Information along familiar routes

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Chapter 1

The problem

1.1 Introduction

Around midnight on a day in December, the driver of a passenger car was waiting for a red light at a signal-controlled intersection. Once the light turned green he started driving. Meanwhile, a tram approached the same intersection at a normal speed. The tram driver routinely glanced at the tram signal to look for the sign that gives him right of way. Every time he approached this intersection his signal turned from red to white ('green') and this night he saw the same. Therefore the tram proceeded. In an instant – just before traversing the intersection – the tram driver noticed the car passing the intersection, but it was too late. The front of the tram crashed into the side of the passenger car and pushed it forwards for several metres. Afterwards both the car and the tram driver claimed they got a 'green' light. Analysis of the traffic control system, however, indicated that only the car driver had a green light. This time the tram driver's light had been red. The investigators concluded that the accident had happened due to a human error (Muller & Verweij, 1991). How could this error occur?

Processing the relevant elements of the traffic environment is imperative to navigate our way through traffic in order to safely arrive at our destination. It is widely agreed that in the traffic environment most of the relevant information is visual (e.g. Hills, 1980; Sivak, 1996; Wickens, Lee, Liu, & Gordon Becker, 2004). This means that, to safely negotiate traffic, most of the relevant information that is filtered and processed by human brains is received through a single sensory modality input: the eyes. In this context, it is important to realise that the action of simply looking around will not result in a replication of what actually can be seen. Although many people are confident that they notice everything around them, in fact they do not at all (e.g. Levin, Momen, Drivdahl, & Simons, 2000). Driven by attentional control the eyes scan the traffic environment in places where relevant information is expected, based on previous experience. When strong, top-down attentional control is lacking, the eyes may 'wander around' the visual field or look at areas that attract attention bottom-up, due to object features such as motion or contrast. Information not focussed by the eyes, or attended in the periphery, remains largely unnoticed (see e.g. Egeth & Yantis, 1997; Lamy & Zoaris, 2009; Leber & Egeth, 2006; Parkhurst, Law, & Niebur, 2002; Theeuwes & Hagenzieker, 1993; Theeuwes, 1993; 1994). This process of visual search forms the first barrier – or filter – for all the visual information elements present in our surroundings to become part of the mental representation of it contained in the human brain. Next, this selected stream of visual information is filtered and processed, interpreted, and supplemented by the human brain in order to create a meaningful representation of our surroundings (Wickens et al., 2004). Previous experiences and current expectations play a role in automatically filtering and interpreting information as well as supplementing information to 'complete' the mental representation (Rasmussen, 1983). Under specific circumstances, looking at something may instead even result in seeing what one expects to see (e.g. Gerbino & Zabai, 2003; Martens & Fox, 2007a).

In short, instead of being a true-to-life reproduction, the mental representation of our surroundings is comprised of (environmental) elements we (un)wittingly attended, enriched with, or even overwritten by, elements accumulated during previous experiences that have been stored in memory. It is this representation that determines for a large part how we look for and find our way in traffic (Wickens et al., 2004).

This PhD dissertation aims to get a better understanding of human beings' processing of the visual information elements in the traffic environment and the role familiarity with this environment plays in this process. With this aim, an attempt was made to contribute to the body of knowledge understanding the cognitive processes involved and explaining what is likely to be seen in the traffic environment and what is not, such as in the example preluding this chapter.

1.2 Information in the traffic environment

For people to be able to act appropriately in a given situation, they must know what is going on around them, a state of mind also referred to as situation awareness (Endsley, 1995). Part of achieving situation awareness is selecting and integrating elements of the traffic environment into meaningful pieces of information. The amount of effort necessary for this cognitive process depends on the individual's level of experience with the task at hand and with the particular situation (Rasmussen, 1983). Rasmussen (1983) proposed that depending on aforementioned levels of experience, human beings perform tasks at a skill-based, rule-based, or knowledge-based level. Rasmussen distinguished between these levels based on how much mental effort and control, thus attention, is needed. Knowledge-based level performance requires most attention, as previous experiences cannot be relied upon, tasks and situations being new. Instead, reliance on previous experiences requires selecting and testing of the most suitable mental models and adapt them to create a new model to fit the new environment. Examples of rule-based level performance are driving in an unfamiliar, foreign city or being a novice driver; driving a car or – in the latter case – the concept of participating in traffic, are not new, though the specific situation or task at hand (being a driver instead of e.g. a pedestrian) is. On the other end of Rasmussen's threefold hierarchy, performance at the skill-based level occurs mostly effortlessly and subconsciously, thus processing of task-related information may require very little attention. Examples of this are navigating from home to work, and stopping at, or crossing, a familiar intersection. Since traffic participants vary in how experienced they are with travelling by a specific means of (active) transport and in a specific area, their ability to look at the relevant elements of the traffic environment and to cope with the flow of visual information greatly varies (Proctor & Dutta, 1995). When regarding the traffic environment as comprised of single elements of information, it should be noted that the number of informational elements may be very high. Although information may be very useful, e.g. signposts guiding people in the right direction, the amount of information may also become overwhelming. Experienced traffic participants will have a more efficient and effective search strategy which relies on automated processing and experience, thus enabling them to select and process large amounts of visual information more easily (Mourant & Rockwell, 1972; Underwood, Chapman, Brocklehurst, Underwood, & Crundall, 2003). In contrast, novice traffic participants or those unfamiliar with the area may experience difficulties to greater or lesser extent. Under specific situations, for example when performing a dual task, processing large amounts of information may even prove difficult for highly experienced and locally familiar traffic participants. Presenting road users with large amounts of information relative to their individual information processing capabilities, may invoke an unacceptably high mental workload, stress and feelings of uncertainty (Dicke-Ogenia, 2012), which are undesired outcomes, as they may lead to failures that might eventually result in accidents (Reason, 1990). However, both road authorities as well as road users have ways to reduce this informational overload.

