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Behavioral Mapping and Tracking

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"Oh my God, that black truck almost hit that old lady crossing the street! She is lying on the road," screamed Maria, as she looked out of the window of their apartment.

Gabriel, Ethan, and Annabelle rushed to the window to watch what is happening. "Those crosswalks don't allow much time for pedestrians. We young people can make it through, but anyone who is older or has some physical problems would have trouble making it across," said Annabelle.

"Drivers are impatient. They have to wait for all the pedestrians to finish crossing before they can make that left turn onto Busy Street. I wonder if moving the crosswalk a few meters south would help. Then drivers making a left turn wouldn't need to wait for the pedestrians," Gabriel added.

Now that Gabriel has convinced Maria how useful behavioral observation can be for understanding environment–behavior interactions (see Chapter 2), Gabriel comes up with an idea. "Why don't we make some systematic observations of what people are doing on our street? If we use behavioral mapping and tracking, we would be able to identify patterns of behaviors. We could then present our findings to the City's Planning Department and improve our street," Gabriel proposed.

The housemates gathered around their dinner table, and worked out a preliminary sampling plan, behavioral categories, and observation procedure. Gabriel drew a plan of their street. Soon they noticed a pattern of jaywalking, pedestrians who are texting or talking on their phones running into garbage bins and lamp posts, parents pushing strollers having trouble negotiating the snow-covered sidewalks, and other problems.

They decided to write a formal proposal to the Planning Department for funding to continue their observations.

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This chapter focuses on three specific observation techniques: direct observation using **behavioral mapping** and **behavioral tracking**, and indirect observation using **physical traces**.

Behavioral Mapping

I first describe what behavioral mapping is, its purposes and importance as an observation tool, and a brief history. Next, I provide recommended procedures for conducting behavioral mapping, illustrating with examples of studies conducted in various physical settings and a case study. Finally, I discuss the challenges and limitations of this research technique.

What it is

Behavioral mapping is a technique used in environmental psychology and related fields for recording people's behaviors and movements systematically as these behaviors occur in particular locations (Bechtel & Zeisel, 1987). A behavioral map is basically a record of where people are, what they actually do, and how their behaviors are distributed in a space. Sommer and Sommer (2002) distinguish two forms of behavioral maps: place-centered or individual-centered. A place-centered map shows the locations of people in a particular setting at a particular time engaging in various activities. Place-centered mapping is appropriate when the goal is to assess the usage of a particular area or location, such as a cafeteria. In contrast, an individual-centered map is a record of a person's movements and activities in a setting or settings over time. Individual-centered mapping is appropriate when the goal is to learn about a person or a group's activities in relation to location and time, for example, where and how teenagers spend their time after school. Place-centered mapping can be used in combination with individual-centered mapping, as in the case study described at the end of this chapter.

Why this technique is important

As reviewed in Chapter 2, behavioral observation in general has several advantages over self-reporting of behaviors. First, for social desirability reasons, people may not provide honest answers to questions about what they do in their daily lives, or where and how they carry out certain activities, particularly if the activity in question is illegal or against the social norm. Second, people may not remember accurately whether they have done something or not, or how often they have done something, particularly regarding routine activities. Third, people may not be consciously aware of their own behaviors.

In addition to recording objectively what actually occurs, behavioral mapping as an observation tool has the advantage of recording behavior in its context. According to Roger Barker's ecological psychology theory (1968), every behavior setting (e.g., homes, classrooms) is associated with certain physical characteristics and a consistent pattern of behavior. Behavioral mapping allows researchers to relate various observed behaviors to particular locations (i.e., where an activity

occurs), physical environmental features (i.e., what feature is used), type of users (e.g., children), and over time (e.g., in a week).

Purposes

Behavioral mapping is used in architectural programming (see Chapter 12), post-occupancy evaluation (see Chapter 13), and behavioral research. Ittelson, Rivlin, and Proshansky (1970) identified four general uses. The first use is for describing the distribution of behaviors throughout a particular space. The second use is for comparing two different situations or conditions, such as usage by men and by women. The third use is to identify general patterns in the use of space in a variety of settings, such as when usage peaks. Finally, behavioral maps can be used to provide quantitative predictions of distribution of behaviors in a new facility before the facility is constructed or occupied, mainly in architectural programming (Chapter 12). Behavioral maps can be a useful tool for checking if the assumptions behind the design of spaces and facilities are accurate, in post-occupancy evaluation (Chapter 13). A record of customer or visitor locations and behaviors, and traffic flow patterns can allow managers and space designers to identify any problems, take remedial and prospective actions to improve services or the use of space (Burke, 2006; Given & Leckie, 2003; Yalowitz & Bronnenkant, 2009).

Apart from its use in descriptive research, behavioral mapping can be used in correlational research. In a study of public squares or plazas, Zacharias, Stathopoulos, and Wu (2004) examined the relationships between user distribution over locations in the square and microclimate within the square (e.g., sunny vs. shady areas, temperature), and users' behaviors (sitting, standing, smoking).

Behavioral mapping is also used in experimental research. In a study of human navigation in a supermarket, participants' search behaviors and their locations were recorded and compared in three experimental conditions, in which items belonging to different categories were placed in different shelf locations (Kalff & Strube, 2009).

Behavioral mapping is often used with young children who may have difficulty verbalizing their thoughts, feelings, and behaviors and those elderly who have cognitive impairment. For example, the spatial movements outdoors, measured with behavioral tracking, were correlated with psychosocial variables in Oswald et al.'s (2010) study of elderly residents with dementia.

