Behavioural observation studies

Peer-reviewed author version

POLDERS, Evelien; VAN HAPEREN, Wouter & BRIJS, Tom (2018) Behavioural observation studies. In: Polders, Evelien; Brijs, Tom (Ed.). How to analyse accident causation: A handbook with focus on vulnerable road users, Hasselt University, p. 127-154.

Handle: http://hdl.handle.net/1942/27196

Chapter 5: Behavioural observation studies

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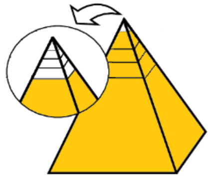

5.1 Introduction

Road user behaviour is a key aspect of road safety. Road safety literature widely acknowledges that road user behaviour is an important factor in the complex interactions between road users, the road environment and the vehicle. According to several studies (Reason, 2000; Sabey & Taylor, 1980; Treat et al., 1979), road user behaviour is the most important contributing factor in nearly all accidents (94%), while the road environment and the vehicle only partially contribute in 18% and 8% of all accidents, respectively. Therefore, interventions targeted at controlling or altering road user behaviour should increase road safety. To understand road user behaviour, predict it in different situations and, if possible, control and modify it, it is necessary to have a technique or method for observing and identifying behavioural processes. This chapter presents such behavioural observation techniques as valuable tools for diagnosing road safety.

What will this chapter tell me?
• What are behavioural observation studies;
• How behavioural observation studies can be used to assess road safety;
• Why conduct a behavioural observation study;
• How to carry out a behavioural observation study;
• What data are collected and how these data can be analysed.

Behavioural observation studies can be used to identify and study the frequency of particular characteristics of road user behaviour in different situations (OECD, 1998; van Haperen, 2016). This includes observing road user behaviour in all types of traffic events, from undisturbed passages to serious conflicts. Such study makes it possible to gain knowledge about the behavioural and situational factors at play both in low-risk encounters and preceding serious traffic events. Behavioural observation studies thus provide an opportunity to better understand the contributory factors influencing accident occurrence. Certain factors—such as speeding, red-light running and failure to wear seatbelts or helmets—not only contribute to accident occurrence but also to injury severity. As behavioural observation studies observe these contributing factors and the specific characteristics of related road user behaviour, the results of such studies can be used to identify which target groups or risk-increasing behaviours require attention to reduce road fatalities and serious injury.

Behavioural observation techniques are particularly useful when studying road user behaviour to diagnose road safety problems at specific locations or among specific target groups. Unlike accident data analyses, observing interactive behaviour provides an insight into the road safety process, not only road safety outcomes. For example, observing road user behaviour can reveal the underlying factors as to whether a given measure improves road safety or not. This chapter serves as a guide for applying behavioural observation studies to assess the road safety of vulnerable and other road users.

5.2 Introduction to behavioural observation studies

Identification of the drawbacks of accident data analysis has led to the development of several other road safety evaluation methodologies. These methods largely use safe traffic interactions as a benchmark and are based on the direct observation of traffic events that result from processes similar to those of accidents, or on observations and analyses of the particular characteristics and determinants of traffic behaviour (OECD, 1998). Behavioural studies are an example of such road safety evaluation methods. Typical behaviours in a behavioural observation study include informal communication, yielding behaviours, crossing behaviours, looking behaviours, red-light running, speeding and seatbelt use.

Behavioural studies are among the first road safety evaluation methods to use non-crash data. Nearly a century ago, Dodge (1923) argued that observing road user behaviour is crucial to improving road safety. One of the oldest behavioural studies was performed by Greenshields, Thompson, Dickinson and Swinton in 1934. They introduced the technique of taking consecutive pictures as a new data collection method to analyse road user behaviour. Since then, behavioural studies have become common practice and have been applied for various research purposes.

Behavioural studies are a type of naturalistic on-site observation technique, as road user behaviour is observed in the real setting in which the behaviour of interest occurs (Eby, 2011). In road safety research, this setting consists of the road environment, the vehicle and the road users interacting with each other in this environment.

What is a behavioural study?
A type of traffic observation study used to examine road user behaviour. These studies emphasise analysing the actions of road users in their natural settings by means of observable, qualitative variables (e.g. gender, age, interaction type, approaching behaviour, looking behaviour, priority behaviour, distraction, communication behaviour, red-light running, seatbelt use) while they interact with other road users, the road environment and/or their mode of transportation.

The basic principle behind the use of behavioural studies is the paradigm that the behaviour of road users is a prerequisite for road safety. According to Svensson (1998), safety levels are closely linked to the quality of the interactive behaviour and communication that takes place between road users. Consequently, road user behaviour—the most important contributing factor in road accidents—forms the core of behavioural studies. These studies aim to define and observe the principles of safe interaction among road users and the road environment by looking not only at unsafe interactions but also safe ones. The rationale behind this approach is that safe and unsafe interactions relate to each other; a subtle change in the interaction process between road users, the vehicle and the road environment can transform a safe situation into an unsafe one.

In capturing the interactions between these elements and the behavioural and situational aspects that precede accidents, behavioural observation studies offer valuable insights into how safe interactions can evolve into potential accidents and how road user behaviour influences the occurrence of accidents and accident-preceding events. Such study allows us to better understand why road users behave the way they do in different situations and events and to predict how road users will behave in certain situations, allowing safety measures to be implemented proactively (i.e. before accidents occur).

5.2.1 Advantages and disadvantages

Behavioural studies are essential to many empirical data collection efforts but, like any technique, have both advantages and disadvantages. The six main strengths of this method are described below.

