

SYSTEMATIC REVIEW

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The space-time budget method in criminological research

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Abstract

This article reviews the Space-Time Budget method developed by Wikström and colleagues and particularly discusses its relevance for criminological research. The Space-Time Budget method is a data collection instrument aimed at recording, retrospectively, on an hour-by-hour basis, the whereabouts and activities of respondents during four days in the week before the interview. The method includes items about criminologically relevant events, such as offending and victimization. We demonstrate that the method can be very useful in criminology, because it enables the study of situational causes of crime and victimization, because it enables detailed measurement of theoretical concepts such as individual lifestyles and individual routine activities, and because it enables the study of adolescents' whereabouts, which extends the traditional focus on residential neighborhoods. The present article provides the historical background of the method, explains how the method can be applied, presents validation results based on data from 843 secondary school students in the Netherlands and describes the methods' strengths and weaknesses. Two case studies are summarized to illustrate the usefulness of the method in criminological research. The article concludes with some anticipated future developments and recommendations on further readings.

Keywords: Time use research; Space time budgets; Routine activities; Innovative methods; Crime; Victimization

Historical context

Time use instruments record systematically how individuals allocate their time to activities over a given time period. They enable researchers to collect data on the duration and sequence of activities, for example per hour or per day. The first publications on time use appeared over a century ago and grew out of studies on family monetary budgets. These early studies addressed, for example, the spare time of American working men (Bevans 1913) and family life in English households (Pember Reeves 1913). Most pre-World War II time use studies concerned living conditions of working class households during the rise of the industrialization or were undertaken against the background of economic planning in the Soviet Union. In the 1950s and 1960s, time use research was often applied in the study of free time and forms of leisure, for example the amount of television consumption (see early overviews of Andorka 1987; Chapin 1974; Robinson and Converse 1972; Szalai 1966).

A milestone in the standardization of time use measurement was the Multinational Comparative Time-Budget Research Project in the 1960s (see Szalai 1972). To enable cross-national comparison of time use, Szalai and colleagues developed methods for sampling, interviewing, coding and data processing that were implemented in all twelve participating countries. These methods and instruments shaped most of the subsequent time use studies (Harvey and Pentland 1999: 6; Michelson 2005: 12).

Time use studies have now appeared on a variety of topics and in a variety of fields. Recent overviews mention time use studies within economics, business administration, gerontology, urban planning, political science and occupational therapy, nursing and medicine, recreation and physical and health education, sociology, anthropology and psychology. Just to give a few examples: in economics, time use data is applied for investigating poverty (e.g., whether individuals have too many obligations to enjoy leisure) or the time spent on paid work relative to 'nonmarket-productive' time such as time spent on domestic activity, education or child care. Health studies and studies in gerontology apply time use data to investigate active and sedentary behavior and time use by older

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people and people with disabilities. Sociologists apply time use data to study, for example, the gender division of domestic work or the quality of life associated with discretionary time. Studies on urban planning apply time use data to investigate the traffic flow to a city center that is associated with people commuting to work (overviews are given by Fisher and Gershuny 2013b; Michelson 2005; Pentland et al. 1999). Time use research has appeared in several countries, and some of the nationally representative studies are repeated every five to ten years (e.g., in the Netherlands, Japan, Canada and Norway; Harvey and Pentland 1999: 7). These national studies are, for example, applied to gain knowledge on daily routines of inhabitants, their involvement in sport activities or voluntary work, and the amount of time people spend on paid work. This massive body of time use studies is mostly organized within a few large projects. The most comprehensive of these is the Multinational Time Budget Study (Fisher and Gershuny 2013a). Other extensive initiatives include the Eurostat Time Use project (Eurostat 2009) and the American Time Use Study (ATUS 2013). Time use researchers of various disciplines are organized in the International Association for Time Use Research (IATUR 2011), which has its own journal (eIJTUR 2004) and annual meeting.

Space-time budget instruments extend time use instruments by incorporating information on the spatial coordinates of locations where activities take place. Space-time budget studies originate from time use research: in the 1960s and early 1970s travel researchers started to address temporal constraints on spatial behavior and at the same time, time use researchers recognized the need to integrate spatial elements in their studies (see Anderson 1971; Carlstein et al. 1978). This new approach of integrating temporal and spatial elements, often referred to as the 'activity-based approach', is largely grounded on the work of Torsten Hägerstrand (1970, see Corbett 2001). Pioneering studies that attached geocoded locations to time diaries were, among others, the Washington studies described by Chapin (1974), the Halifax time-budget study (Elliott et al. 1976), and a study conducted in Hamburg (Germany; Dangschat et al. 1982). See Kitamura (1988), Kurani and Lee-Gosselin (1997), Bhat and Koppelman (1999) and Harvey (2003) for overviews of space-time budget research.

Methods for time use measurement

Several methods have been developed to measure (space-) time use. The most straightforward way is *stylized questioning*: asking respondents how much time they spend in certain activities in, for example, 'an average week'. Although this method is relatively inexpensive and replicable (it is found to accurately measure change and stability in time use within populations, Juster et al. 2003), there are

several problems associated with stylized questioning. First, since respondents are asked to aggregate the details of their time, their answers may be affected by memory problems (Juster et al. 2003). They may not recall all activities, or they may find it difficult to estimate episode lengths across the day. Some activities are easier to reconstruct than others (e.g., 'How many hours did you spend at school?' is easier to answer than 'How many hours did you watch television?'). Social norms (e.g., about the 40-hour work week) may further alter respondents' memory about their actual time allocation (Robinson 1999). Second, respondents' answers will vary with individual interpretation. For example, some respondents will incorporate time spent on commuting and lunch break in their notion of 'work', whereas others will not. Third, respondents are likely to experience difficulties with separating main activities from other activities if several activities take place simultaneously (Robinson 1999). Fourth, the data provided by stylized questioning are limited in scope. They contain the total amount of hours per time period spent in each activity, but they do not provide, for example, information on the time of day and the order in which the activities were performed.

The *time diary* method deals with (most of) these problems. Lundberg et al. (1934) are often credited as methodological pioneers for this method. The method implies the recording of every (main) activity during a given time period. A time diary, also called 'time budget', can be completed through retrospective questioning ('yesterday basis'), but also by asking respondents to keep a log of their activities ('tomorrow basis') during a given period (e.g., 24 hours or a week). A specific feature of the time diary method is that respondents can use their own terminology when describing their activities, which reduces possible bias due to interpretation differences between respondents. Furthermore, time diaries make it possible to analyze activities in their geographical and social context, because the method leaves room to include information on, for example, the location of the activity, who else was present or the respondents' emotional state (Harvey and Pentland 1999). Disadvantages of this method are that it requires more effort from interviewers and analysts to categorize the self-reported activities, that the interviews (therefore) usually take up more time compared to self-reported questionnaires, and that it may underestimate secondary activities and activities that take up little time or little attention, such as 'trying to find things' (Robinson 1985). Ås (1978) formulates the following choices that researchers should make if they want to apply time diaries in their data collection: a) Are fixed time intervals used, or should the respondents indicate the start and end times of an activity?; b) If fixed time intervals are used; what is the duration?; c) Do you ask about locality and social interaction in

addition to the activity?; d) Do you record secondary activities alongside the primary ones?; e) For what lengths of time do you need to ask the respondents about their activities (e.g., a daily cycle, a week, if not a week: week-end days as well as week days)?