A brief history

It is generally recognized that William Ittelson, Leanne Rivlin, and Harold Proshansky of the City University of New York first introduced behavioral mapping to environmental psychology. They defined behavioral maps as "a technique for studying the relationships between behavior and the physical space in which it occurs" (Ittelson et al., 1970, p. 349). Behavioral maps include descriptions of behavior, participants, and statements about the relationships between the behavior and design features in the physical setting. Using behavioral mapping, these early environmental psychologists observed – somewhat obtrusively – and documented the behaviors of adult patients in two psychiatric wards in a large, urban hospital (Ittelson et al., 1970), a children's psychiatric ward (Rivlin & Wolfe, 1972), and

children in open classrooms (Rivlin & Rothenberg, 1976). A precursor to this technique was demonstrated in a series of studies in college libraries in the 1960s, in which Robert Sommer and his colleagues observed systematically how seats at a table in college libraries and study halls were occupied (e.g., Sommer, 1966).

According to Hill (1984), behavioral tracking (or individual-centered mapping in Sommer & Sommer's terminology) was first used to study pedestrian movement by Weiss and Boutourline (1962). They accompanied visitors to a World's Fair, observed (obtrusively) and recorded as trip logs visitors' movements and locations and when each movement took place. Weiss and Boutourline (1962, as cited in Hill, 1984) proposed that an *obtrusive observer* did not affect the behavior of the observed. Bechtel disagreed, and demonstrated in his study possible "observer effects," that is, museum visitors who knew they were being observed had different movement behaviors than those who were unaware that they were being observed (Bechtel, 1967).

Unobtrusive observation then became an important criterion. In an effort to develop a photographic simulation for testing visitors' behaviors in the laboratory, Winkel and Sasanoff (1966) tracked visitors' movements unobtrusively through a museum in Seattle by observing at an appropriate distance. Tracking involved recording the visitor's movements by drawing a line on a base map that corresponded with the visitor's movements in the actual gallery. Using the same tracking technique, Hill (1984) observed and recorded pedestrians' movements unobtrusively through urban areas. To reduce obtrusiveness, Garbrecht (1971) observed pedestrians' trips through a parking lot from an office building in Boston.

Bechtel (1967) was the first to use "machine observers" to replace human observers in behavioral mapping. A hodometer was used to record automatically the number and location of footsteps across the floor of a museum. The device "consists of a cluster of electric switch mats covering on entire floor space with each mat connected to an electric counter" (p. 54). The use of the hodometer allowed the researcher to measure the area covered by a visitor, the number of footsteps, and the time the visitor spent in the exhibit room.

Since then, researchers have used both human observers and machine observers to record behaviors in various spaces. Two well-known projects are used to illustrate such use. In the Street Life Project, described in the book *The Social Life of Small Urban Spaces* (1980), a team of researchers led by William Whyte used both human observers and time-lapse photography to record how the spaces in New York City parks, plazas, and other public spaces were actually used. Where possible, the researchers took photographs at regular intervals from a tall building overlooking the public space. Based on these objective records of diagrams and photographs, Whyte was able to identify several important factors in the success of small urban plazas. Their findings helped to improve the design of parks and plazas throughout the world. In a 25-year project conducted by Envirosell, a marketing research consultant company, Paco Underhill used a combination of video and human observers – trackers – to do behavioral mapping in a systematic and unobtrusive way in a variety of stores. Very detailed and useful, though sometimes surprising, results for retailers are summarized in Underhill's book, *Why We Buy: The Science of Shopping* (1999, updated 2009).

The use of behavioral mapping and tracking waned as researchers relied more and more on self-reported methods of data collection, perhaps because of the intensive

time and resource commitment and the stringent ethics requirements for unobtrusive observation (to be discussed later in the chapter). Page (2000) lamented that the lack of unobtrusive observation studies had jeopardized the ecological validity and relevance of knowledge to real-life situations. Giuliani and Scopelliti (2009) observed the decline of observational studies in environmental psychology since the 1980s. There have been a small number of studies conducted in a variety of settings over the years. More studies have been reported by researchers and professionals in environmental design at recent conferences (e.g., Khasawneh, Kato, & Mori, 2013; Zamani, 2012).

Advances in computing and communication technologies in recent years have facilitated automatic observation, recording, data entry, data analysis, and data visualization. The use of portable or handheld devices, radio frequency identification (RFID), global positioning system (GPS), and geographic information system (GIS) have become increasingly common in behavioral research. At the same time, the use of such technologies for mapping and tracking people's behaviors has raised new ethical issues for researchers. More will be discussed later in this chapter.

Procedure

Ittelson et al. (1970) identified five elements of behavioral mapping: (1) a base map identifying the essential physical features of interest; (2) behavioral categories with their definitions and codes; (3) a schedule of observation; (4) a systematic procedure of observation; and (5) a system of coding and counting (yes/no, or frequency). Based on these elements, I recommend the following steps in conducting place-centered behavioral mapping.

Step 1: Create a base map The first step is to create a base map, a scale drawing of the physical space, identifying each area with the kinds of behavior expected to occur there (e.g., eating in a living room) and any salient environmental features that may affect the behaviors of interest to the researcher (e.g., windows). The architect's blueprint can be used as a guide, but these floor plans may not be up to date and may not include the portable features of the space, such as chairs and direction signs (Sommer & Sommer, 2002). The recording document can be in forms other than a map; a table in which rows representing physical locations and columns representing behavior would suffice (Bechtel & Zeisel, 1987). Researchers can use an established scale for measuring the physical or architectural features of a particular setting (e.g., residential care facility).

