The role of route familiarity in traffic participants' behaviour and transport psychology research

Harms, Ilse; Burdett, Bridget ; Charlton, Samuel

Published in:
Transportation Research Interdisciplinary Perspectives

DOI:
10.1016/j.trip.2021.100331

Transportation Research Interdisciplinary Perspectives 9 (2021) 100331

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: www.elsevier.com/locate/trip

The role of route familiarity in traffic participants' behaviour and transport psychology research: A systematic review

Ilse M. Harms [a,b,*], Bridget R.D. Burdett [c], Samuel G. Charlton [d]

[a] University of Groningen, Netherlands
[b] Ministry of Infrastructure and Water Management, Netherlands
[c] MRCagney, New Zealand
[d] University of Waikato, New Zealand

ARTICLE INFO

Keywords:
Route familiarity
Systematic review
PRISMA
Skilled behavior
Automaticity
Everyday driving

ABSTRACT

Studies of how transport behaviour (e.g., driving, cycling, and walking) is affected by practice and familiarity are not commonplace, in spite of the fact that much of our travel takes place on familiar, well-practiced routes. In other areas, it is well-established that repetition affects cognition, particularly memory and attention. The goals of the current systematic literature review were 1) to explore how researchers have described and examined the effects of people's familiarity with routes and road types, and 2) to obtain a better insight into the cognitive processes, and behaviour that occur in familiar road environments.

The systematic review was conducted based on the principles described in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). Scopus' database was searched systematically using predefined search combinations which involved (1) the transport modes of driving, cycling, and walking; (2) research methods that typically involve route- or situation-familiar participants (e.g., naturalistic studies, observational studies and field operational tests); and (3) various words associated with route familiarity (e.g., familiar, everyday, and commute).

Ninety-four studies met all inclusion criteria. Results were analysed in terms of the cognitive and behavioural changes associated with familiarity, as reported in the studies. Route familiarity was typically reported to reduce the amount of cognitive control used to process the immediate environment and to increase mind wandering, compared to unfamiliar situations. Familiarity also increased recall accuracy and opportunities for self-regulatory behaviour, and decreased task difficulty.

Familiarity appears to have large effects on how people attend to and process the environment. Given the proportion of time people spend travelling in familiar situations, this low attention, high familiarity state should be considered the default mode and as a more integral context for experimental, naturalistic and observational research in transport psychology.

Contents

* Corresponding author.
E-mail address: dr.ilse.harms@gmail.com (I.M. Harms).

https://doi.org/10.1016/j.trip.2021.100331
Received 23 August 2020; Revised 13 February 2021; Accepted 17 February 2021
Available online 16 March 2021

1. Introduction

In their daily lives, people typically walk, cycle, and drive in familiar environments. Studies of travel and transport behaviour, however, are typically conducted under unfamiliar circumstances such as in a driving simulator. As such, people are considered in new, experimental road environments, or they are studied in semi-experimental settings while using an instrumented vehicle, such as a car or a bicycle. For simulator or instrumented vehicle studies it is assumed that they closely resemble regular traffic conditions so conclusions regarding human capabilities can be more easily translated to real-life conditions (Kaptein et al., 1996; Wang et al., 2010). The results of these studies are often generalised widely, even though many such studies involve a simplified, isolated aspect of behaviour, with its complex, everyday context removed. Alternatively, researchers may attempt to study natural behaviour by asking their participants to reflect on their behaviour in hindsight, e.g. through interviews or questionnaires. Interviews or questionnaires often include the implicit assumption that the behaviour displayed is (at least to some extent) consciously controlled and that knowledge regarding this behaviour is semantically accessible. That is, participants are supposed to be consciously aware of how and why they behave as they do, and be able to articulate and report on those choices for the researcher.

Researchers use these methods to gain a better understanding of how people behave when on roads and in traffic. These methods, however, run the risk of treating transport as an isolated, artificial task, instead of a skilled action integral to people's everyday lives. The usual or everyday context is left out. It is questionable whether this approach and the resulting conclusions concerning traffic psychology match the circumstances under which most people participate in traffic. In this paper, it is argued that in the case of driving, cycling, and walking, this usual or everyday context is repetition and familiarity.