The Space-Time Budget method developed by Wikström is, in fact, largely based on the time diary method. Wikström et al. (2012a: 69) argue in line with the work of Robinson (1985) that time diaries are superior to other methods for time use measurement in terms of reliability and validity. We will discuss the decisions regarding the development of the Space-Time Budget method in the subsequent sections. For more information on time diaries in general (not the Space-Time Budget method particularly), see Belli et al. (2009) for a recent and thorough discussion.

The *experience sample method* gives respondents signals at random moments throughout the day through their digital watch, electronic pager or, more recently, their mobile phone. At that particular moment, respondents are asked about their current activity. This method enables the recording of brief activities that are underreported in the time diary approach, because they would be difficult to recall at a later point in time. Also, this method enables the recording of more detailed information on descriptors that vary across the day, such as affective or physiological states (Juster et al. 2003). Disadvantages of the method are that the method is found to underreport activities that respondents are reluctant to interrupt such as sports activities (Csikszentmihalyi and Larson 1987) and that the method records activities out of their (temporal) context: no information is collected on activities performed in the period before and after the signal (Harvey and Pentland 1999).

Another method of collecting data on time use is to obtain and analyze *secondary data from the 'supply side'*. Facilities such as museums usually keep records of their visitors and this enables, for example, the study of museum visits in weekends (Harvey and Pentland 1999). Similarly, with *on-site verifications*, researchers count the number of people at a particular site at a particular time, for example in parks or at school (Robinson 1999). This method is mostly location-oriented and less useful for studying individual behavior across time.

Direct observation is a method in which researchers follow, observe and record the activities and social contacts of respondents. This method is very time consuming and nearly only feasible for short time spans in restricted areas. It may therefore not be useful if one is interested in (large) representative samples (Ås 1978). Less time-consuming is an adjusted form of the method: *spot sampling*, or 'random observation', where observations are conducted at randomly chosen times across the day (Larson and Verma 1999: 704).

Space-time (Budget) research in criminology

Although the previous sections illustrate the time use instruments in *geography and social sciences* on which Wikström's Space-Time Budget instrument was inspired, related instruments and measures have been used in *criminological research* as well. Since the present paper is specifically focused on the application of the Space-Time Budget method for *criminological* research, we will first briefly discuss these projects before reviewing the instrument developed by P-O. Wikström.

In a survey amongst adolescents, Riley (1987) included a time budget of the Saturday before the interview to measure activity patterns and relate them to delinquency. The stylized questions included in, for example, the studies of Osgood et al. (1996) and Agnew and Petersen (1989), do not represent time budgets but are also meant to measure details about activity patterns and relate them to deviant or delinquent behavior. An altogether different approach, aimed to estimate activity based measures of victimization risk, was followed by Lemieux and Felson (2012). They combined national-level data from the USA National Crime Victimization Survey (NCVS) and the American Time Use Survey (ATUS) to calculate activity based victimization risks of violent crime. The Los Angeles Family and Neighborhood Survey (L.A. FANS; Sastry et al. 2006) collected, among other things, geographical information on the key places in respondents' daily activities and information on their substance use, crime and violence. The Space-Time Adolescent Risk Study (STARS) in Philadelphia is aimed to collect data on the nature and location of adolescents' activities combined with their risk of being assaulted (e.g., Basta et al. 2010). An early application of the geographic aspect of space-time use measurement is Rengert and Wasilchick (2000), who asked burglars to reconstruct a 'journey to burglary' by describing places visited and activities performed on the day of a recent burglary. An interesting contemporary example is provided by Rossmo et al. (2012), who collected very detailed geographic data recorded by automated monitoring systems used in an electronic monitoring community corrections program. These data enabled the researcher to reconstruct the geographic details of journeys to crime committed by parolees who were in the program.

The Space-Time Budget (STB) method as developed by Wikström is the first in criminology that aims to collect data on a large scale with time diaries enriched with geo-coded locations. This methodology offers new opportunities to study the influence of social environments on individual offending and victimization, because it measures more precisely the exposure to environments that is associated with individual routine activities together with the risk of getting involved in law-breaking behavior (Wikström 2007). An additional innovative feature of this method for

criminology is namely that it includes criminologically relevant items, among which offending and victimization.

The Space-Time Budget (STB) method was piloted in the Peterborough Youth Study (PYS; Wikström and Butterworth 2006) and refined in the Peterborough Adolescent and Young Adult Development Study (PADS+; Wikström et al. 2010, 2012a). The Peterborough Youth Study (PYS) took place between the autumn of 2000 and early summer of 2001 among college students of 14 to 15 years old (year 10 in school). The first STB interviews covered seven days before the interview (all days of the week, including Sunday). As temporal unit of analysis, it was chosen to apply fixed time units of an hour. Wikström et al. (2012a: 73–75) argue that ‘the exact timing of activities’ is of less interest in their study and that ‘an hour is specific enough to capture the diversity of places and activities in which young people spend their time, while maintaining the focus on where they spend *most* of their time and their *main* activities’. Hours are considered to be units that are ‘easily quantified and interpreted’. Moreover, the researchers felt that more temporal detail would affect the reliability of the data due to recall problems (Wikström and Butterworth 2006: 208) and would extend the duration of the (already lengthy) interviews (Wikström et al. 2012a: 75). The choice for the unit of analysis defined the focus on primary activities: secondary activities may be underrepresented. This problem is largely avoided for a few main items of interest that are also often secondary activities, by asking the respondents specifically about involvement in crime events or other incidents. Since this approach is time consuming, it can only be applied for a few activities. In addition to their hourly activities, respondents were also asked about the location of that activity and who else was there. Wikström et al. (2012a: 73) argue that ‘this combination of codes is central to the space-time budget methodology’, because only the combination of the components (location, people present, activity and time) captures ‘the detailed circumstances of settings’. As spatial unit of analysis, Wikström et al. (2012b: 117) argue that smaller is better, since ‘data can always be aggregated’. The smallest available unit for official data may differ per country. Wikström and colleagues selected output areas that incorporate approximately 125 households, because these were the smallest spatial units available for official data in the United Kingdom. Preliminary analyses of these first STB data mainly addressed where adolescents spent their time (at school, at home, on the street), how they allocated their time over, for example, school, leisure and transportation and with whom they spent their time (Wikström and Butterworth 2006). The findings showed, among other things, that the individual routine activity patterns differed by individual risk-protective scores, area of residence- and school structural risk scores.