Why should I use behavioural and interactional studies?	
Advantages	**Disadvantages**
Direct observation of road user behaviour in a natural setting	Only observes revealed behaviours
Practice-ready (convenient to learn and apply)	Difficult generalisability of results
Data can be collected quickly for fast evaluation of road safety situations	Labour-intensive data collection
Inexpensive	Observer bias
Insights into behavioural and situational aspects that precede accidents (supplement to accident data)	Susceptible to adverse weather conditions, difficult at night
Can be combined with other techniques (i.e. supplement to accident data)	

First, these behavioural studies allow the direct observation of road user behaviour in a natural setting, making for strong face and construct validity (Eby, 2011). Their interpretation does not rely on road user behaviour proxies as self-reporting techniques do (Eby, 2011), and the results of these studies are more likely to reflect reality than those of other research methods (such as driving simulators). Further, observing road user behaviour in a natural setting reduces the effects of behavioural adaptation that can lead to risky or aggressive behaviour while driving (Shinar, 1998).

Second, these studies are practice-ready and convenient to learn and apply. Human observers can be trained in as little as two days because of the method's ease of use. These studies are so easy to use because no complex research resources are required; collecting road user behavioural data requires only trained human observers. These human observers can be complemented or even replaced by video cameras, but the locations of such cameras and the privacy legislations that can restrict their use should be considered properly.

Third, behavioural studies allow road safety situations to be diagnosed very quickly, as the data necessary for such diagnoses can be collected in a short period of time. These studies thus offer the advantage of responsibility, as road safety can be diagnosed and evaluated at locations perceived as unsafe before serious accidents occur.

Fourth, behavioural studies are inexpensive compared to other safety diagnostic methods, as they do not require costly training programmes or tools. This opens opportunities for road safety research in developing countries.

Fifth, these studies provide insights into the causes of accidents by describing the behavioural and situational aspects that precede them, as well as the specific characteristics of a location that may influence observed road user behaviour. This allows for the selection of location-specific road safety solutions.

Finally, behavioural studies can be used in combination with other techniques. To maximise the benefits gained from behavioural studies, it is recommended to combine results of these studies with traffic violation data, accident data analyses, self-reports and traffic intensity measurements (Lötter, 2001). When combined with these techniques, behavioural studies—which can be easily adapted to the requirements of a specific situation—are an effective tool for diagnosing road safety problems at specific locations or for specific target groups.

As a road safety diagnostic method, behavioural studies also have some disadvantages. The main shortcoming of these studies is that only variables describing the revealed behaviours of road users can be observed and collected, meaning the underlying causes of these behaviours remain undetected (Eby, 2011).

Another disadvantage is the lack of results generalisability (Eby, 2011). Because the observations of road user behaviour are location-specific, it is difficult to verify that the observed behaviours will also occur at locations where no behavioural study has been performed. As such, results interpretation requires caution.

Another drawback is the labour-intensive quality of the method's data collection. It is very time-consuming to conduct a behavioural observation study, as the observers must study the road user behaviour on-site for several hours. This requires significant endurance from the observers, who must remain focused during the entire observation period. Although the use of video cameras can reduce this intensity of labour (events can be replayed multiple times and the continuous observation period split into smaller blocks), it cannot eliminate it.

Another disadvantage is that the human observers on whom the studies rely may have biases that affect what they see and record (Eby, 2011). This observer bias can be mitigated through training or the use of video cameras to register road user interactions.

Finally, the execution of these studies is susceptible to adverse weather conditions and relies on daytime hours as these aspects limit the visibility of human observers to accurately record road user behaviour. Additionally, not all video cameras are able to sustain adverse weather conditions.

5.3 When to conduct behavioural observation studies

Behavioural observation studies provide information about the frequency of specific characteristics of road user behaviour in different situations. Unlike traffic conflict observation studies, these studies are not used to quantify road safety levels in terms of the expected number of injury-inducing accidents (OECD, 1998; van Haperen, 2016). On-site behavioural observation studies can be used for a wide variety of purposes and are especially useful when assessing road safety situations where there is no accident data available, or when the available accident data lacks detail (OECD, 1998). In the context of diagnosing and evaluating road safety, behavioural observation studies are used primarily for the following (OECD, 1998; van Haperen, 2016):

- Monitoring the frequency of road user behaviour;
- Checking the findings of accident and traffic conflict studies regarding possible accident factors;
- Evaluating the effects of road safety countermeasures or strategies;
- Developing behavioural models for simulation purposes; and
- Developing and testing automated video analysis software

When behavioural studies are used for monitoring purposes, their focus lies in observing the frequency and characteristics of road user behaviour at one or multiple (i.e. identical) locations to determine the most prevalent behaviours. An example of such a study is that by Langbroek et al. (2012), who used behavioural indicators to investigate interactions between pedestrians and motor vehicles at signalised intersections.

Results based on accident and/or conflict data alone can be insufficient for determining possible accident factors or providing detailed insights into the causes and behavioural elements behind road safety problems. This is especially the case in situations where there is little accident or conflict data available, or when the available data lacks detail. Behavioural observation studies can help assess the road safety situation by checking the findings of accident and traffic conflict studies regarding possible accident factors. An example is the study by De Ceunynck, Daniels, Polders and Vernyns (2015), who aimed to gain a better understanding of the interactions between drivers of motor vehicles and cyclists at roundabouts with separated cycle paths to identify the road safety issues facing cyclists at these locations. Earlier studies based on accident data had been unable to determine whether it was safer to implement priority for cyclists crossing the exit and entry lanes of roundabouts with separate bicycle paths.

Behavioural studies are also effective when evaluating whether a measure has had its intended effect and to identify unwanted side effects at an early stage. The observation of 'normal' interactive behaviour is particularly relevant when determining why a given measure is an improvement to road safety or not. Unlike accident data analyses, interactive behaviour observation provides insights into the road safety process in addition to road safety outcomes, as demonstrated by Polders et al. (2015).