Step 2: Define behavioral categories and their codes/symbols, and develop a system of coding The next step is to define the behavioral categories that are relevant to the research problem under investigation. These behavioral categories must be explicit, precise, and relatively narrow. The development of behavioral categories involves three sub-steps: cataloging observed behaviors, generalizing the behaviors into categories for observation, and combining observational categories into analytic categories. Cataloging the behavior involves having observers record all specific examples of a particular behavior over a period of time, then eliminating any duplicate, trivial, or idiosyncratic observations to form a list of summary observational categories.

Trained judges divide the list of behaviors into observational categories that are similar within the group and different among the groups. The observational categories can be combined further into analytic categories that address the particular problems being studied (Ittelson et al., 1970). Special scoring symbols are then used to represent each behavior (e.g., Eat = eating, Wri = writing). Develop a system of coding and counting (e.g., yes/no, frequency of occurrence, or ratings of intensity).

Step 3: Develop a schedule of observation Behavioral observation can be either event-contingent or time-contingent at either fixed intervals (e.g., every 15 minutes) or random intervals. Mapping should take place at all possible times that the area is used, just in case observation may reveal the occurrence of unexpected events or behaviors. To reduce the likelihood of observing the same people engaging in the same activities, spread out the sessions throughout the day (Sommer & Sommer, 2002).

Step 4: Develop an observation procedure Scan the physical spaces of the site systematically (e.g., following a pre-determined path in a clockwise direction). Observation can be on an "instantaneous" basis by having enough observers to complete all areas in as short a time as possible. Observations can be recorded on data sheets that include such information as the location and time of observation, the number and type of users engaged in each category of activities (Ittelson et al., 1970). Well-trained observers will spend considerable time on site to become familiar with the behaviors of the users. The users may be aware of the presence of the observer but observers should avoid direct involvement in the activities of the users (Ittelson et al., 1970). An individual's location in space can be recorded using time-lapse photography, video tape, and prepared diagrams (Sommer & Sommer, 2002), and newer technologies (see elsewhere here and in other chapters).

Step 5: Training of observers and pre-testing Train observers so as to ensure there is good agreement in the coding of the environmental features of the setting, behavioral categories, and observation procedure. Pre-testing helps to identify any problems that need to be rectified before the actual study is conducted. It can also identify how much time is needed to scan the setting.

Behavioral Tracking (Individual-centered Mapping)

Researchers can follow the steps below to conduct individual-centered mapping.

Step 1 As in place-centered behavioral mapping, a map of the observation area is drawn. A rectangular grid of the area could help with identifying specific locations within an area (Sommer & Sommer, 2002).

Step 2 Define behavioral categories and their codes or symbols, and develop a system of coding, as in place-centered mapping.

Step 3 The next step is to identity the sampling strategies and the sample. As this procedure can gather detailed information about the movement and activities of

individuals, a much smaller number of individuals are involved than in place-centered mapping (Sommer & Sommer, 2002). An individual with specific characteristics may be selected for tracking, or an individual can be selected at random by picking the third person, for example, who enters a setting. Follow a sampling plan that ensures coverage of all days and times.

Step 4: Develop an observation procedure The observer needs to obtain the individual's cooperation, and perhaps consent, to be followed. The researcher may need to observe the individual in stages to allow for habituation to the observer's presence. The researcher can observe the same individual continuously over a period of time (e.g., a work day) or periodically at intervals throughout the day (e.g., for 10 minutes in every hour). More than one individual could be observed when time sampling is used. The researcher could shift to observing a second individual when further observation would not provide any new information (Sommer & Sommer, 2002).

Track and record the movement of the individual through the space by drawing a line on the plan with arrows showing direction of movement. If the individual being observed stops at a location, the line is drawn up to the location and the time spent at that point recorded. The observer may record other behaviors and information such as sex, estimated age, and alone or with a group. At all times the tracker should try to remain inconspicuous by observing at an appropriate distance (Winkel & Sasanoff, 1966).

Step 5: Training of observers and pre-testing As in place-centered mapping, training of observers and pre-testing of the study are important steps. Pre-testing may help identify how likely people are aware of being observed and what the reactions of those being followed are. Strategies need to be devised to deal with such situations, taking into consideration the ethical issues to be discussed later in the chapter.

Data Analysis and Presentation

In most studies, the results of place-centered behavioral mapping are presented in simple, descriptive statistics such as number and percentage of observations at a certain location in tables, charts, or figures. Often, tabulations of activity by location, type of people by location, type of people by activity, and occasionally location or activity over time are presented. When observations are recorded on a map, a series of maps that represent behaviors at intervals can be combined into a single composite map to show the usage for all time periods (Sommer & Sommer, 2002). Data can also be aggregated and presented in visual form, using number of dots or people to represent the frequency or percentage of occupants present at a particular time, as in Ledingham and Chappus's (1986) study of playgrounds.

Ittelson et al. (1970) suggested that behavioral mapping can help identify several general principles in the use of space. Peaking indicates that certain areas are consistently used primarily for a single type of activity. Constancy indicates that certain behaviors tend to remain constant over many different conditions. Reciprocity refers to spaces where an increase in behavior in one space is associated with a decrease in that behavior in another space.

Sanoff (1971) proposed three ways of analyzing behavioral maps: (1) behavioral density refers to the total frequency of all types of activities at a place; (2) activity profile refers to the frequency of specific types of activities occurring at a place; and (3) behavioral range refers to the range of different activities occurring at a place, indicating the degree to which the setting is a diffuse setting. For example, the behavioral density for each behavioral category and the total behavioral densities for each square of the grid were calculated in Ledingham and Chappus's (1986) study of children in playgrounds.