1.1. The prevalence of travelling along familiar routes

Most of our trips are not unique or unusual, they are to places we go to often, using the same modes over and over again (Mucelli Rezende Oliveira et al., 2016). In other words, people repeatedly visit the same areas, using the same routes and the same transport modes. Because of this routine behaviour, human patterns of mobility are highly predictable (Mucelli Rezende Oliveira et al., 2016). Examples of repeated exposure to the same routes are the daily commute from home to work, a weekly trip to the supermarket and regular though less frequent trips to friends' places. It is through the repetitive daily sensory experiences, such as seeing, smelling, and hearing, that places become familiar to people (Tuan, 1977); which means that traffic participants are familiar with most of their trips. One aspect of this familiarity is known as route familiarity, a phenomenon with which we primarily refer to trips taken repeatedly, but also to particular roads, locations, and situations that traffic participants have encountered many times before.

Although travelling along familiar routes is commonplace, exact figures on the prevalence of travel (that is, distance travelled) along familiar routes compared to the total amount of travel, are lacking. In addition, some studies refer to distance travelled ('amount of travel'), while others refer to 'trips' (a set distance between an origin and destination). Concerning car driving, Dicke-Ogenia (2012) has reported that drivers prefer taking the same route over and over again, becoming increasingly familiar with a particular route. Moreover, car drivers use these familiar routes – such as the route from home to work – at approximately the same hours each day (Pendyala, 1999; Schönfelder, 2006). Knapper et al. (2016) reported that over a period of five to six weeks, in which twenty-one drivers made 1,306 trips in total, 57% of the trips matched other trips. In other words, they were repetitive. These figures are corroborated by Burdett et al. (2017), who showed that roads within eleven kilometres (6.8 miles) of home accounted for half of all travel. Even higher percentages were found for cycling and walking. A recent Belgian study on mobility habits of e-bikers revealed that 76% of the trips concerned the cycle route from home to work, and vice versa (Lopez et al., 2017). In addition, a contemporary case study in Prague showed that daily walking routines – such as the walk from home to the public transport station and the walk from the car park to the workplace and back – covered, on average, 85.4% of people's daily walking activity (Sobková and Čertický, 2018). In conclusion, it is safe to assume that, regardless of modality, most trips are made, and most travel is done on roads and paths well-known.

1.2. Effects of routine activities and familiar task contexts on cognitive processing

The repetitive character of where and how we travel described above shows driving, walking, and cycling are routine, not special activities. This is important, as within the fields of experimental psychology, social psychology, and sports psychology, studies of familiarity and expertise have shown that repetition has large effects on how we process information. Human cognition changes through education and experience obtained through exposure (Turing, 1950). With practice, humans gain expertise and skill so they are not overwhelmed with stimuli anymore. The process of skill development was described in the now classic model by Fitts and Posner (1967), which has often been used in e.g. sports psychology. They discerned three sequential stages: the cognitive, associative, and autonomous stages. The latter, autonomous, stage marks the final stage of skill acquisition, in which further practice hones performance into an automatised routine. In their model, control shifts from an initial, explicit control into more procedural forms of control. This final level of skill acquisition bears strong similarities with the skill-based level described by Rasmussen (1983), well-known within experimental psychology. Rasmussen proposed that actions performed at this skill-based level, under similar circumstances, have been associated with swift processing and require less conscious awareness and less mental effort than required in the initial stages of learning a new skill. Furthermore, he proposed that repeated exposure affects perception such that 'the total performance is smooth and integrated, and sense input is not selected or observed: the senses are only directed towards the aspects of the environment needed subconsciously to update and orient the internal map' (Rasmussen, 1983, pp. 259). Reputable examples of these effects of repetition – and the associated routine behaviour – on perception and visual search have been provided by e.g. Schneider and Shiffrin (Schneider and Shiffrin, 1977; Shiffrin and Schneider, 1977). One of the effects of automaticity is to reduce the attention and memory demands required for the automatised task or process, which allows people to devote some of those resources to other objects, tasks, or even to engage in non-task mind wandering. As such, the probability of reporting mind wandering is increased when the primary task is familiar or well-practised (Mason et al., 2007).

Familiarity resulting from practice has also been shown to affect various aspects of memory. Miller (1956) has shown that with experience, many pieces of information consolidate into chunks that can be actively held in memory at the same time, thus increasing the instantly available amount of information. One of the resulting advantages is that people familiar with a specific situation – people who may be regarded as experts due to their extended practice – are able to react much quicker in this specific situation and can recall it much more accurately, than novices can. This has been clearly demonstrated in multiple studies on chess skill (Chase and Simon, 1973; De Groot, 1946). In recall and perceptual processing speed, expert chess players outperformed novices as long as stimuli concerned chess pieces positioned in familiar arrangements. Routines are also known to influence people's perception of time, affecting temporal memory. For tasks performed in routine conditions their duration has been remembered as being shorter compared to non-routine conditions (Avni-Babad and Ritov, 2003). Additionally, patterns of knowledge obtained through extensive practice and stored in memory – also referred to as schemata – affect what people attend to and how they will behave in that environment (Brewer and Treyens, 1981). From social psychology theory it is known that due to these stored patterns, an environment or stereotyped stimulus may not only automatically trigger specific behaviour but it may also result in implicit judgements (Bargh and Gollwitzer, 1994). An example from traffic psychology might be the automatically generated 'choice' to travel by car when undertaking the familiar trip from home to work (Aarts and Dijksterhuis, 2000). Human beings might not even be aware of the mental shortcuts they take under familiar circumstances.