Finally, behavioural observation studies can be used for software and model development. With model development, behavioural observation data can be used as input to develop, calibrate and/or validate behavioural models such as microsimulation models (van Haperen et al., 2018). For example, Kadali et al. (2015) used behavioural observation data based on a video graphic survey as input to develop a pedestrian gap acceptance model. Behavioural video data of road user interactions can be used to develop and test automated video analysis tools (van Haperen et al., 2018). An example of such work is that by Zaki and Sayed (2014), who studied non-conforming pedestrian behaviour at an intersection in Vancouver, Canada. In this study, the authors developed and tested an automated system for identifying pedestrian crossing non-conformance to traffic regulations based on pattern matching. Their results revealed a high rate of noncompliance among different pedestrian populations and provided general information on the behaviour of crossing pedestrians (e.g. illegal crossing rate at the facility).

To summarise, behavioural observation studies are applied predominantly for monitoring and evaluation purposes, but are also used (to a lesser extent) to develop behavioural models and software (van Haperen et al., 2018).

Interactions between pedestrians and motor vehicles at signalised intersections (Langbroek et al., 2012)

A joint Belgian–Swedish study analysed interactions between pedestrians and motor vehicles at two-phase signalised intersections by means of video-based behavioural observations at three intersections in Sweden and Belgium. The study collected the following behavioural indicators: number of pedestrians, age and gender of involved road users and behavioural aspects like yielding, crossing and looking behaviours.

The analysis of the behavioural aspects revealed that men and young road users violated red traffic signals more often than women and older road users. Red light violation was also more prevalent at Swedish intersections than at Belgian ones. No differences were noted between pedestrians walking alone and pedestrians walking in groups. One interesting result was the fact that red traffic violations appeared to be independent of the presence of an approaching vehicle. Further, pedestrians often did not yield when violating a red traffic signal. Regarding looking behaviours, around 30% of pedestrians in general did not look both ways before crossing. Pedestrians who did not look both ways before crossing were involved in more traffic conflict situations than those who did.

Motorcyclists' road safety-related behaviour at access points on primary roads in Malaysia: A case study (Abdul Manan & Várhelyi, 2015)

An observational study focusing on motorcyclists was conducted at access points on straight sections of primary roads in Malaysia to gain more insight into actual road traffic situations at these sites. Motorcyclist behaviour was observed by means of video recordings and trained human observers at selected locations. The video camera was installed unobtrusively inside a parked car. Two observers were seated in the car; one operated the video camera while the other noted all the interactions and associated characteristics (e.g. identification of serious conflicts, course of events preceding the conflict, road user behaviours influencing the course of events).

The results revealed that the majority of motorcyclists kept to the speed limit and reduced speed when approaching an access point, especially in the presence of other road users. Motorcyclists tended to participate in a risky right turn movement (i.e. Opposite Indirect Right Turn [OIRT]) from the access point onto the primary road. Most of the motorcyclists who engaged in the OIRT manoeuvre did not comply with the stop line rule. The motorcyclists exhibited high compliance with helmet and headlight usage but were poor at utilising the turning indicator.

Yielding behaviour at roundabouts with separated cycle paths (De Ceunynck, Daniels, Polders, & Vernyns, 2015)

This Belgian study observed interactions between drivers of motor vehicles and cyclists at six roundabouts with separated cycle paths—three with priority for cyclists and three with no priority for cyclists.

By means of a standardised observation form, detailed information about 165 interactions was collected in a structured way. The observations showed that there were substantial differences between the two types of roundabouts concerning interaction behaviours between cyclists and motor vehicle drivers. At the roundabouts with priority for cyclists, the cyclists usually were given priority from the motor vehicle drivers. At roundabouts with no priority for cyclists, situations in which the motor vehicle drivers took priority occurred most frequently.

Looking behaviour also played a role in the interaction process. When a motor vehicle driver looked in the direction of a cyclist, the probability of the cyclist continuing to ride increased significantly. This probability was also higher among male cyclists. At roundabouts without priority for cyclists, motor vehicle drivers often were denied priority by male cyclists. Similarly, motor vehicle drivers took their priority less frequently when interacting with male cyclists than with female cyclists. Notably, the share of motor vehicle drivers who did not use direction indicators was quite high at 29%.

In sum, there was a high degree of heterogeneity among the interactions between cyclists and motor vehicle drivers, especially at roundabouts without priority for cyclists. This could indicate a potential safety risk for cyclists.

Drivers' behavioural responses to speed and red-light cameras (Polders et al., 2015)

Many signalised intersections worldwide have been equipped with enforcement cameras to tackle red-light running or to enforce speed limits. However, various impact evaluation studies of red-light cameras (RLCs) show that the presence of these cameras leads to increases in rear-end collisions (up to 44%). The principal objective of this study was to provide possible explanations for the increase in rear-end collisions at combined speed and red-light camera (SRLC) installation sites.

Real-world behavioural observations and driving simulator-based observations were used. Video recordings at two signalised intersections where SRLCs were about to be installed were used to analyse rear-end conflicts, interactions and driver behaviours under two conditions (with and without the SRLC). One of these intersections was also built into a driving simulator equipped with an eye tracking system. At this location, two test conditions (SRLC and SRLC with a warning sign) and one control condition (no SRLC) were set for examination. Data from 63 participants were used to estimate the risk of rear-end collisions via a Monte Carlo Simulation.

The results of the on-site behavioural observation study revealed decreases in red and yellow light violations, a shift in the dilemma zone (closer to the stop line) and a time headway reduction after SRLC installation. Based on the driving simulator data, the odds of rear-end collisions (compared to the control condition) for the conditions with SRLC and SRLC + warning sign were 6.42 and 4.01, respectively. To conclude, the real-world and driving simulator observations indicated that the risk of rear-end collisions increased when SRLCs were installed. However, this risk might decrease with installation of an early warning sign.