In individual-centered mapping, the maps can be summarized in tables showing the percentage of time spent in various locations and activities. The person's journey each day can also be recorded as a single line, which becomes thicker with more frequent travel (Sommer & Sommer, 2002). Separate tracking maps can be converted into composite maps, which give an overview of the paths taken by the individuals. Breakdowns of the composite maps according to the path behavior of the sample can be made (e.g., men vs. women). However, the composite maps alone do not tell why people take different paths (Winkel & Sasanoff, 1966). One technique is to calculate the behavior range, that is, the number of different settings that the person enters during a given time period (Sommer & Sommer, 2002).

Needless to say, how data are analyzed is dependent on the purpose of study. In a study of primary and secondary school classes, Martin (2002) measured mobility within the classroom as the percentage of total area of the room covered by the teacher and degree of centeredness as the time spent at specific locations as a percentage of the total lesson time. The combined tracking data showed the route taken by the teacher within the room and the total area covered by the teacher during the lesson. She found that some teachers tended to circulate throughout the classroom, while other teachers remained close to their desks throughout the school day. Various behaviors were related to the flexibility in the layout of the classroom, calculated as the total area of the room where changes could be made.

Behavioral mapping data have also been analyzed using multi-regression analysis to predict spatial behaviors such as standing and sitting as a function of temperature, sunny or shaded areas, and seating (Zacharias et al., 2004).

Examples

Behavioral mapping and tracking have been used in studies of a variety of settings: playground and schoolyard, classroom, library, psychiatric ward, long-term care facilities, urban neighborhood, retail setting, aquarium and museums, public squares, and university plaza. A few examples of such studies are provided below.

Public squares

Hampton, Livio, and Goulet (2010) used a combination of place-centered and individual-centered behavioral mapping to record behaviors and locations of wi-fi users in seven public squares in the United States and Canada in 2007. Between place-centered observations, they selected one Internet user (and accompanying group) at random for tracking for 30 minutes. The researchers observed that the

wi-fi users were largely white, male young adults who were alone. The majority of them used their wireless Internet connection to communicate with people who were not physically present. Users spread out evenly throughout the square, and their locations were influenced by the presence of power outlets, comfortable seating, or relative privacy. They observed that a limited number of wi-fi users in one of the parks were there to work – busy shuffling papers and scribbling notes – and did not socialize with either any strangers or their companions. Working was facilitated by the abundance of small tables and chairs with desk attachments, which provided limited space for any companions.

Playground and schoolyard

Ledingham and Chappus (1986) used behavioral mapping to study the importance of the physical and social environment for social play among 32 children with behavior problems. To evaluate the extent of localization of behaviors and the effects of social density, they calculated the behavioral densities for each observational category and the total behavioral densities for each square of the grid. They reported that cooperative play, rough and tumble play, and games play alone tended to be concentrated in open areas whereas individualistic behaviors tended to be at the play structure. The results have important implications for the design of playgrounds. Fjortoft, Kristoffersen, and Sageie (2009) used portable GPS units and GIS to track 71 six-year-old children's movements and locations within two schoolyards in a study in Norway. They reported that even though the two schoolyards provided different space and qualities of outdoor environment for the children, the physical activity level as measured in heart rate did not differ when playing in these schoolyards.

Aquarium

In a review of visitor tracking studies, Yalowitz and Bronnenkant (2009) conclude that there are distinct patterns of visitor behavior in museums, zoos, and aquariums. For example, Yalowitz and Ferguson (2006) observed unobtrusively 155 visitors at Monterey Bay Aquarium to see what visitors attended to and for how long. They reported that large live animal tanks were attended to by the highest percentage of visitors (90%; staying 77 seconds), followed by hands-on or interactive exhibits, and the lowest among text-only exhibits. These findings helped exhibit personnel to set realistic expectations for particular types of exhibits, to arrange exhibits in a way that would lessen visitor crowding and maximize circulation, and to assess how changes to the exhibits may influence patterns of visitor behavior.

Residential care setting

Milke, Beck, Danes, and Leask (2009) investigated the activity patterns of 184 elderly residents with Alzheimer's disease and the staff in five similarly designed residential care facilities. Assessments of general architectural design features and the overall environmental quality using established scales revealed no significant differences between the two 12-resident facilities and the three 20-resident facilities. The researchers collected samples of behaviors systematically in 1998 using

place-centered behavioral mapping. At every hour over 14 hours on each of two days at each site, observers followed a pre-planned path through the buildings and recorded quickly on copies of floor plans individuals present at a public space and the type, time, and location of their activities.

Trained on-site staff followed instructions in a procedure manual that specified standardized use of behavioral categories with comprehensive definitions, floor-plan notation, ethogramatic checklists, and time-locked sampling. General activity categories included just sitting, activities of daily living, light housekeeping, leisure, disruptive behavior, walking, watching, and other behaviors. The results of behavioral mapping revealed that residents' activities did not conform to the architects' expectations. In practice, more use of the common spaces for activities was seen in the 12-resident house design whereas more activities were held within the house in the 20-resident house design. Behavior was affected by the house design and by the way that staff chose to organize activities.

Library

Given and Leckie (2003) used a place-centered behavioral mapping technique they called "seating sweeps" to observe patrons' behaviors in two larger public libraries three times daily for a six-day period, Monday through Saturday. Their results showed that most patrons were male and were younger than 60 years old. The busiest time of day was mid-afternoon. The most popular location was the study carrels or work tables, followed by computer workstations, and the food court or indoor street area. Library patrons had with them most frequently books, carrying cases, and some had food and drinks even though these items were not allowed in the libraries. Not surprisingly, reading was the most prominent activity. Talking to other patrons was fairly common even though talking was discouraged in the libraries.