The Peterborough Adolescent and Young Adult Development Study (PADS+) now consists of seven waves of data collection (collected between 2004 and 2012), with three more waves scheduled for the coming years. Respondents were 11 to 12 years old in the first wave. At the time of the fifth wave, no less than 693 of the 716 respondents who participated in the first wave still participated in the study (Wikström et al. 2012b: 112). The STB method applied in PADS+ differs somewhat from the method applied in PYS. In PADS+, four days are questioned, whereas seven days were covered in PYS. The restriction to four days instead of seven was made to limit demands on the memory of respondents, since activities are recorded retrospectively (Wikström et al. 2012a: 71). Wikström et al. (2012a: 70) make a case for this decision by referring to findings of the American Time Use Survey that activities between Monday and Thursday are essentially similar. They further argue that Friday and Saturday evenings differ substantially from other evenings. Sunday evenings are assumed to resemble school day evenings, because they are characterized by preparations for the school week. Sunday is therefore not incorporated in the STB interview. The code lists for activities, locations and present people were adjusted based on experiences from the PYS. Also, the STB interview and questionnaire are held preferably at the same day for one respondent, whereas in the PYS there was a gap of six months between these interviews. In ‘Breaking Rules’ (Wikström et al. 2012a), one of the main publications on the PADS+ data, the STB data of the first five waves are used to describe adolescents’ spatial activity patterns and their involvement in family-oriented, school-oriented, work-oriented and peer-oriented activities. Central in the book are the interrelations of crime patterns, activity patterns (‘exposure to criminogenic settings’) and ‘crime propensity’ (morality and self-control) of the individual, based on situational action theory. In a nutshell, this theory proposes that an act of crime is an outcome of a perception-choice process that occurs when individuals are exposed to temptations and provocations in the environment. The theory aims to explain why crime occurs by investigating the characteristics of these individuals (particularly their crime propensity) and the features of the environments in which they take part (e.g., Wikström 2014). The theory also aims to explain why certain kinds of people commit crimes and why certain kinds of areas come to have higher crime rates than others, by explicitly focusing on the interaction of situational, social and developmental mechanisms. Furthermore, the theory distinguishes between causes of crime and causes of the causes of crime and in doing so the theory distinguishes between crime and criminality.

The Space-Time Budget (STB) method is adopted in three research projects that collaborate with the

PADS + project: SPAN in The Hague, the Netherlands, MINDS in Malmö, Sweden, and SP MAD in Ljubljana, Slovenia. The Adolescent Health and Development in Context study in Ohio incorporates a somewhat altered version of the PADS + Space-Time Budgets. These Space-Time Budgets are, for example, organized around stable location periods and travel periods instead of around fixed one hour time units (Browning et al. 2014; Browning and Soller 2014). Townshend and Roberts (2013: 499) state that their ‘weekend activity diaries’ are based on the Space-Time Budgets of Wikström and colleagues, but nevertheless apply a method that differs in several aspects.

Empirical criminological studies, published in English, that use data derived with the Space-Time Budget method as developed by Wikström and colleagues are the studies of Wikström and Butterworth (2006), Wikström (2009), Wikström et al. (2010), Ceccato and Wikström (2012), Wikström et al. (2012a), Weerman et al. (2013), Bernasco et al. (2013a, 2013b), Wikström (2014), Hoeben and Weerman (2014), Janssen et al. (2014) and Averdijk and Bernasco (2014).

What does the method entail?

The Space-Time Budget (STB) method as developed by Wikström and colleagues, applies a time diary approach to collect data on activities and whereabouts of adolescents. In one-to-one personal interviews, respondents

are questioned retrospectively about four days. For every hour (fixed time unit), they are asked about their primary activity, the location where the activity took place (both functional –e.g. school– and geographical –e.g. where in The Hague), whom the respondent was with and whether the respondent experienced ‘extra incidents’, such as involvement in fights. Respondents answer in their own words, and these answers are coded by the interviewer during the interview. Figure 1 shows the STB form as used in the SPAN study, but translated to English. This form is completed by the interviewer using a laptop.

The first column of the STB form in Figure 1 (‘act’) refers to *activity*, for example ‘studying at school’ or ‘playing soccer’. Some activities can be coded quite fast, because they continue for multiple hours (e.g., sleeping). If more than one activity takes place in an hour, interviewers may ask the respondent which activity he or she considers the main activity (either because it took the most time or because it was most important to the respondent). If the respondent is involved in two activities at the same time during two or more hours, one activity can be coded for the first hour and the other activity for the second hour. This strategy can also be applied across multiple days: if a respondent starts every weekday with an hour of simultaneously having breakfast and watching television, the activity in this hour can

Hour	Act	Place	Geo	Family	Peers	Others	Truancy	Extra incidents														
								Alcohol/Drug use			Risk			Victim			Offend			Weapon		
								a1	a2	a3	r1	r2	r3	v1	v2	v3	o1	o2	o3	w1	w2	w3
6																						
7																						
8																						
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24																						
1																						
2																						
3																						
4																						
5																						
ID number								Abnormal STB								(0 is a normal day)						
Interviewer								Day of the week														
Date of interview								Notes														

Figure 1 Empty space-time budget form.

be coded as 'having breakfast' for the first day and as 'watching television' for the second day.

The second column of the STB form in Figure 1 ('place') refers to the *function of the location* where the activity took place, for example 'home', 'at a friend's house' or 'supermarket'.

The third column ('geo') refers to the *geographical location*. The geographical location is coded by using detailed maps that show small units in the research area. In the PADS + study, the units are 'output areas', which are the smallest available administrative units defined in the census of the United Kingdom. In the SPAN study, the units are cells of 200 by 200 meter (656 by 656 feet) in a grid overlaying the study area. Thus, they are determined independently of the administrative neighborhood boundaries defined by the municipality. See Figure 2 for examples of these units in the SPAN research area. To help respondents navigate through the detailed map, interviewers use special city maps that include alphabetical lists of street names and corresponding page numbers of the detailed map. The interviewers usually start with geographically coding the respondents' home address and work from there during the rest of the interview. For hours that are spent travelling (e.g., by bus, car or bike), the geocode of the departure area is noted. For hours spent otherwise moving (for example by walking around with a group of peers), the geocode of the unit where they spent most of the time is noted.