5.4 Methods for observing road user behaviour

Behavioural observation studies for diagnostic purposes are usually designed according to the behaviour of interest or situation under observation. From a methodological point of view, behavioural observation studies can be divided into two categories: unstructured and structured.

In *unstructured behavioural observation studies*, researchers look with an 'open mind' at road user behaviours and record any observable action or behaviour that seems interesting or conspicuous. In this sense, these studies help researchers to 'get acquainted' with the research site. Unstructured behavioural observations typically complement traffic conflict observation studies; interesting situations are identified and collected when analysing the conflict observation data. Behavioural observations are not the goal of the research, but rather provide the bonus of rich qualitative information about road safety at a specified location. An example of an unstructured behavioural observation study is that by Manan and Várhelyi (2015).

In contrast, *structured behavioural observations* are well-prepared and can expand on results from unstructured observation studies. These studies conduct explicit and detailed observations of specific safety-related behaviours such as crossing and looking behaviours or traffic rule compliance at a certain location. In most cases, standardised forms of observation are used to study the behaviour of interest. These studies, especially when combined with other research methods, are essential for understanding complex road safety problems. An example of a structured behavioural observation study is that by Langbroek et al. (2012).

Regardless of the type of behavioural observation study, the two most common methods for collecting behavioural observation data are on-site human observers and video cameras (or a combination of the two, as mentioned by Van Haperen et al., 2018). Both methods are easy to apply, can be used to observe all types of road users and allow the collection of a wide variety of behavioural indicators. The applied data collection method depends on the purpose of the study and the type of behavioural indicators under observation. Table 1 provides an overview of the two data collection methods and their characteristics.

Table 1: Overview of data collection methods.

Method	Cost	Time consumption	Suitable target group	Suitable sample size	Type of behavioural indicators
Human observers	Medium	High	All types of road users	Small to medium	Yes/No
Video cameras	Medium	Medium to high	All types of road users	Large	Yes/No and more detailed measurements

Types of behavioural indicators (adopted from Van Haperen et al., 2018)

Yes/No	More detailed
Red-light running	Crossing path
Gap acceptance	Waiting time
Evasive action	Waiting position
Protective clothing	Lateral position
Carrying items	Crossing time
Use of pedestrian push button	Gap size
Mobile phone use	Headway
Wrong-way driving	Yielding distance
Turn indicator	Other distractions
Lane change	Other violations
Stop-sign compliance	Lane choice
Lights	Distance to stop line
Stop/go decision	Merging distance
Yellow-light running	Overtaking attempts
Overtaking	Intersection entry time
Smoking	Speed (related)
Seatbelt use	Looking
Child restraint use	Yielding
Speed (related)	Merging
Looking	
Yielding	
Merging	
Behavioural observation studies also register variables describing the personal characteristics of individual road users (e.g. age and sex) and informal communication actions like head, eye and hand movements and eye contact.	

5.4.1 Human observers

On-site trained human observers are a flexible and basic means to collect behavioural observation data. Researchers or observers stand next to roadways and intersections, look into vehicles and at vulnerable road users (VRUs) and record what they see (Eby, 2011). Behavioural observation studies by means of trained human observers have the advantage of only needing a watch, pen and behavioural observation form to register the revealed road user behaviour. The variables that are registered on the behavioural observation form are mostly 'yes/no' and 'single value' indicators. Further, the data of interest can be collected very quickly and efficiently (van Haperen et al., 2018). This method is useful when collecting behavioural data at different types of locations (e.g. roundabouts, intersections, part of an intersection) and for all types of road users.

The costs of using human observers for data collection primarily involve labour costs and depend on the number of observers for each project. The number of observers depends on the purpose of the research and the size and complexity of the study location. For instance, for a moderately sized intersection or a not-too-complex location, one observer is generally sufficient; more than one observer is recommended for more complex intersections or locations. When using multiple observers, some observation data will overlap, but this is compensated by the gain of additional information that can be observed and registered. The use of several observers is most useful in situations where multiple events occur simultaneously. It should be noted that in all projects involving human observers, the collected data must be digitised before data analysis may commence.

A disadvantage of behavioural observation studies using trained human observers is that the data collection process is influenced by inter- and intra-coder reliability (Williams, 1981), subjectivity (Grayson, 1984) and possible registration errors when the human observers are involved in operations for extended time periods. According to van Haperen et al. (2018), these drawbacks become more significant when the data collection process is complex and when the measurements are based on estimations that cannot be verified after the fact. Due to these limitations, it is recommended to only apply this data collection method for small-to-medium sample sizes (e.g. observe for two hours, then take a break before resuming observations). Further, the observers must be trained prior to collecting the data to ensure that the observations are performed as systematically and objectively as possible to yield valid results. Currently, many behavioural observations that use human observers also use video recordings. This allows the observer to review the observed interactions and behaviours when analysing the results. An example of a behavioural observation study by means of trained human observers is that by Langbroek et al. (2012).