Simpson (2007) studied patrons' behaviors in relation to locations within a small library in a university. Data were entered into an Excel spreadsheet on a personal digital assistant (PDA), and then analyzed and visualized using GIS software ArcGIS (Environmental Systems Research Institute, 2006). The results of behavioral mapping showed the lack of use of the stacks, the need for more space for group study and for the use of laptops, and conflicting needs for space for quiet reading and for talking.

Retail setting

Sorensen (2003) used a real-time tracking system to record the location and paths of shopping carts and baskets, as proxies for shoppers. The tracking system consists of a small tag mounted under the shopping cart that emits a uniquely coded signal; antennae around the perimeter of the store to pick up the signals from each shopping cart; a locate processor system that locates the tags; and a software system that integrates location data, purchase transaction data, and planogram data to produce marketing data.

The most important finding was that the average shopping trip only covers about 25% of the store; this led to the suggestion of pushing the products shoppers are interested in onto their path rather than having shoppers come to the products. Sorensen also suggests setting up "anchor departments" to attract shoppers to

certain locations. In the same study, Larson, Bradlow, and Fader (2005) used a multivariate clustering algorithm to analyze the data sets, taking into account spatial constraints such as location of aisles and other inaccessible areas of the store. They observed that shoppers tend to travel only to select aisles or to take short excursions into and out of the aisle, and that short trips tend to be to the perimeter and convenience store areas.

Challenges and Limitations

Despite its usefulness, behavioral mapping has its limitations and poses several challenges for researchers.

Intrusiveness and reactivity

Place-centered mapping can be intrusive, and individual-centered mapping can be even more intrusive. Except in crowded places such as a busy store or shopping mall (Underhill, 1999), an observer following someone around will have difficulty not being noticed by the person observed and others (Hill, 1984; Sommer & Sommer, 2002). Observers should try to blend in as much as possible with the surroundings (Given & Leckie, 2003), or observe from tall buildings or other fixed spots high above (Hill, 1984). Using a handheld device is likely less noticeable than using a clipboard to record data.

Reactivity can be a problem when people are aware that they are being observed in a setting, as demonstrated in Bechtel's (1967) study of museum visitors. In research using multiple methods, researchers should complete mapping (the less reactive procedure) before interviewing or photographing (the more reactive procedures) (Sommer & Sommer, 2002).

Ethical issues

As behavioral mapping and tracking involve unobtrusive observation, researchers need to address several major ethical issues: informed consent, and privacy and confidentiality. Current *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (2010) stipulates that research involving naturalistic observation of people in public places where specific individuals cannot be identified does not require review by research ethics boards (Article 2.3). However, in some jurisdictions, publication of an image of an identifiable individual taken in a public place may be considered an invasion of privacy in civil law (Article 10.3).

Take caution that some "public places" such as a shopping mall are not in fact public. When in doubt, seek approval from institutional ethics review boards and any appropriate jurisdictions and organizations where the study is to be conducted. As in any research involving human participants, it is the responsibility of the researcher to weigh the potential social benefits against the social costs of the research.

Researchers have taken several measures to alleviate these ethical concerns. First, to respect the privacy of the individuals, make sure that the individuals being observed are not identified by name (Burke, 2006; Given & Leckie, 2003; Milke et al., 2009;

Sommer & Sommer, 2002). Typically, the results of the behavioral maps are reported in aggregated form. Securing the privacy of individuals is particularly important in individual-centered mapping or behavioral tracking. Anything seen or heard by the observer must be kept confidential. In a small sample, it may be very difficult to conceal the identity of an individual; in which case, it may be necessary to broaden the description of the individual's activities to maintain the privacy of that individual (Sommer & Sommer, 2002).

To address the issue of lack of informed consent, researchers can let potential subjects know that a research study is being undertaken, and that they may be observed. For example, visitors to public places such as a museum or a public library can be informed directly before they are being observed, or at the least indirectly with a sign posted. The observer must explain what is occurring and what the purpose of the study is, perhaps by handing out an information sheet explaining the study, if an unobtrusively observed individual suspects that he or she is being observed. If behavioral tracking is to be followed by an interview, the individual should be informed at the beginning (Given & Leckie, 2003; Yalowitz & Bronnenkant, 2009).

The increasing feasibility of researchers using new technologies to record behaviors in natural settings has raised additional ethical concerns. Goodwin, Velicer, and Intille (2008) suggest that to address the issues of privacy and confidentiality, data can be encrypted and indicators be in place to inform participants that they are being sensed or recorded. Researchers must also ensure that research participants understand what data are being collected, what the data could be used to infer, and how they can stop the collection of their information if they wish. Particularly disconcerting is the increasing use of electronic surveillance to track the mobility patterns of the elderly with dementia, who are unable to give informed consent and yet their privacy is invaded during such surveillance (Shoval et al., 2008).

Reliability and validity

As discussed in Chapter 2, inter-observer reliability can be established by having two observers report behaviors at the same setting at the same time independently (Ittelson et al., 1970). Observers must be trained to record behavior in a systematic and reliable manner through repeated practice and feedback. Where reliability for a specific behavior is low, that behavior may be removed from the data analysis (Sommer & Sommer, 2002).

To establish convergent validity, the results of behavioral mapping and tracking can be compared with data obtained in other ways (e.g., interview). To establish discriminant validity, verify any expected differences in behaviors between two conditions (e.g., weekdays vs. weekends) (Ittelson et al., 1970).