1.2.1 Informational overload and uncertainty: a road authority's perspective

Firstly, the design of the traffic environment itself is generally largely the responsibility of a road authority. Road authorities can facilitate road users' processing of what is relevant by structuring and standardising informational elements and limiting their number to essentials. In this context, informational elements in the traffic environment may entail anything from information painted on the road surface (e.g. delineation, texts, arrows) to roadside information, such as travel information (for psychological and ergonomic guidelines on presenting roadside travel information see e.g. Arbaiza & Lucas-Alba, 2012; Campbell et al., 2010; De Vries-De Mol & Walraven, 1988; Dicke-Ogenia, 2012; Roskam et al., 2002). Although road authorities have been reported to compensate for feelings of uncertainty by installing additional road signs, this 'solution' increases the informational load. Limiting the amount of information and structuring and standardising it are acknowledged as more integral solutions to improve road user behaviour (Theeuwes, Van der Horst, & Kuiken, 2012). Limiting the provision of information to what is necessary and relevant may be achieved in various ways. One example is using dynamic information carriers. While the dynamic information carrier can contain various messages that might be relevant at a specific location, the message on display can be limited to what is necessary and relevant at a specific moment in time. In comparison, to provide the same information using fixed road signs a multitude of road signs is needed, such as in Figure 1.1 (the concept of dynamic traffic management will be elaborated on further along this chapter). When the amount of information is limited based on relevance and necessity, the remaining relevant information elements may be structured and standardised to further facilitate them being perceived. By consistently using the same symbols, grouping together specific information elements and consistently positioning specific information in the same location in the traffic environment, road users will learn these visual patterns and have expectations on where to find relevant information (Theeuwes & Hagenzieker, 1993; Theeuwes et al., 2012). Structuring and standardising information elements could be done across road categories, but it may also be used to distinguish between road categories. By providing separate road categories with their own typical characteristics, road authorities are able to communicate which behaviour is expected of road users per road category instead of per every single road. The best example of this is the concept of self-explaining roads, in which road layout differentiates between road categories such as motorways and woonerfs (Theeuwes & Godthelp, 1995). The approach of consistently structuring and standardising relevant road attributes enables road users to process information quicker, to form solid patterns of which behaviour is expected and to reduce uncertainty (Dicke-Ogenia, 2012; Ranney, 1994). At the same time it enables road authorities to take advantage of road user' expectations to guide behaviour and make roads more predictable. To make this concept of reducing informational load and uncertainty work, repeated exposure to the same category of roads is a prerequisite.

Figure 1.1. Left, a single dynamic road sign which can display e.g. both a speed limit of 80km/h or 100 km/h, dependent on relevance for each specific moment in time. Right, the multitude of fixed road signs that is needed to convey the same message. Both are examples from the Netherlands.

1.2.2 Informational overload and uncertainty: a road user's perspective

Secondly, road users' ways to reduce informational overload and uncertainty are discussed. How do road users react and consequently behave in the traffic environment? Road users own actions to cope with informational overload and feelings of uncertainty appear to roughly boil down to three strategies (Brookhuis et al., 2008; Dicke-Ogenia, 2012; Erke, Sagberg, & Hagman, 2007). Firstly, reducing the speed at which one travels, consequently allowing for more time to process the information that is presented. Secondly, ignoring information.

And thirdly, sticking to familiar routes, i.e. the ones very well known, which reduces the amount of new information that needs to be processed and it increases predictability. The latter was confirmed by Charlton and Starkey (2013) in a simulator study, in which drivers repeatedly drove the same route. Charlton and Starkey demonstrated that with increasing familiarity with the driving environment, ratings of mental demand declined. However, when the visual surroundings along the route were changed while using a road geometry identical to previous drives, the reported mental effort increased to the same level as in the initial drive along the route. This shows that route familiarity in driving depends highly on visual input. In fact, habitually taking the same routes, hence becoming increasingly familiar with them, is a widely applied strategy to get from A to B. Habitual behaviour allows people to cultivate and rely on automaticity, which is used for information processing, decision making and consequently for behaving (Aarts & Dijksterhuis, 2000b; Aarts & Custers, 2009; Engström, Victor, & Markkula, 2013). Since repetition in route choice is such a common part of mobility as a whole, Chapter 2 features a systematic review concerning the effect of route familiarity on road user behaviour, to get a better understanding of the mechanism involved in commuting along familiar routes. Route familiarity may be a good model for studying the effects of habits and automaticity in visual information processing and, consequently, human behaviour when participating in traffic. Hence Chapter 2 forms the theoretical framework for this thesis.