The fourth, fifth and sixth column on the STB form in Figure 1 address *the people present in the setting*, specified in terms of their relation with the respondent. 'Family' members include parents, siblings or other family members such as uncles or aunts. 'Peers' include friends, classmates, teammates or a partner. Also specified is whether one peer is present or two or more peers, and whether they are male, female, or a mixed group. 'Others' include teachers, trainers, coworkers or parents of friends. In the latest waves of the PADS + study, in which some of the respondents have become parents themselves, their own children are included as a separate category of people present.

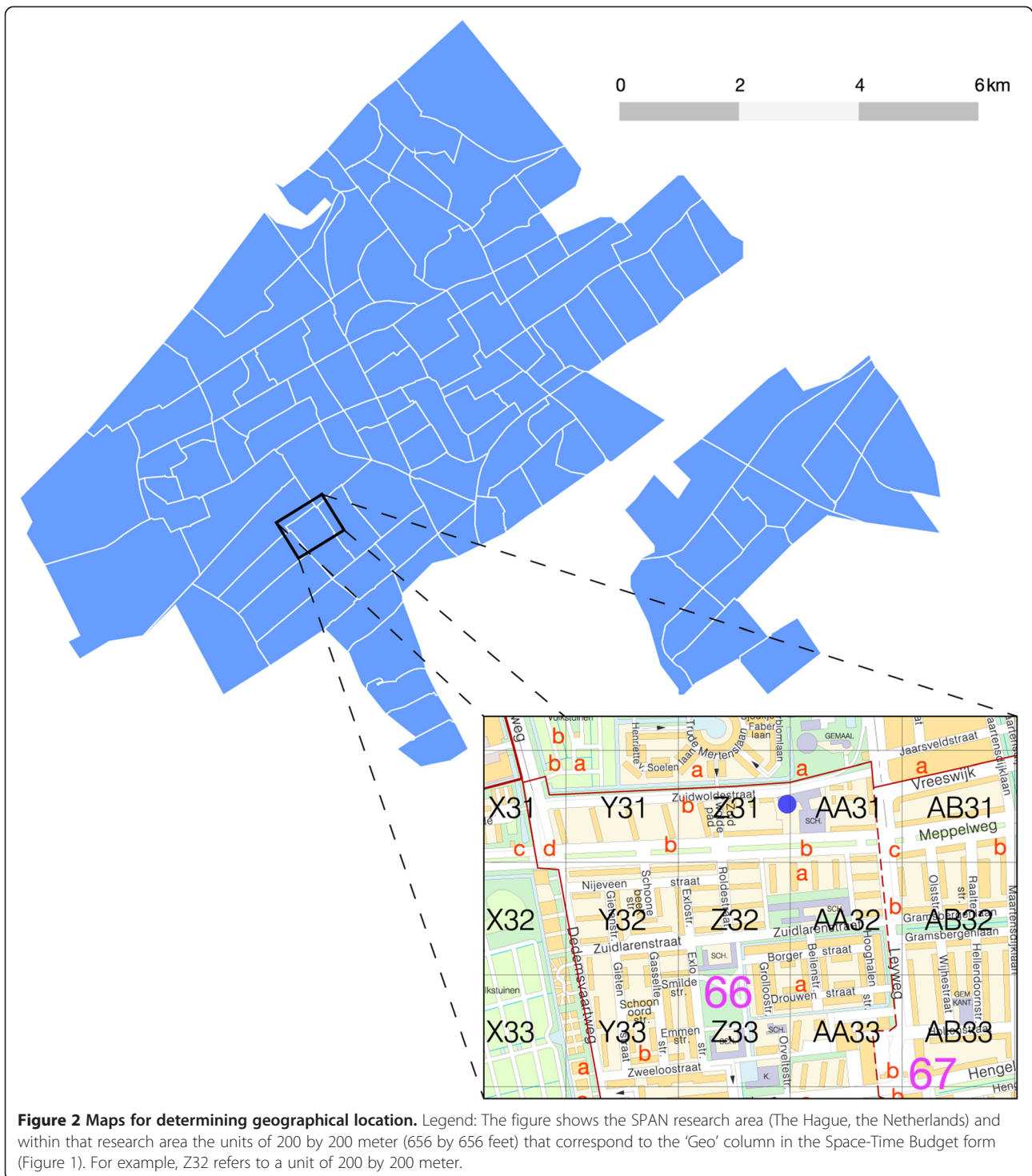
Finally, the 'truancy' and 'extra incidents' columns in the STB form in Figure 1 leave room to register *truancy*, *substance use* (alcohol and drugs), witnessing or involvement in *risky situations* (e.g., fights, provocations, police contact), *victimization* (of theft, vandalism or violence), involvement as an *offender* (in theft, vandalism or violence), or *weapon carrying*. Contrary to the activity, location and presence of other people, these incidents are not probed per hour, since they are unlikely to occur every hour. At the end of coding each STB day, interviewers ask: 'Have you been playing truant during this day?' 'Have you used alcohol or drugs during this day?' 'Were you involved in fights, or have you witnessed fights

or violence (from a distance) during this day?' 'Was something you possess stolen or broken? Has somebody beaten you, attacked you or did somebody start a fight with you?' 'Did you steal something or damaged something that belonged to someone else or were you involved in a fight?' 'Did you carry a weapon at some point during this day?' If the respondent answers affirmative to any of these questions, the interviewer asks further details to code the time and specifics of the incident. Extra incidents are also coded if their duration is less than an hour. Up to three different incidents of each type can be registered per hour. If more than three incidents occur (which is very rare), general codes can be used to 'group' incidents. For example, there is a code for 'consumption of a combination of soft- and hard drugs'. The use of these general codes should be explained in additional notes below the STB form.

Although the interviews are structured by the STB form in Figure 1, interviewers ask open questions and respondents answer in their own words. These answers are then coded by the interviewers, using long lists of activity-codes, location-codes, people present-codes and incidents-codes (comprehensive code lists are printed in Appendix A2 in Wikström et al. 2012a and Appendix B in Wikström and Butterworth 2006). When in doubt on the right code, interviewers may consult the respondent on which code would best represent the specifics of their activities.

To prevent coding mistakes or typing errors, all completed STB forms need to be cleaned according to a strict protocol. Cleaning involves not only checking for missing entries, but also extended consistency checks. For example, the activity 'sleeping' is not a logical combination with a place code for 'swimming pool'. Also, if a respondent went to bed at his parents' house, it would be illogical that he or she woke up the next day somewhere else (or the interviewer missed an interesting story). We recommend that all STB forms are cleaned and corrected by the interviewer who conducted the interview and again by one of the other interviewers.