Data analysis

Techniques for analyzing behavioral maps are not yet well developed. Combining behavioral maps from several individuals observed at various times can make interpretation difficult (Sommer & Sommer, 2002). A combined place-centered behavioral map of 10 observational sessions in a schoolyard may show 10 dots at a specific location. These 10 dots may represent one child observed at that location 10 times

or 10 children on one occasion. Is the number of different users important or not? Or is the percentage of time that a particular location or a particular environmental feature is used more important than the number of users? Answering temporal and context-dependent questions may require appropriate statistical techniques for modeling longitudinal data both within and across individuals (Goodwin et al., 2008).

Explanations for behavior

Although behavioral mapping data can reveal environmental choices made by individuals, the data do not explain why these choices are made. The maps must be supplemented with interviews or other data in order for researchers to understand the motivation behind these choices (Sommer & Sommer, 2002).

Labor intensive

Behavioral mapping and tracking with pencil and paper are labor intensive and time consuming. Transferring data from paper to a database is also time consuming and subject to human error. New technologies can help.

Use of Technology

New mobile computing and telecommunication technologies have become available to facilitate observation, recording, data entry, analysis, and visualization of behavioral mapping and tracking data. Compared with the paper-and-pencil technique, electronic behavioral coding and analysis systems can be more accurate (Hecht, 1997), permit separate times recording for concurrent behaviors, eliminate data entry, and are less intrusive.

In the last two decades or so, researchers have used handheld devices such as personal digital assistants (PDAs) to record behavioral mapping data in the field (e.g., Lulham & Tietjen, 2004; Simpson, 2007; Wener, 2002). Wener (2002) used BMAP software on Psion, and Lulham and Tietjen (2004) used the "Track" program from the field of biology on a Palm Pilot. A number of other software programs have been developed, such as Pocket Observer 3.0 and Outdoor Explorer for recording behavioral mapping data, and WayTracer for behavioral tracking. For a comparison of the functionality of these software programs, refer to Dalton, Dalton, Holscher, and Kuhnmunch (2012). The PeopleWatcher App, being developed to run on the iPad, can be used for behavioral mapping and tracking, and is particularly suitable for wayfinding and navigation tasks (Dalton et al., 2012; see Chapter 9).

The use of GPS in tracking movements is becoming popular in the area of dementia care. Such technology can allow the caregiver to monitor the location of a person with dementia when outdoors. The external tracking device that can be worn on clothing or part of the body sends GPS position coordinates to a secured website. The caregiver can then look up on a map the actual position of the person with dementia and the route the person took (Pot, Willemse, & Horjus, 2011; Shoval et al., 2008). Various measures such as walking speed, time spent in different places, trip length, or change of direction can be monitored (Oswald et al., 2010).

The main drawback of using GPS in tracking is that any kind of obstruction, such as buildings, will produce an inaccurate reading. Its main advantage is that it virtually spans the globe (Shoval et al., 2008).

Land-based tracking systems consist of antenna stations distributed throughout a local area and the end unit does not have to be exposed directly to the antenna stations (Shoval et al., 2008). Wearable computing and ubiquitous computing technologies have made it possible to embed various sensors in clothing or accessories, and in objects in our physical environment (Goodwin et al., 2008)

Still photography and video photography can provide useful data regarding people's use of space and their movement. However, normal video cameras cannot track visitors over larger spaces, at least not with a single video camera (Burke, 2006; Yalowitz & Bronnenkant, 2009). New technologies that use specialized cameras or multiple overlapping camera views have been developed to allow behavioral tracking of people automatically and non-intrusively (Spink, Locke, van de As, & Noldus, 2013). And of course, security surveillance video cameras that are now installed at road intersections, retail stores, public buildings, and just about everywhere can store an enormous amount of data. In a novel way, Hipp, Adlakha, Eyler, Chang, and Pless (2013) were able to access existing public data feeds from the Archive of Many Outdoor Scenes (AMOS) images from public webcams in order to assess the effects of introducing protected bike lanes at a road interaction had on transportation mode usage.

Retail stores can now use a combination of RFID, GPS, and video-based camera systems to track shoppers' navigation. One such system recently developed is TrackLab by Noldus Information Technology that incorporates tracking technologies (GPS where satellite reception is possible, ultra-wideband sensors and tags for indoors, stereo cameras) to track behaviors of customers in retail environments and to provide visual presentation of the data. Such a system can be used in other settings as well (Spink et al., 2013).

GIS is becoming more commonly used as a visualization tool to help analyze behavioral mapping and tracking data (e.g., Fjortoft et al., 2009; Simpson, 2007).

The increasing popularity of smartphones has made it economically feasible for their users and behavioral scientists to record and log their users' daily activities. Data collection is unobtrusive in that data logging runs reliably in the background of the smartphone.

Perhaps the most promising feature of the smartphone for behavioral mapping and tracking is its sensing ability that allows for automatic gathering of location data, currently at a crude level. More accurate location data can be collected when integrated with a GPS device, although the need to carry an external device is likely to increase reactivity of measurement. Other sensors can be integrated to allow gathering of physiological data (e.g., heart rate), or activity data (e.g., accelerometers). The smartphone also allows for self-documentation of experiences, feelings, and thoughts with its audio and text, still images, and video functions. No doubt technological advances in the future will overcome the current limitations (Miller, 2012; Raento, Oulasvirta, & Eagle, 2009). Newer systems that might integrate information from GPS, motion, infra-red light, and perhaps ambient sound sensors will likely be developed (Intille, 2012). Technologies are changing so fast that behavioral scientists will need to keep abreast of any new developments constantly.