TIP: Training of observers

Observers should be trained properly in conducting behavioural observation studies. During a short, multi-day training course, the observers participate in:

- Theoretical lectures
    - How to compose a behavioural observation form
    - How to perform a behavioural observation study
    - Points of attention
- Practical instructions:
    - Exercises are done to learn how to observe road user behaviour accurately and efficiently on location
    - Real-life field observation sessions take place at a study location to ensure everyone gets acquainted with the behavioural observation form, knows which behaviours/interactions to observe and to check consistency in the recorded observations.
    - Camera placement (if used)
    - Processing, analysing and interpreting the data and results
    - Taking a good position with respect to the point of observation

Three main issues that need to be addressed during training (Eby, 2011):

- Training for consistency and accuracy: each observer should collect the behavioural data by following the same procedures (protocols and identical data coding). This should be practiced before starting the actual study.
- Inter-observer reliability: when using multiple observers, all observers should be trained together and tested for inter-observer reliability to ensure the collected data are comparable. This can be achieved by checking and comparing the recorded results of each observer after the practice session. If the inter-observer reliability is low (i.e. less than 85%), the observers should discuss how they are coding data and continue practicing until the comparability between the results is greater than 85%.
- Intra-observer reliability: the variability in the recordings of a single observer over time (Archer, 2005). The discrepancies of an individual observer can be attributed to different factors, including lack of training, inadequate definitions of the observed situations, fatigue, excessive conflicts and the occurrence of complex conflict types (Chin & Quek, 1997). These inconsistencies can be overcome through training programmes and video analysis techniques.

At the study location, observer(s) should have unobstructed visibility (i.e., a good overall view) and should wear unobtrusive clothing so as not to influence road user behaviour (Lötter, 2001).

5.4.2 Video cameras

Video cameras are a more objective and accurate means of collecting behavioural observation data. Per this method, one or multiple cameras are installed inconspicuously at the location(s) of interest and record road user interactions and behaviours (Eby, 2011). This method can be used to collect behavioural data at different types of locations (e.g. roundabouts, intersections, part of an intersection) and for all types of road users. Video cameras allow the continuous observation of road user behaviour, and the recorded interactions can be replayed and reviewed to verify the results. Registerable variables include both 'yes/no' and more detailed indicators.

Data collection by means of video cameras is less labour-intensive due to the approach not requiring the presence of a trained observer during data collection. The subsequent data analysis is still time-consuming, however, as automated video analysis tools are currently still under development (see chapter 4). An example of a behavioural observation study by means of video cameras is that by van Haperen et al. (2018). For more information on using video recordings for observation purposes, please consult section 4.6 in chapter 4 of this handbook.

TIP: Using video cameras

The following points should be considered when using cameras:

- Authorisation from the road authority is required to place a camera.

- A good location (e.g. lamp post, building) is required to place the equipment. This place should be inconspicuous.
- The availability of electricity is an important factor.
- The camera’s point of view must include the entire research area.
- Weather and lighting conditions must be accounted for (e.g. provision of a protective rain cover).
- The equipment must have some protection against theft.
- Privacy issues must be taken seriously. Video footage is a type of personal data, so all privacy regulations must be respected. These rules specify how the recorded video footage must be handled (e.g. blur license plates or faces, type of resolution to be used while recording). These rules vary from country to country, with some requiring permission from the privacy commission or authority before recording may commence.
- Available data storage space (e.g. hard drives, SD cards) must be monitored to avoid the overwriting of data and keep data loss to a minimum.

Conventional video cameras suffice for recording video footage at certain locations, but for longer observation periods (e.g. one week or more), the use of professional video cameras is recommended. These cameras can be rented from companies specialised in equipment for traffic studies.

Yielding behaviour and traffic conflicts at cyclist crossing facilities on channelised right-turn lanes (van Haperen et al., 2018)

A Belgian study investigated the safety performance of crossing facilities for cyclists using channelised right-turn lanes (CRTLs). Site-based observations of yielding behaviours were used to evaluate the effect of the priority rule on cyclists’ safety in two CRTL designs. Four locations in Belgium were selected for video observations: two where the priority rule favoured cyclists and two where motorists had priority.

With regard to yielding, four types of crossing behaviours were identified and defined. Independent of the priority rule, cyclists crossed the conflict zone first in most interactions without taking the initiative to cross first. Underlying reasons for motorists willingly yielding their right-of-way could not be determined, but courtesy or fear of inflicting injuries on VRUs may have been of influence. The results lightly suggested that locations with motorist priority and right-to-left cyclist crossings (from the driver’s point of view) produce the highest proportion of safety-critical events.

5.5 How to collect behavioural observation data

Behavioural observation studies typically follow a well-defined study plan. This section provides a step-by-step guide for setting up a behavioural observation study. The basic stages of a behavioural observation study are as follows:

1. Deciding to apply a behavioural observation study;
2. Selecting locations for observations;
3. Determining what road user behaviours to observe;
4. Formulating observation protocols;
5. Defining the research design;
6. Defining a data collection methodology;
7. Conducting the behavioural observation study.

These stages are described in greater detail in the subsections below.

5.5.1 Deciding to apply a behavioural observation study

Behavioural observation studies are a useful method for diagnosing many road safety issues. However, not all road safety issues can be assessed by means of this naturalistic observation method. Therefore, the following four qualities should be considered before deciding to use behavioural observation studies as a method (Eby, 2011):

1. Purpose of the study (research objective)
2. Reliability
3. Population of interest
4. Resources

First, the purpose of the study needs to be determined. Behavioural observation studies are suitable when examining the frequency or occurrence of road user behaviours but are not appropriate for gaining an in-depth understanding of the underlying causes (e.g. motivations, beliefs, attitudes) of the revealed behaviours (Eby, 2011). Determining the purpose of the study or research objective is a crucial step in applying behavioural studies, as doing so dictates the entire study design (e.g. location, target group, behaviours for observation, observation time and duration). Second, you must determine whether it is possible to judge the behaviour of interest accurately and reliably through visual inspection (Eby, 2011). Third, it is important to identify the population of interest (Eby, 2011). In some cases, it can be difficult to design a behavioural observation study that both represents a large population and is cost-effective. Further, the population must occur in natural settings. Finally, you must have access to sufficient resources to conduct such studies, which can be very costly due to reliance on labour-intensive work and depending on the study's scope and design.