By design, the four days covered in the STB always need to incorporate one Saturday, one Friday and two random weekdays. The two random weekdays that are questioned alongside Friday and Saturday should be the most recent weekday before the interview and the most recent weekday before that. The ordering in which the four days are recorded during the interview is allowed to vary. To obtain a representative overview of daily activities, interviews address 'normal' school or workdays as much as possible: if respondents were on holiday or ill at home (for example) they are questioned about another 'regular' day, with a maximum of seven days before the interview. If that is not possible, the days are



recorded but a note is made on the STB form that they are 'abnormal' (see Figure 1).

Efforts to deal with memory problems include: allowing the respondents to check their schedule book or mobile phone, making reference to previous activities (e.g., 'What did you do after basketball training?'), making

reference to external memorable events, such as television shows or the weather, and as a last resort, asking respondents what they would normally do 'at such a day' or 'at that time of day'. If respondents experience difficulties to remember their whereabouts or to find their geographical location on the map, interviewers can help them by using

geographical 'landmarks', such as the location of local shops, parks or the respondents' school or home address (Wikström et al. 2012b: 123).

To avoid social desirable answering, respondents are allowed to just shake their heads or nod and point at the right code. The STB interviews should be conducted in a quiet area away from peers or authority figures, where respondents feel free to talk. Additionally, interviewers should be explicitly instructed to refrain from judgmental responses and to convince the respondents about the confidentiality of their answers prior to the interview. We recommend selecting interviewers based on skills such as social awareness, patience and conscientiousness. Most of the interviewers in the SPAN project just graduated or were still in college. Conform findings in the literature that both too much and too little respondent-interviewer social distance will produce biasing effects (Dohrenwend et al. 1968; for an overview see Nederhof 1985) we believe this age gap minimizes the tendency of respondents to provide social desirable answers.

The STB interview requires 45 to 50 minutes to administer. In the SPAN data collection, we experienced that the respondents generally liked the attention that interviewers showed to their daily schedule and that they were generally willing to cooperate. These experiences are in line with those of PADS+ (Wikström et al. 2010: 66–67, Wikström et al. 2012a: 77). The interviewers did not report fatigue among the respondents.

Two case studies

To illustrate the relevance of Space-Time Budget method (STB) for criminological research, we discuss two case studies. The first study by Weerman et al. (2013) provides a case in which STB data from the SPAN study were employed to specify the influence of adolescent activity patterns on individual differences in delinquent behavior. In particular, they aimed to get an increased insight in the conditions under which spending time with peers is conducive to delinquency. Traditional studies used survey methods (stylized questioning) that measured how often respondents reported they were together with friends in general (e.g., Warr 1993) or how often they thought they spent time with peers in certain activities (Osgood et al. 1996). Such measures are based on rather imprecise recall, not capturing detail about the conditions under which time is spent with peers. In contrast, the STB data of the SPAN study enabled to establish in much more detail where and with whom time is spent with peers, and what respondents are doing when they are with peers. In particular, these data enabled Weerman et al. (2013) to systematically contrast spending time with peers a) in physical as opposed to 'online' interaction, b) in public space as opposed to private space, c) unsupervised as opposed to supervised by adults d) just socializing as

opposed to activity-based e) in settings with access to alcohol or drugs as opposed to settings without access to substances, and f) with a group as opposed to a single peer.

Analyses among 843 respondents showed that the association between time with peers and delinquent behavior is substantially different between conditions. It appeared that delinquency is rather strongly positively related to time with peers when it is spent in public, without supervision, just socializing or with two or more peers. However, time with peers 'online' or by phone, and time spent with peers supervised by adults, in non-public places, doing activities and with only a single peer, had a weaker or even an absent relation with delinquency.

The second study by Bernasco et al. (2013b) used the same SPAN data to identify causes of crime that can be attributed to situations rather than to persons. To eliminate all stable between person factors as potential confounds, they analyzed the STB data as repeated observations of the same person in different situations, with within-individual fixed effects analyses. The STB instrument provides 96 observations for each respondent, because it records attributes per hour over four days. The analyses only included the hours awake (hours asleep were excluded) from the 76 individuals who reported having committed an offense during the STB days; these 76 individuals reported 104 offenses. The aim of the analysis was to assess in which type of situations the adolescents offended and in which situations they did not. For each hour, information was available on a) whether the situation included interaction with peers, b) whether adults were absent, c) whether the action took place in public space d) whether the respondent was involved in unstructured activities e) whether alcohol was consumed f) whether cannabis was used, g) whether the respondent carried a weapon, and finally h) whether the respondent perpetrated an offense.

Results showed that offending was strongly and positively related to all hypothesized situational causes except cannabis use and weapon carrying. For example, the presence of peers and the involvement in unstructured activities both almost doubled the odds of offending (odds ratios 1.96 and 1.93 respectively), the use of alcohol more than doubled it (odds ratio 2.32), the absence of adult handlers more than tripled the odds, and presence in public space increased the odds even by almost a factor 10 (odds ratio 9.92).

Strengths of the method

The Space-Time Budget (STB) method can be applied in a variety of ways, for example to address questions on leisure activities (e.g., Larson and Verma 1999) or shopping behavior, but also for health related studies

that investigate exposure to risk associated with daily routines (see overviews in Fisher and Gershuny 2013b; Michelson 2005). The present study is particularly concerned with the relevance of the method for *criminological* studies. In this section, six ways are discussed in which the method may contribute to criminological research.

First, the STB method enables a detailed operationalization of individuals' lifestyles (Hindelang et al. 1978), routine activities (Felson and Boba 2010; Osgood et al. 1996) and exposure to behavior settings (Barker 1968; Wikström et al. 2012a). Previous studies showed that individuals underreport leisure activities when questioned on activities over longer periods of time (Niemi 1993; Robinson and Godbey 1999) and that stylized questioning is plagued by several other problems (Robinson 1999), which may give a distorted account of individuals' general activity patterns. These problems are partially solved by the structured questioning per time unit or activity episode as implemented in the time diary approach, and by its feature of letting respondents report in their own words.

Second, the STB method collects information on criminological relevant items such as substance use, truancy, weapon carrying, offending, victimization and other incidents (e.g., fights). These 'rare' events occur in small timeslots and are, more than other activities, prone to social desirable answering. They may therefore be underreported in other time use instruments. The STB method attempts to deal with these problems by asking specifically about these items for every day that is covered. The questions refer to every type of incident, thereby attempting to avoid recall problems and interpretation problems.

Third, because the method collects information on activities and contextual specifics per small time unit (an hour), it enables the study of situational contexts for crime or victimization directly, as illustrated by the previously described case study (Bernasco et al. 2013b; see also Averdijk and Bernasco 2014). This small time unit also enables the study of activity sequence (e.g., which activities precede criminal activity and which activities follow substance use?) and of temporal correlations (e.g., do crimes occur more often in the weekends than during the week, or more often in the evening than during the day?).