Case Study: Behavioral Mapping and Tracking in a Small Public Library

Let me illustrate the process and challenges of using behavioral mapping and tracking in a post-occupancy evaluation of a small public library. Although the study was completed by myself and the editor of this volume many years ago, the principles remain much the same. Suffice to say, various technologies could now help with data recording, entry, and analysis. Nevertheless, similarly small projects are feasible for a senior undergraduate or a graduate student to complete in a semester or a year, and at low cost.

The plan to relocate a small public branch library in Esquimalt, British Columbia, Canada provided us with an opportunity to study the use of space and to assess the effectiveness of the physical design from the library user's perspective. Two of the goals stated explicitly in the building program for the new library included: (1) adequate seating for study and leisure reading for adults and children, and (2) provision for expansion and relocation of shelves and counters.

The new library occupied the main floor of a two-story building on a busy road near a small shopping mall. It had a usable floor area of 6300 square feet, including a multipurpose room for community activities. At the time of data collection, the library had been open to the public for three months. The library served adults, youths, and children and had books, magazines, audio records for loan, and reference material.

Three data-collection techniques were used in this study: a questionnaire survey, behavioral mapping, and behavioral tracking. The study was approved by the Greater Victoria Public Library Board and the Ethics Review Committee at the University of Victoria. We addressed the librarians' concerns by posting a sign that said the University of Victoria was conducting a study on the physical features of the library, minimizing following patrons, observing before questionnaires were handed out, voluntary participation from questionnaire respondents, and interviewing employees.

Before data collection, the four observers met to ensure agreement on the behavioral categories. The questionnaire and the observation procedure were pretested. Data were collected on two weekdays (10 a.m. to 9 p.m.) and on Saturday (10 a.m. to 6 p.m.) for three consecutive weeks.

Behavioral mapping provided information about the distribution of user behaviors in various locations throughout the library. At 15-minute intervals, the observer made the rounds of the library and marked on a floor plan the location and activity of each patron in the library. It usually took the observer one to two minutes to complete each observation and recording. In 133 observation periods, 1342 behavioral mapping observations were made. No observation of behaviors was made during periods when questionnaires were distributed. This eliminated the possibility of recording questionnaire-related behaviors, which of course were not typical library activities.

Behavioral tracking served to identify sequences of users' activities during library visits, and the duration of these activities. A trained observer positioned herself so that as much of the library as possible was visible. She then randomly selected the first library patron who entered the library, and recorded the patron's activities,

locations, and time spent on each activity in a sequence using a stopwatch. At times, it was necessary for the observer to move around in order to keep the patron in sight. The observer experienced no difficulty blending in with other patrons so as not to be intrusive. After the patron had left the library, the next patron who entered the library was observed. Figure 3.1 shows the recording sheet.

The behavioral mapping data show that there were, on average, 9 to 10 patrons in the library at any time. The stacks (except those in the youth area) were used most intensively and about equally. The longest visits were made to the sitting area near

Time Diary

Subject No._____ Sex _____ Age _____ Brief description_____

Date_____ Day of the week_____ Weather _____ Observer_____

Activity Code	*Location Code*
Browsing B	Circulation C
Study/work SW	Entrance E
Check out/return Bo	Information I
Talking T	Office OF
Playing PL	Sitting lounge 1-5 L1-L5
Waiting (standing) WST	Stacks 1-5 ST1-ST5
Parenting PA	
Waiting (sitting) WSI	
Reading R	
Walking W	
Searching S	
Writing WR	
Sitting SI	

Activity No.	Activity	Starting time	Finishing time	Amount of time	Alone	With friends/family	With patron	With staff	Location	Remarks
1										
2										
3										
4										
5										
6										
7										

Figure 3.1 Behavioral tracking recording sheet.

Figure 3.2 A composite behavioral map showing the percentage of total observations of patrons present at each location.

the adult magazine section (average 13.5 minutes). Of the five sitting areas, the one at the magazine section was the most intensively used (15% of the patrons at a given time) (see Figure 3.2). Reading at this corner of the library comprised 12% of the observations. The sitting area in the youth section was used the least (1%).

Behavioral tracking of 93 patrons showed that they spent, on average, about 13 minutes in the library. The longest stay was one hour. As expected, reading was the activity on which patrons spent the most time (an average of 16.5 minutes), followed by browsing (11.5 minutes). Analysis of traffic patterns showed that 38% of the patrons who were tracked stayed close to the library entrance. The activities involved were either checking out or returning library materials, or making photocopies. Most patrons (63%) visited only one or two sections of the library. A small percentage of patrons (7%) seemed to wander about the library aimlessly. Figure 3.3 shows the paths taken by two library patrons.

The results of the study showed that library patrons were generally pleased with the physical design of the library. Our observational data indicated that tables and seats were substantially underused (an average of 3 of the 42 seats occupied at any