5.5.2 Selecting locations for observations

Once you have decided to conduct a behavioural observation study, it is important to determine where the observations will take place. This decision relates closely to the study's purpose and the research objective. For example, your focus could be to evaluate road infrastructure re-designs at a certain location or to monitor the frequency and characteristics of road user behaviours at one or multiple locations to identify prevalent behaviours; such studies would require entirely different locations.

When selecting observation sites, it is crucial that they represent the behaviour of interest accurately—simply put, the behaviour for study must occur naturally at the chosen location. Generally, behavioural observation studies are applied at intersections in urban settings because VRUs appear more frequently in urban areas, as do road user interactions.

Selection of study location(s) (van Haperen et al. 2018)
Based on accident data: Locations with reasonably high numbers of reported accidents are selected for the behavioural observation study. **Based on infrastructural characteristics:** Locations are selected based on their infrastructural characteristics. These characteristics should be as similar as possible to limit the influence of confounding factors. To guarantee the transferability of results, behavioural studies should focus on locations free of location-specific factors that may influence road safety conditions.

5.5.3 Determining what road user behaviours to observe

Once you have set your study location, it is important to select the variables for observation. These variables can relate to:

- The road user type to be observed: all road users or a specific group (e.g. only VRUs, only drivers).
- Personal characteristics of the road user: age, gender, helmet use, etc.

- Road user behaviour: looking, yielding, crossing, communication (e.g. use of directional indicators, hand gestures) and other behaviours.
- Infrastructural elements: priority rules at the location, colour of the traffic light while crossing, etc.

Laureshyn (2010) provides a detailed overview of the different variables that can be used to observe individual road user behaviours and interactions. These variables are clustered according to the main road user group for study (i.e. drivers of motor vehicles, cyclists or pedestrians). This overview indicates the data type and preferred data collection method for each variable. For more information regarding this topic, consult Laureshyn (2010). Interesting variables can also be selected based on the available road safety data at the study location; variables can be tailored to reflect the types of accidents for which additional information about road user behaviour is needed. Another option is to observe an intersection without any preparation; this method brings the advantage of obtaining an overall picture of the location's road safety and traffic situation (see section 5.4, *Unstructured behavioural observation studies)*.

In observations using trained observers, the selected variables are noted on a standardised behavioural observation form specifically developed for the study. On this form, the various behavioural and situational aspects of the interaction are represented in the form of binary (yes/no) or categorical variables. By structuring and standardising interactions in such a way, it is possible to carry out quantitative analyses on the collected data. An example of such a standardised behavioural observation form is provided in Annex 1.

5.5.4 Formulating observation protocols

An observation protocol defines when and for how long the behavioural observation study will take place. The observation period should be determined according to the purpose of the behavioural observation study. If, for example, the road safety problem or behaviour of interest relates to specific weather conditions, traffic conditions or time of day (e.g. peak hours, night), the behavioural observations will need to be conducted at an appropriate time to meet these conditions (Lötter, 2001). Before starting formal observations, you should collect background information to acquaint yourself with the road safety problems at the study location. Accident data and inquiries with the local police department or residents near the study location can provide valuable insights (Lötter, 2001). It is crucial to consider the entire observation period thoroughly. When defining this period, you must ensure that it is reliable and representative of the road user behaviour under study. You can assure this representativeness by spacing the observations evenly throughout the hours of the day and days of the week (including weekends if necessary) to avoid possible biases.

The duration of the behavioural observations will depend on the situation under study, the desired reliability level, traffic density and the number of interactions at the location. In most cases, 30 hours of behavioural observations at a site are sufficient to provide an overview of the prevalent road user behaviours and allow for a road safety analysis. Generally, observations carried out by human observers (see section 5.4.1) are divided into blocks of no longer than two to three hours, each followed by a break of 10 to 15 minutes. To ensure each observation period begins on time, the observers should arrive at the study location at least 10 minutes before the start of the behavioural observations.

Observation protocol example
There are no standardised observation protocols currently available. Instead, researchers develop individual protocols tailored to their specific studies. Researchers do not uniformly describe study characteristics at the same level of detail, significantly limiting the transparency and transferability of research results (van Haperen et al., 2018). The following observation protocol example has been taken from De Ceunynck et al. (2013, p. 41), who used it to observe vehicle–vehicle interactions at two non-signalised intersections: *Each intersection was observed for 30 h during the November 24 through December 5, 2011, period. All observations took place in dry weather conditions during the daytime because of the need to look inside the vehicles to collect information about the drivers' gender, age and looking behaviour. Twilight, night, and rainy conditions did not allow this. The observations were done in blocks of 2 to 3 h, spread evenly throughout the hours of the day and days of the week (including weekends) for both intersections to avoid possible biases. All observations were executed by one observer using a standardised observation form. All variables were objectified and standardised as binary or categorical variables to allow quantitative analyses of the interactions.*

5.5.5 Defining the research design

The research design of a behavioural observation study is linked to the purpose of the study. For instance, if the purpose of the study is to evaluate road infrastructure re-designs, a before-and-after design is recommended. In such a study, road user behaviours are observed before and after the implementation of the infrastructural measure of interest to see whether the measure has its intended effect and results in positive road safety changes.

Behavioural observation studies can also use a single observation design, which focuses on observing the frequency of road user behaviours at a location. For example, the crossing behaviours of VRUs at signalised intersections could be observed. Variables could include the number of times pedestrians violate red traffic signals, whether they look both ways before crossing or whether they yield.

TIP: Before and after study design

The same observation periods must be applied before and after the studied measure's implementation, and the characteristics of these observation periods (e.g. weather conditions, traffic conditions) must be as identical as possible. The 'after' observations should begin at least six weeks after the implementation of the measure to reduce the influence of the novelty effect and ensure road user behaviours have adapted to the changed traffic conditions (Polders et al., 2015).