Fourth, the geographical information on the location of the respondents (the 'geo' column in Figure 1) enables the investigation of environmental influences of locations where adolescents spend their time over and above the investigation of environmental influences from their community or neighborhood of residence. Analyses of STB data showed that adolescents spent more than fifty percent of their time awake outside the direct surroundings of their home and that 90 percent of the reported

crimes occurred while away from the direct home environment (Wikström et al. 2012a: 68). This demonstrates the relevance of studying environmental influences outside of the residential neighborhood.

Fifth, combining the geographical information on the location of respondents from the STB with geographical information from other (secondary) sources (preferably on small units, Wikström et al. 2012b), enables the study of a variety of ecological criminological theories at the individual level. Scholars can for example analyze whether the time that an individual spends in communities with low collective efficacy (Sampson et al. 1997) is related to increased involvement in delinquency. Examples of complementary data sources are community surveys, census data from local governments, police information on geocoded offenses, and Systematic Social Observations (SPAN data sources are described in Bruinsma et al. 2013 and Janssen et al. 2014).

More generally, although the method was specifically developed to inform and test situational action theory, its focus on situational causes makes it a potentially useful instrument for many other theoretical frameworks. The routine activity perspective (Cohen and Felson 1979; Felson and Boba 2010), the routine activity theory of individual deviancy (Osgood et al. 1996), situational crime prevention (Clarke 1983, 1997) and crime pattern theory (Brantingham and Brantingham 1981, 1993) all emphasize situational rather than personal causes of crime, and implicitly suggest that they should be measured and analyzed. The Space-Time Budget method is also potentially useful for social disorganization theory (Sampson 2012), as it allows researchers to replace proxy measures of exposure (e.g., neighborhood of residence) with detailed actual measures of exposure to various environments, including neighborhoods.

Weaknesses of the method

Of course, the method has its weaknesses as well. A first weakness of the method is that the data collection is sizeable and costly. The interviews are lengthy, even more if one wants to enrich the Space-Time Budget (STB) data with background information of the respondents. Also, every completed STB form has to be cleaned and corrected extensively to avoid coding mistakes. Because the coding responsibility is on the interviewers, the method requires comprehensive training on dealing with the code lists for activities, locations and present people, but also on dealing with the spatial equipment needed to geo-code the locations of the respondents.

Second, studying lifestyle theories or other theories that concern information over a longer period of time with STB data, requires the assumption that the four days are representative for that longer period. There is potential seasonal influence (the influence of the time of

year in which data is collected), but time use researchers disagree to which extent this influence occurs (Harvey 1999; Hill 1985). Also, holidays and Sundays were excluded in the implementation of the STB method presented here, but this limitation could easily be reduced by using another design for the sampling of days from the past week.

Third, a problem with the application of time use instruments in criminological research is that crime, victimization and the like are rare events: not every person is involved in crime and for those who are, it is not a daily activity. This implies two issues that researchers need to take into account. The first issue is that the method may not be appropriate to study inter-personal variation in offending: 'Zero time in a particular activity in a short diary means either that the respondent is always a non-participant (...), or is just a non-participant during the sampled period' (Gershuny 2012: 251). The second issue is that the sample needs to be large, because the data will otherwise not capture any criminal events at all (Harvey 1999: 21). A solution for this can be to draw a sample among a group of known offenders.

Fourth, the method is prone to underreporting second or third activities (if activities occur simultaneously) and of activities that have a short duration. To avoid the underreporting of main topics such as substance use, victimization and offending, the STB method separately asks for these and other incidents. Unfortunately, because it is very time consuming, this approach can only be applied to some main items of interest.

Fifth, the chosen time unit of one hour is not specific enough to establish the duration of activities that have a shorter time slot. The STB method is therefore not appropriate for studying, for example, the duration of crimes or of transportation between school and home; it is only relevant for establishing the frequency and contexts of such activities.

Sixth, a disadvantage of the geographical information collected with the STB method is that researchers have to make decisions on the shape and size of the spatial units (200 by 200 meter in the SPAN study) prior to the data collection, which leads to the 'modifiable areal unit problem' (Openshaw 1984). This problem entails that the choice of the units is based on arbitrary reasons, but nevertheless may affect the results of later spatial analyses. The magnitudes of spatial correlations may increase if data are aggregated to larger areas. An additional disadvantage of the geographical STB information is that data collection on large research areas such as countries is not feasible with the method in its current form.

Finally, the STB method has thus far only been applied to adolescents and young adults. Application of the method to adult respondents requires adjustment of the code lists. For example, the codes for job activities

should be extended, as well as the codes for people present so that they include spouses and offspring, and probably also different categories of 'peers'. Furthermore, daily activities of adults may cover a larger geographical area than daily activities of adolescents, for example due to the distance between home and work: in 2011, 34 percent of the residents of The Hague worked outside of the municipality (Worp and Beeckman 2013). This complicates the collection of geographical information.

Validation

The Space-Time Budget (STB) method as developed by Wikström et al. (2012a) has been validated, but the extent of validation is limited. Wikström and Butterworth (2006: 210–211) compared the frequency of offending and victimization during the seven days covered in the STB interview of the PYS study with the frequency of those events in the previous year as reported in the questionnaires. They report significant zero-order correlations of 0.35 for offending and of 0.13 for victimization. Validation analyses of the PADS + data showed an even stronger correlation (0.57) between self-reported crime in the questionnaire and in the STB interviews. Additionally, Wikström et al. (2012a: 325–327) found that adolescents who reported crimes in the STB interviews were more likely to have a police record or reprimand, a warning or a conviction, compared to adolescents who did not report crime in the STB interviews (correlation coefficient is 0.20, $p < 0.01$). Wikström et al. (2010; 2012a) further note that the spatial distribution of the STB reported crimes is similar to the spatial distribution of police-recorded crimes for young offenders in the research area and that the temporal distribution (occurrence at different moments of the day) of STB reported violence is similar to the temporal distribution of police-recorded assaults.

Using SPAN data to compare information from the questionnaire with that of the STB, Bernasco et al. (2013b) report correlations of 0.64 in the first wave of the data collection and 0.73 in the second wave of the data collection for alcohol use-measures and correlations of 0.57 and 0.63 for cannabis use-measures. Hoeben and Weerman (2014) compared in a similar fashion the questionnaire and STB information on 'time spent with peers on the streets and in parks' (correlations were 0.44 and 0.43 for the two respective waves of data collection) and 'time spent with peers at youth centers and societies' (correlations were 0.38 and 0.44 for the two waves of data collection).

