monthly and seasonal routines together with strong variety seeking behaviour. Daily habitual travel patterns are usually taken as a basis, but for transportation planners more knowledge is needed on longitudinal trends in human ATB. Empirical data on prolonged perspective are hard to come by while mobile phone based call detail records could be one means of narrowing this research gap. By implementing this method, the present study attempts to provide new insights on individual monthly spatial travel behaviour. Using call detail records obtained from a set of anonymous mobile phone users, we examined their activity locations and activity spaces for 12 consecutive months. We found modest monthly variation in the number of activity locations, whereas there were great variations in the sizes of individual activity spaces. The monthly variation in individual spatial behaviour is explained up to 17% by seasonality, although the variance is predominantly attributed to individual factors and results indicate significant intrapersonal monthly variability. Findings suggest new avenues for future work on ATB from a longitudinal perspective.

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## 1. Introduction

The importance of adopting an intrapersonal perspective in the study of human activity-travel behaviour (ATB) has increased in recent years as a result of globalisation, individualisation and the development of mobile technologies (Graham, 1998; Kwan, 2007). These changes have increased the complexity of individual ATB; it is becoming more flexible, fragmented and adventure-seeking (Doherty, 2006; Mokhtarian et al., 2006). Already in developed countries work-related or mandatory travel constitutes approximately one fifth of all trips and up to one quarter of the total distance people travel, while the biggest share of travel is leisure-related (Schlich et al., 2004; McGuckin and Srinivasan, 2005). Frändberg (2008) therefore questions whether the concept of human daily routine in relation to ATB should be revised because long-distance travel for leisure, occupational, or social interaction (Limtanakool et al., 2006) has become a part of the daily activity of many individuals. Hence there is a need to understand more about human ATB from a longitudinal (monthly, annual) perspective.

It is helpful to understand human spatial behaviour and its temporal variability over a prolonged period of time in relation to a myriad of different societal issues. For instance, an ability to assess how intrapersonal and environmental (societal and natural) factors affect the ATB of individuals is essential in that it gives urban planners the tools to deal with urban sprawl and design better neighbourhoods (Calabrese et al., 2013). It also enables transport planners to develop intelligent (public) transportation systems, develop strategies to limit traffic congestion, and to improve accessibility (e.g. Rose,

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2006; Tang and Thakuria, 2012; Miller et al., 2013; Perchoux et al., 2013). However, to date, most studies in this area have been predominantly based on short periods of time relating to data obtained from daily travel diaries. Such an approach could be criticised for neglecting the mid- or long-term perspectives of an individual's ATB and for not considering that intra-personal variability may be equal to or even greater than interpersonal variability (Pas and Koppelman, 1987; Schlich et al., 2004; Kitamura et al., 2006). One of the first studies to explore the use of longitudinal data indicates that there are clear temporal patterns in individual ATB (Schönfelder and Axhausen, 2010). Moreover, it seems to be a fundamental element of an individual's daily life along with intrapersonal variability.

Generally, however, the longitudinal perspective has been neglected due to a lack of data for longer periods. Exceptions exist. For instance, Lanzendorf (2010) analyses key events and the effect of these events on travel behaviour through the use of so-called mobility biographies. But the conventional approach is to collect data using travel diaries or interviews. This approach is expensive, creates a high response burden for the respondent, and the responses can be biased (Golob and Meurs, 1986; Richardson et al., 1995; Axhausen et al., 2007). Mobile phone call detail records (CDR) offer a means of overcoming these drawbacks, and enable us to better understand and map individual mobility patterns and to provide new insights on human spatial behaviour (González et al., 2008; Ahas et al., 2010; Järv et al., 2012). Given the ubiquity of mobile phones in our lives (Townsend, 2000) and the advantages provided by mobile phone-based data (Asakura and Hato, 2004; Bar-Gera, 2007; Herrera et al., 2010), CDR data could be a valuable complement to traditional methods, especially in longitudinal human ATB research.

In light of the above, we herein attempt to extend current understanding of human spatial behaviour from a longitudinal perspective using CDR data. The objective of our study is to reveal the variance in individual monthly spatial behaviour during a longer (one-year) study period and to examine the factors that affect variability. Therefore, two research questions are addressed:

- (i) To what extent does monthly spatial behaviour vary over a period of 12 months?
- (ii) To what extent do interpersonal and intrapersonal factors and seasonality explain monthly variations in human spatial behaviour?

Individual spatial behaviour is measured using computational geometry, and statistical analyses are applied to characterise the variance in human spatial behaviour. Our study is in part exploratory, and unique in the following ways: first, we propose an alternative, yet complementary method that makes use of a mobile phone-based dataset to measure individuals' ATB; second, a 12-month study period is used; and third, the monthly variability of activity spaces is analysed. The remainder of the paper is organised as follows. In Section 2 we introduce the theoretical and conceptual background to our research approach. We then explain the data, methods, and research design specification in Section 3. We provide our empirical results in Section 4 and discuss our findings, draw conclusions, and suggest directions for future research in Section 5.

## 2. The research background

### 2.1. Variability in human spatial behaviour

Individual ATB is a complex pattern of paths and activities in space and time and is the outcome of the interconnection between individual factors, interaction with other individuals, and external factors such as the surrounding environment and social structure (Hägerstrand, 1970; Pred, 1984). It is (re)shaped by the socio-economic attributes, as well as the needs, life values, preferences, attitudes, prejudices and habits of individuals (Van Acker et al., 2010). Although predominantly based on short-period multiday travel surveys, there is a substantial body of literature that provides information on intra- and interpersonal day-to-day variability (Hanson and Huff, 1982; Jones and Clarke, 1988; Buliung et al., 2008). The findings confirm significant intrapersonal variability, which suggests that half the observed variability in human day-to-day ATB is explained by intrapersonal variability (Hanson and Huff, 1982; Pas and Koppelman, 1987). However, to some extent, intrapersonal variability is influenced by personal attributes (Pas and Sundar, 1995; Susilo and Kitamura, 2005; Buliung et al., 2008). The degree of variability clearly varies due to methodological differences in how human ATB and its variability are measured (Jones and Clarke, 1988; Schlich and Axhausen, 2003).

Variability in individual weekly ATB has been examined in some studies covering from one week up to a period of six weeks (Pas, 1988; Schlich and Axhausen, 2003; Spissu et al., 2009; Tarigan and Kitamura, 2009). The results suggest a weekly pattern in human ATB that is spatially and temporally stable: individual ATB is more routine during the working week, while at weekends it is more dispersed with respect to activities and spatial extent (Schlich and Axhausen, 2003; Srivastava and Schönfelder, 2003; Roorda and Ruiz, 2008; Kamruzzaman and Hine, 2012). In contrast, Buliung et al. (2008) and Miranda-Moreno and Lee-Gosselin (2008) found the spatial extent of ATB to be larger during weekdays, whereas the first study also reported greater day-to-day variation in spatial behaviour during the week than on weekends. However, the latter study suggests that, towards the weekend, activities are more impulsive in terms of perceived flexibility in time and space.

On the other hand, Schönfelder and Axhausen (2010) argue that some activities are performed over different durations, which results in different patterns for certain activities, such as leisure activities (Schlich et al., 2004) or shopping in

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