Another option for research design is the cross-sectional approach. With this design, two or more locations (e.g. intersections) are selected. These locations must be as comparable as possible in terms of infrastructural design characteristics, vehicle speeds and traffic flows, but differ in one aspect (e.g. right-of-way rules). The behavioural observations at all the locations then examine how this one difference influences road user behaviour.

5.5.6 Defining a data collection methodology

The data collection method you choose to apply will depend on the purpose of the study and the type of behavioural indicators that need to be observed. The two most common data collection methods are on-site human observers and video cameras (or a combination of the two, as mentioned by Van Haperen et al., 2018).

Video camera vs trained observers (Van Haperen et al.,2018)

Variables such as gender, age and communication between road users (e.g. informal signals, eye contact) cannot be obtained easily from video data and should be collected by on-site observers.

Video cameras offer the advantage of continuous data collection for longer time periods, whereas trained observers may take only a sample of a situation. Video data allow the registration of continuous variables (e.g. speeds), which can then be analysed accurately using video analysis. Video data also create the possibility of verifying the quality of measurements and replaying the videos as many times necessary to extract all relevant information (Van Haperen et al., 2018). Finally, videos are very efficient in communicating research findings to other researchers and the public. However, only events happening in view of the camera can be analysed.

For more information, consult section 5.4.

5.5.7 Conducting the behavioural observation study

Once you have completed all preparations, it is time for the actual behavioural observation study. Trained human observers must be present at the study location during the entire observation period. If using multiple observers, they will need to synchronise their watches before the start of the study so as to record road user behaviour occurrences on the behavioural observation form accurately. Time synchronisation also simplifies the data analysis process to follow. If using a camera at the study location, all human observers should synchronise their watches with the internal clock of the video camera to make it easier to retrieve interesting behaviours during the data analysis stage. You should also verify that the camera is working properly at the start of the study.

5.6 Presentation and interpretation of results

Descriptive statistics are commonly used to present the results of behavioural observation studies (see Table 2 and Figure 1). These statistics indicate the frequency of certain behaviours and are completed using the following information:

- Identification of common road user behaviours;
- Identification of the situations and circumstances in which the observed behaviour takes place;
- Characteristics of the road user exhibiting the behaviour.

Table 2: Descriptive analysis example of possible yielding events between cyclists and motor vehicles and the distribution of crossing directions (adopted from van Haperen, Daniels & De Ceunynck, 2016).

Location	**'No crossing' events**		**Interactions** Crossing direction		
	Total (#)	Unnecessary yield (#)	L ⟶ R (#)	L ⟵ R (#)	Total
C (Z)	4	3	58	59	117
C	103	54 [52%]	330	225	555
M (Z)	385	109 [28%]	397	145	542
M	2	2	116	36	152
Total (n)	494	168	901	465	1366

Note:
C = cyclist right-of-way (no zebra crossing); C (Z) = cyclist right-of-way (with zebra crossing)
M = motor vehicle right-of-way (no zebra crossing); M (Z) = motor vehicle right-of-way (with zebra crossing)
L = left; R = right

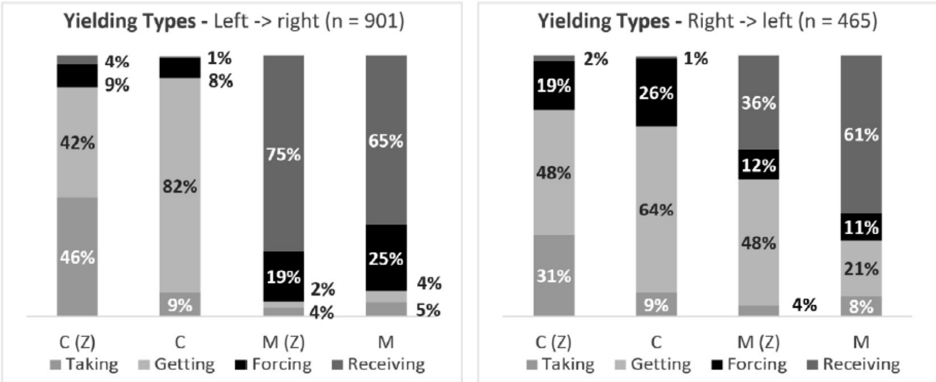

Figure 1: Illustration of analysis of yielding behaviour between cyclists and motor vehicles (adopted from van Haperen et al., 2018).

If using a before-and-after study design, the following questions should be addressed:

- Did the implemented measure result in a reduction of the targeted behaviour?
- Did the implemented measure lead to the occurrence of other behaviours?

As mentioned earlier, the generalisability of behavioural observation study results is an issue. Because road user behaviours are observed at specific locations, it is difficult to guarantee that the observed behaviours also occur at other locations where no behavioural studies have been performed. Therefore, some caution is required when interpreting results.

5.7 Complementary studies

Behavioural observation studies are usually complemented by other road safety data collection methods to create a comprehensive picture of the road safety situation at a given location. The study of Polders et al. (2015) is an example of an integrated study in which behavioural observations, traffic conflict observations and driving simulator research are combined to diagnose road safety holistically. These complementary studies are described in greater detail in the subsections below.

5.7.1 Traffic counts

The amount of cyclist, pedestrian and other traffic correlates positively to the number of encounters among the various road users. Exposure is a useful addition of traffic safety analysis and is important when proposing safety countermeasures. For more information regarding the collection of traffic counts or exposure data, consult the PIARC Road Safety Manual (PIARC, 2003).