For this contribution, we extended previous validation analyses by comparing the results of the SPAN Space-Time Budget (STB) interviews with results from the SPAN questionnaires on several other activities: daily activities, substance use and offending. Together with the STB interview, respondents completed a questionnaire that incorporated self-report questions about substance

use (5 items) and offending (20 items). It also included, among other things, many stylized questions about the daily activities of the respondents, for example: 'How often do you eat evening meals with your parents? (Almost) every day (6–7 days a week); several times a week (3–5 days); few times a week (1–2 days); (almost) never.' The validation analyses were conducted on a combined dataset of the 843 respondents from the first wave of the SPAN study and the 613 respondents from the second wave who completed both the questionnaire and the STB interview (for more information on the SPAN data collection and sample, see Bernasco et al. 2013b, Weerman et al. 2013 and Hoeben and Weerman 2014). Abnormal STB days, on which respondents were ill or had a day off school due to special circumstances, were excluded from the analyses (2.4 percent of the hours from the first wave and 3.6 percent of the hours from the second wave were excluded).

Results in Table 1 show that all Spearman's correlations were significant and ranged from 0.100 to 0.685, providing at least tentative support for the claim that the STB measures the involvement in activities that it was intended to measure. The correlations for offending were relatively weaker than the correlations for daily activities, whereas the correlations for substance use were stronger. Interpretation of these findings is impaired by uncertainty about which instrument actually has the highest accuracy. It may even be the case that high correlations are the result of systematic errors in both instruments. However, based on earlier studies that argue the superiority of time diaries over survey estimates (e.g., Robinson 1999; Schulz and Grunow 2012), we expect that involvement in daily activities and substance use is more accurately estimated by the STB method than in the questionnaire. The low correlations between the STB- and

Table 1 Comparing the SPAN STB interview and questionnaire on daily activities, offending and substance use

	STB		Quest.		Correlations
	Mean	SD	Mean	SD	
<i>Daily activities</i>					
How often do you eat evening meals with your parents? ^a	3.17	1.95	2.46	0.84	0.190*
How many times a week do you help your parents around the house (housekeeping, cooking, doing the dishes, buying groceries etc.) ^a	1.23	1.89	1.58	1.01	0.198*
About how much time do you spend on homework each day? ^b	2.27	3.09	1.39	0.78	0.465*
How often do friends visit you at home? ^a	2.61	7.39	0.99	0.81	0.278*
How often do you visit your friends at their house? ^a	3.61	6.93	1.09	0.74	0.314*
How often do you hang out with your friends in the street, on squares or parks? ^a	2.51	3.94	1.13	1.04	0.399*
How often do you hang out with your friends in a youth center or a sport club? ^a	1.73	2.92	0.70	0.83	0.388*
How often do you hang out with your friends in shopping malls or the city shopping center? ^a	0.60	1.49	0.87	0.84	0.226*
<i>Offending</i> ¹					
How often in the past year have you damaged or destroyed something not belonging to you? ^c	0.03	0.23	0.55	0.87	0.161*
How often in the past year have you stolen something (from a shop, a bike or scooter) ^c	0.01	0.07	0.28	0.60	0.100*
How often in the past year have you beaten up somebody? ^c	0.04	0.22	0.61	1.15	0.193*
How often in the past year have you carried a knife or other weapon? ^c	0.48	4.30	0.51	1.26	0.294*
<i>Substance use</i> ¹					
How often do you drink alcohol? ^d	1.33	3.22	1.08	1.16	0.685*
How often do you smoke hash or weed? ^d	0.31	1.76	0.34	0.80	0.603*
How often do you use other drugs, for example XTC, cocaine, speed or something else? ^d	0.23	1.42	0.06	0.33	0.332*

*p < 0.01.

^a(Almost) every day (6–7 days a week); several times a week (3–5 days); few times a week (1–2 days); (almost) never; ^bNever; less than one hour a day; about 1–2 hours a day; more than 2 hours a day; ^cZero times; 1 time; 2 times; 3–5 times; 6–10 times; more than 10 times; ^dNever; less than once a month; once or a couple of times per month; once or a couple of times per week; (almost) every day. ¹Analyses conducted on multiple imputed questionnaire items (imputation with Expectation-Maximization method).

Legend: The table shows the results from Spearman's correlations between STB interview items and questionnaire items on the SPAN sample in both waves (wave one and two combined N = 1456). The values of the STB items express hours per respondent over the four STB days (96 hours), whereas the values of the questionnaire items express respondents' estimates of how often they are usually involved in daily activities, how often they use substances and how often they committed an offense in the past school year. Answer categories differ per questionnaire item (see notes below the Table). The SPAN data collection took place in The Hague (the Netherlands) and incorporated two waves of data collection. The first wave was in 2008–2009, the second in 2010–2011. Respondents were 11 to 17 years old and were approached through the secondary school they attended. The mean age of the sample was 14.1 in the first wave and 16.0 in the second; the combined sample consisted of approximately 53.9 percent boys and 46.1 percent girls. Adolescents with an ethnic minority background (45 percent) and adolescents who followed lower forms of secondary education were somewhat overrepresented in the sample compared to the Dutch adolescent population. Also, the respondents all had a highly urbanized background, because The Hague is the third largest city in the Netherlands.

questionnaire measures of offending are not surprising when taking into account how infrequent offending occurs. Because the STB incorporates four days, only very persistent offenders have a substantive probability to have their offending recorded in the STB. The instrument cannot distinguish between non-offenders and low- or medium frequent offenders (Wikström et al. 2012a: 324). The questionnaire may therefore be a better instrument to measure variations in offending over extended time periods. Gershuny (2012) suggests using a combination of both instruments to capture long-term as well as short-term estimation of individual time use. Nonetheless, one should keep in mind that the STB method is not primarily aimed at measuring the prevalence of offending. Its strength is rather to measure the conditions under which offenses occur.

When (not) to use the space-time budget method

In summary, the Space-Time Budget (STB) method can be very useful for criminologists who seek to operationalize 'lifestyles' or similar theoretical constructs in a more detailed way; for scholars who want to study activity sequences, temporal correlations or (micro) contextual influences on offending, victimization or other risky situations, and for scholars who are interested in 'exposure' from locations where respondents spend their time (over and above the influence of their community or neighborhood of residence). STB data can be aggregated in different ways and therefore enable analyses with time slots, spatial locations and individuals as main units of analysis.

It is not recommended to use the STB method when limited (financial) resources are available, when one is mainly interested in the prevalence of offending among a group of 'average' respondents, when the study concerns a spatial area larger than a city, when the population of interest consists of adults or children or when the study concerns the duration of activities that cover less than an hour (e.g. travel, offending). Adjusting the time unit of an hour to smaller time units is possible, but might require a different interviewing format: a smaller time unit may hamper retrospective questioning over four days due to memory problems.