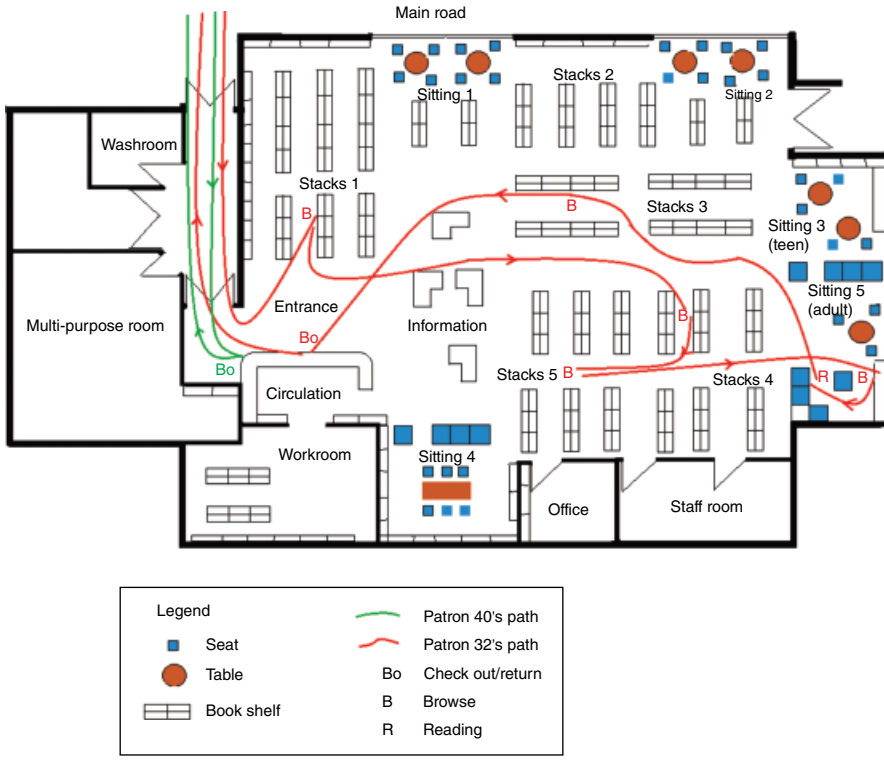

Figure 3.3 A behavioral tracking map showing the paths taken by two library patrons.

given time). Yet one-third of the respondents in the questionnaire survey complained that the tables were too small and that there were not enough tables and seats. This conflict in the findings suggested that the tables and seats were not located where patrons wanted them. As the adult sitting area at the magazine section was the most heavily used area, future expansion of library services may consider adding magazines, newspapers, and reading and study areas.

This evaluation demonstrated that behavioral mapping and tracking techniques, when used together with a questionnaire survey, can provide a more comprehensive picture of patrons' satisfaction with the library and their space use pattern than any one technique alone (Ng & Gifford, 1986).

Physical Traces

In addition to observing behaviors as they are occurring, behavioral researchers can use physical traces to infer people's behaviors. Physical traces are physical evidence of people's past behaviors or their interactions with the physical environment. Trace measures are of two general forms: accretion and erosion (Sommer & Sommer,

2002; Webb, Campbell, Schwartz, & Sechrest, 2000); additional trace measures include adaptations and repairs to a space, and personal and public messages displayed in a space (Zeisel, 2006). **Accretion** refers to physical evidence of people's past behaviors or their interactions with the physical environment; for example, empty beer bottles and litter left after a party, graffiti on walls in washrooms, and dirty footprints on the carpet. **Erosion** refers to deterioration of the physical environment that results from use; for example, bare spots on a lawn or footprints in the snow suggest a shortcut from one building to another. Signs of wear and tear in floor tiles are another example.

The collection of physical traces is unobtrusive because the researcher is seldom present at the scene where the behaviors occurred. Physical traces are often collected indirectly, after the people whose behaviors are being measured have left the scene, which makes the measurement of physical traces non-reactive.

Researchers can use physical traces in creative ways to test hypotheses about behaviors and preferences. These measures can be used to assess the validity of verbal reports. Consider, for example, the posters of pop music stars on the walls of a teenager's room, which may be used to assess the validity of that teenager's expressed liking for his or her favorite stars.

The use of physical traces as measures of past behaviors has its limitations. Measures of physical traces can be imprecise as they do not indicate who, when, and for how long deposits or wear and tear are made. However, systematic monitoring of these physical traces can improve precision of these measures (Sommer & Sommer, 2002). Other factors can influence the deposit or erosion of physical traces, so it is important that physical trace measures not be used alone. The researcher must consider alternative hypotheses or explanations, and then collect data from other sources to refute these alternative hypotheses. For example, are the empty beer bottles left by one person or many persons, and is this the result of janitors on strike? The best approach is to use multiple methods to collect data to test the same hypothesis. If different methods lead to the same conclusion, then the researcher has increased confidence in the hypothesis.

Summary and Conclusions

Behavioral mapping is a research tool used to observe and record behaviors in a particular setting at a particular time. Behavioral mapping can be either place-based or individual-based, depending on whether the focus of the observation is to identify locational or temporal patterns of behaviors. Behavioral mapping can be used in descriptive, correlational, or experimental research, and is used in architectural programming and in post-occupancy evaluation. Behavioral mapping follows several steps, including preparing a floor plan of the setting, identifying behavioral categories and their coding, developing a sampling plan and standardized observation procedure, training observers, and pre-testing. In addition to being a more objective measure of behaviors than self-reports, behavioral mapping facilitates the study of behaviors in their physical and social contexts. However, it has several challenges, including ethical issues, intrusiveness and reactivity, difficulty in data analysis, intense time and labor commitment, and

the inability to infer individuals' motivation behind their behaviors. Advances in technologies have, and will no doubt continue to, lessen time and labor commitment. When combined with other methods of data collection, behavioral mapping can be a useful tool for environment–behavior research.

Glossary

Behavioral mapping An observational technique used to record people's behaviors and movements systematically as these behaviors occur in particular locations at a particular time.

Behavioral tracking An observational technique used to record a person's movements and activities in a setting or settings over time.

Physical traces Physical evidence of people's past behaviors or their interactions with the physical environment.

Accretion Deposition of material on the physical environment as a result of people's past behaviors or their interactions with the physical environment.

Erosion Deterioration of the physical environment that results from use.

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