5.7.2 Speed measurements

Vehicle speed plays a critical role in accident occurrence and injury outcomes. As such, speed measurements can be used as a background reference and diagnostic tool to conduct behavioural observation studies (e.g. identify locations where VRUs might be at a higher accident risk due to fast-moving vehicles). As speed is a major determinant of VRUs' risk of injury, studies seeking to diagnose the safety of VRUs should always include speed measurements. Behavioural observation can then be applied to gain a better understanding of the relevant road user behaviours and their determining features at the specified location. For more information regarding the use of speed measurements, consult the PIARC Road Safety Manual (PIARC, 2003).

5.7.3 Accident data

Sometimes there is little accident data available, or the available data lacks the detail necessary to obtain a satisfactory evaluation or diagnosis. In such cases, behavioural observations can complement accident analyses to support the action design and, where appropriate, can even compensate for shortages of information on accident-generating processes (Muhlrad, 1993). The behavioural items to observe and locations of interest are determined primarily by the accident analysis findings. Often, behavioural observations are used to verify the findings of accident studies regarding possible accident factors. For more information on the use of accident data, consult chapter 2 of this handbook.

5.7.4 Traffic conflict observation studies

Behavioural observation studies are often combined with traffic conflict studies to cover diverse aspects of the road safety situation of interest. Unstructured behavioural observations are typically additions to traffic conflict observation studies. Interesting situations are identified and compiled when analysing conflict observation data. In this way, behavioural observations add value to traffic conflict studies by providing more insight into the behavioural aspects and elements that affect traffic conflict occurrence. For more information on traffic conflict observation studies, consult chapter 4 of this handbook.

5.7.5 Driving simulator studies

A driving simulator consists of a mock-up vehicle surrounded by screens displaying a virtual road environment. Participants in driving simulator studies navigate the simulated road environment by controlling the vehicle actuators (steering wheel, brake pedal, throttle, gears). The simulators log detailed information about the user's driving behaviours and performance parameters.

Driving simulators allow for the proactive and detailed modelling of driving performance. These studies provide insights into how driver, vehicle and roadway characteristics influence driving safety and monitor how road safety improvements or measures influence driver performance (Boyle & Lee, 2010). Driver awareness of and response to risky situations, near-accidents and even accidents can be monitored in a simulator (McGehee & Carsten, 2010). Simulator studies also provide insights into the underlying mechanisms of safety-critical events (Boyle & Lee, 2010). Driving simulators have the potential to identify road design problems, explore effective infrastructural countermeasures, test advanced vehicle technologies and investigate a variety of driver impairments. Consequently, they provide very rich information about road safety.

Driving simulators do not only focus on the road safety of car and truck drivers. Driving simulators for motorcyclists and cyclists are also applied to assess the road safety of VRUs. For more information regarding driving simulator studies, consult Carsten and Jamson (2011) and Fisher, Rizzo, Caird and Lee (2011).

5.7.6 Stated preference studies

Interviews can aid the collection of information from road users of a location of interest and can provide data about safety-related phenomena. Even brief interviews with passing road users can yield critical information about the site that the observer might not have noticed in a short period of time. As such, these opinions form a solid basis for consecutive behavioural observations. The main reason for combining behavioural studies with stated preference studies is to determine the extent to which self-reported behaviours, attitudes, beliefs and opinions resemble the observed behaviour (see Geller, Casali & Johnson, 1980; Hakkert, Zaidel & Sarelle, 1981).

5.8 Conclusions and key points

Behavioural observation studies have a long history in the examination of road user behaviour and road safety and are still in common use today. These studies are particularly useful when seeking to diagnose road safety problems at specific locations or for specific target groups in order to identify which target groups and risk-increasing behaviours require attention. Typical behaviours in a behavioural observation study include informal communication, yielding behaviours, crossing behaviours, looking behaviours, red-light running, speeding and seatbelt use.

In the context of road safety evaluation and diagnosis, behavioural observation studies are used mainly to monitor the frequency of road user behaviours, to support findings from accident and traffic conflict studies regarding possible accident factors and to evaluate the effects of road safety countermeasures and strategies. Observing road user behaviours in their natural settings is a valuable method because it yields critical knowledge about effective road user behaviour and provides a means to identify and describe the determining features of such behaviour.

Behavioural observation studies are designed according to the specific behaviour and/or situation of interest, and as such require a well-prepared study design, established protocols, extensive observer training and adequate resources to yield valid results. The two most common methods to collect behavioural observation data are on-site trained human observers and video cameras (or a combination). The main remaining issue with these studies is the generalisability (or lack thereof) of results. Because road user behaviour is observed at a specific location, conclusions that the behaviour will also occur at locations not under study are difficult to secure. To combat this limitation, behavioural observation studies are often supported by other road safety data collection methods (accident data, traffic conflict observation studies, driving simulator research, speed and exposure measurements) to compile a comprehensive picture of the road safety situation at a certain location.

5.9 Recommended reading

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	Interaction characteristics			Arrival	
ID		Presence of a car			
	Number of pedestrians	Yes	No	Pedestrian arrives first	Motor vehicle arrives first
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Annex 1: Example of a behavioural observation form

Date:	
Time:	**Pavement condition:**
Weather conditions:	**Intersection name:**

	Pedestrian characteristics/Behaviour											
ID	Gender		Age				Yielding		Traffic light		Directional lights	
	M	F	C	Y	M	O	Yielding	Not yielding	G	R	Yes	No
1												
2												
3												
4												
5												
6												
7												
8												
9												

10												

	Characteristics/behaviour car driver											
ID	Gender		Age				Yielding		Traffic light		Directional lights	
	M	F	C	Y	M	O	Yielding	Not yielding	G	R	Yes	No
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

ID: ID of observed interaction
Gender: M = Male; F = Female
Age: C = Child (age 0-17 years); Y = Young adult (19-30 years); M = Middle age (31-65 years); O = Old (65+ years)
Traffic light colour: G = Green; R = Red