Anticipated future developments

Future research projects will probably further refine and improve the Space-Time Budget (STB) method to enable its application to research areas larger than a city and to enable its application to adults and children. Developments in that direction already take place: the PADS + study currently consists of seven waves and the respondents are now between 22 and 23 years old. The method has constantly been adjusted to the respondents' new life stages.

We anticipate that the increasing role of information and communication technologies in daily activities will

have substantial consequences for individuals' spatial and temporal behavior and therefore on their delinquent behavior. Hägerstrand (1970: 15) already noted that 'telecommunication' allows people to connect 'without (or nearly without) loss of time in transportation'. Yu and Shaw (2007) reinterpreted his thoughts taking into account the technological developments of the last decades (see also Janelle 2012, and Figure nine in Harvey 2003). These developments will demand instruments that are able to map virtual behavior, or that are at least able to take these changes into account.

On the other hand, we expect that the same developments regarding information and communication technologies, will increasingly broaden the methodological possibilities for space-time use research. A prominent example is the application of smartphones. Although the application of smartphones for social science research is in its infancy (e.g., Miller 2012; Raento et al. 2009), it has great potential for time use research. A mobile app that questions respondents about their activities may reduce the costs of the data collection substantially, by decreasing the duration of the interview and by making home visits superfluous. It may also reduce the burden on the respondents and thereby increase response rates, because respondents carry smartphones with them constantly already and they could fill out questions on 'lost' moments during the day. Moreover, smartphones can record geographical information, which could easily be combined with a specific app asking for information on activities, functional locations and present others. First attempts have already been made to apply smartphones in time diary research (Sonck and Fernee 2013), and the step to a criminological application is relatively small. For example, Browning et al. (2014) just started the data collection of a project on adolescent development and behavioral outcomes in which respondents carry smartphones that collect information on their geographical location. This information is used to guide subsequent space time use interviews. Evidently, the use of smartphones for this kind of research raises new issues regarding privacy and regarding differences between experienced and inexperienced users of these devices. It would also require further development of analytical techniques and computational capacity to handle big data. Nevertheless, we expect that the use of smartphones will offer a substantial methodological improvement on current time use research.

Further reading

Pentland, WE, Harvey, AS, Lawton, MP, & McColl, MA. (1999). *Time Use Research in the Social Sciences*. New York: Kluwer Academic Publishers.

Reference book on time use research: gives an elaborated historical overview of time use studies in the last

century, discusses new analytical strategies and addresses a variety of different applications of time use research. Additionally, this book discusses the specifics and pitfalls of implementing a time use data collection.

The Centre for Time Use Research offers an extensive overview of publications on time use at www.timeuse.org.

Anderson, J. (1971). Space-time budgets and activity studies in urban geography and planning. *Environment and Planning*, 3(4), 353–368.

Bhat, C, & Koppelman, FS. (1999). A retrospective and prospective survey of time-use research. *Transportation*, 26(2), 119–139.

These two publications provide an overview of the theoretical and empirical developments in space-time use research around the time of their publication. The study of Anderson (1971) gives an overview of the early works into space-time use research. Bhat and Koppelman (1999: 118) describe, nearly three decades later, the developments that carried the field ‘past the tip of the iceberg’.

Hägerstrand, T. (1970). What about people in regional science? *Papers of the Regional Science Association*, 24, 7–21.

Classic work in which Hägerstrand’s time-geography approach is presented. He introduces individual space-time prisms and describes the types of constraints that have to be taken into account in studying these prisms. This work has provided a theoretical foundation as well as a basis for later analytical approaches into studying individual space-time activity patterns.

Belli, RF, Stafford, FP, & Alwin, DF. (2009). *Calendar and Time Diary: Methods in Life Course Research*. Los Angeles: SAGE Publications.

Reference book on the time diary method: it points to the problems that are associated with the implementation of the method (shortcomings of the method as well as problems with the burden on respondents and corresponding response rates) and addresses several applications of time diary data in research.

Wikström, P-OH, & Butterworth, DA. (2006). *Adolescent Crime: Individual Differences and Lifestyles*. Collumpton: Willan Publishing.

Wikström, P-OH, Oberwittler, D, Treiber, K, & Hardie, B. (2012a). *Breaking Rules: The Social and Situational Dynamics of Young People’s Urban Crime*. Oxford: Oxford University Press.

Wikström, P-OH, Treiber, K, & Hardie, B. (2012b). Examining the role of the environment in crime causation:

Small-area community surveys and space-time budgets. In D Gadd, S Karstedt, & SF Messner (Eds.), *The SAGE Handbook of Criminological Research Methods* (pp. 111–127). Los Angeles: SAGE Publications.

Reference works on the Space-Time Budget method that was developed by Wikström and colleagues for application in criminological research. Wikström and Butterworth (2006) describe the findings of the pilot study, the Peterborough Youth Study. ‘Breaking Rules’ (Wikström et al. 2012a) concerns the follow-up study (PADS+). The latter gives an historical background of the Space-Time Budget method and an overview of what the method entails. It further describes interviewer-trainings, materials used for geo-coding, and the background of the decisions made on time units, spatial units, the choice for incorporating four days of measurement and the choice for one-to-one interviews. Additionally, these books describe the first empirical results obtained with the STB data. The SAGE handbook chapter (Wikström et al. 2012b) gives a concise and accessible overview of the technicalities of the STB method and describes the steps scholars should take when developing a Space-Time Budget method.

Empirical studies that applied Wikström’s Space-Time Budget methodology for criminological research are also recommended for further reading (Averdijk and Bernasco 2014; Bernasco et al. 2013a; Bernasco et al. 2013b; Ceccato and Wikström 2012; Hoeben and Weerman 2014; Janssen et al. 2014; Weerman et al. 2013; Wikström 2009; Wikström 2014; Wikström and Butterworth 2006; Wikström et al. 2010; Wikström et al. 2012a).

Abbreviations

STB: Space-Time Budget; SPAN: Study of Peers, Activities and Neighborhoods; PADS+: Peterborough Adolescent and Young Adult Development Study; PYS: Peterborough Youth Study.

Competing interests

This research was not funded by third parties. The authors declare that they have no competing interests.

Authors’ contributions

WB, FW and LP were involved in the design of the SPAN study, EH coordinated the second wave of the SPAN data collection. WB outlined the manuscript, EH conducted the time use literature review and drafted the manuscript except the sections on the SPAN case studies, which were drafted by FW and WB. SvH performed the analyses for the validation-paragraph. All authors contributed to finalizing the manuscript and read and approved the final manuscript.

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