1.2.3 The ever-changing traffic environment

Again, when considering the traffic environment as comprised of single elements of information, another distinct feature that is of great importance for information processing is that the traffic environment is inevitably ever-changing. The environment holds a mix of both fixed elements, such as fixed road signage, and elements that are dynamic, such as traffic participants. Previously, dynamic elements mainly consisted of other road users. These days, however, with the increased use of dynamic traffic management, especially in places with higher volumes of traffic, they also include information displayed on dynamic traffic management information carriers. These dynamic information carriers have become an increasingly common element in the traffic environment which, by nature, vary the information shown to traffic participants. The information displayed changes on a regular or irregular basis – hence the word *dynamic* –, depending on the situation at hand. The oldest and probably most well-known forms of dynamic traffic management might well be the police officer and the traffic light. In the introductory example, the tram driver had been exposed repeatedly to a particular traffic light predominantly signalling the tram had right of way. Patterns based on repeated exposure are building blocks for the formation of expectations. In this particular case, repeated exposure to the right-of-way signal may have created such a strong expectation in the tram driver's mind that at the rare occurrence of the light signalling the tram driver had to stop, the tram driver was rendered incapable of seeing what actually had been clearly visible. Instead, he saw what he expected to see. This perceptual failure may in fact not be that exceptional, and most of the time it will not result in fatal injury. This specific failure is also referred to as 'the failure to apprehend', which has been extensively described by Martens (e.g. 2007). As part of this phenomenon, the variability of information plays a pivotal role. Human beings in general have difficulties detecting if, and when, information in their surroundings changes, and, therefore, so do traffic participants (e.g. Rensink, 2002; Simons & Levin, 1997). This may even be the case when the changing information is relevant for their task to negotiate safely through traffic. However, studies by Charlton and Starkey (2011; 2013) demonstrated that this perceptual error does not occur under all circumstances. To be able to better understand human beings' processing of the visual information elements in the traffic environment and the role familiarity with this environment plays in this process it is necessary to have a clear understanding of current relevant models of cognitive psychology applied in the traffic environment. Hence these models are part of the theoretical framework for the empirical studies described in this thesis.

1.2.4 Thesis outline

When the stage has been set in a theoretical chapter (Chapter 2), describing the theoretical framework on route familiarity, four empirical chapters (Chapters 3-6) follow which are concluded by a general discussion and conclusions on the contribution of this dissertation (Chapter 7).

Chapter 3 describes an experiment designed to establish whether dynamic traffic management information 'en route' indeed may suffer from perceptual errors under routine driving conditions. The experiment examines the effects on implicit, behavioural output – in this case driving speed – and explicit knowledge of what changed. The primary independent variable was people's ability to detect speed limit changes in electronic speed limits, an important feature in the traffic environment. The route had been driven repeatedly in a driving simulator – stimulating route familiarity – before the actual speed limit change occurred.

Chapter 4 comprises a follow-up experiment on Chapter 3, aimed at improving the detection of changes in important traffic-relevant information along a familiar route. Again, electronic speed limit signs were used in which the speed limit eventually changed. This time, videos were used, which were viewed repeatedly to familiarise drivers with the driving environment. To examine the effect on people's ability to process the information contained in the signs, various countermeasures were tested, designed to make the changed, traffic-relevant information more conspicuous. One of the countermeasures consisted of adding flashing amber lights, a method commonly used by road authorities to attract drivers' attention.

Chapter 5 explores the effect on information processing and behaviour by displaying both task-relevant and task-irrelevant information, on the same information carrier along a familiar route. In particular, the experiment examines drivers' ability to adequately turn critical task-specific route-guidance information into behaviour and records how this information was memorised. Similar to Chapter 3, a driving simulator was used to familiarise drivers with the route. This time, the information that changed consisted of a message imperative for route guidance, displayed on an electronic overhead sign (a variable message sign, or VMS). The task-irrelevant information comprised a variety of advertisements displayed on the same sign in previous drives, while for the control group during these drives it was left blank.

Chapter 6 again, similar to Chapter 5, addresses the issue of the processing of information that guides behaviour and whether we become aware of this information. This chapter examines how much awareness is prerequisite to avoid obstacles while walking in a stimulus-rich environment and whether the level of awareness is related to the instant of obstacle avoidance. An inevitable component of information processing is the distribution of attention while processing elements in the traffic environment. Therefore, this observational experiment takes into account differences in secondary task engagement, mind wandering and route familiarity. Instead of driving, the experiment focusses on an active mode of transport which is arguably less effortful in the sense of information processing demands: walking.

Chapter 7 contains a general discussion and conclusions of the four empirical chapters. In particular the significance of the findings will be discussed in reference to the theoretical framework on route familiarity which is presented in Chapter 2.