1.3. Rationale for this review and our twofold objective

Despite the ubiquity of repeated exposure to the same routes or tracks and the clear indications that routines affect cognition, investigating behaviour in familiar road environments is not commonplace. By default, most research within traffic psychology is done by observing voluntary participants perform tasks in one-off scenarios they are not familiar with. As such, common current research methods often do not match the actual circumstances under which most people participate in traffic. This is a problem because the results of the research might not be relevant to everyday traffic psychology; they risk lacking ecological validity.

A first attempt to review the effects of route familiarity was conducted by Intini et al. (2019), who focussed on safety-related behavioural performances of drivers and the negative outcomes of these behaviours. Their review revealed route familiarity affected drivers' motor output. Though outside the scope of Intini's review, we suspect that route familiarity also influences other driving performance. Moreover, it raises the question how cognition, which underlies most behaviours, is influenced and whether cycling and walking are affected similarly by route familiarity. The prevalence of travelling along familiar routes justifies a review with a wider scope regarding modes of transport and behavioural performances, and which provides a better understanding of the cognitive mechanisms involved.

For experimental purposes, Intini et al. (2019) proposed a familiarity identification criterion, based on repetition and distance from home. However, a clear definition of route familiarity is currently lacking. There is a conceivable continuum from a route never used before, to the classic case of the daily commute. In between these extremes, various objective measures (based on number of passes or kilometres travelled, or distance from home, for example) or subjective measures (how familiar the route 'feels') could define intermediate points on a scale.

Furthermore, studies that do include route familiarity are very much dispersed and may not even be labelled as such. For example, a naturalistic research approach may not be aimed at route familiarity per se but may be likely to include many route-familiar traffic participants.

For the current study a systematic literature search was conducted to address two main objectives: 1) to explore how researchers have described and examined familiarity as a context for driving, cycling, and walking performance; and 2) to obtain a better insight into the cognitive processes, and transport behaviour (i.e., behaviour displayed while driving, cycling, or walking) that occur in familiar road environments. For the latter objective, it is addressed what the effects of route familiarity are, if any, on a) processes involved in human information processing, b) mental state, such as affective state and stress, and c) subsequent behaviour. This systematic review was aimed to understand the effects of familiarity on human behaviour when travelling; and the extent to which researchers consider those effects.

2. Methodology and research protocol

2.1. Research design

The systematic literature review was conducted following the PRISMA principles (Liberati et al., 2009). It consisted of a broad, exploratory search, as currently research involving route familiarity is very much dispersed. The systematic search strategy – which was developed to guide the literature review – involved (1) the transport modes of driving, cycling, and walking; (2) research methods that typically involve route-familiar traffic participants (e.g., naturalistic studies, observational studies and field operational tests); and (3) various words associated with route familiarity (e.g., familiar, everyday, and commut*). The types of research methods and words associated with route familiarity were combined with each transport mode to narrow down the search systematically. The search strategy is described in further detail in Section 2.2 of this paper. The search consisted of 125 combined search terms and followed the process of identification, screening, and assessing eligibility and inclusion. Identification and screening started on February 21, 2017. Identification based on the systematic search was finalised in April 2020, when all search combinations received a final update. Identification was completed by additional records identified through the authors' knowledge of existing literature. The study protocol of this review has been provided in Appendix C.

2.2. Search strategy

In accordance with the study protocol, the title, abstract and keywords of the manuscripts, contained in the database Scopus, were searched for combinations of search terms. These terms were defined by selecting a few well-cited manuscripts on route familiarity and working backwards by varying search terms until they returned both the selected manuscripts as well as a broad variety of other manuscripts. All search terms are provided in Table C.1 in the appended study protocol (Appendix C). Based on a pilot using the same search terms in various search databases it was decided to confine the current systematic review to the Scopus database as it yielded the most eligible results and the other databases did not produce additional results on top of what was already found through Scopus.

2.3. Study selection and eligibility criteria

Studies from searches that yielded a maximum of 160 results were considered for screening. If a search yielded more than 160 results, none of these studies were considered, but the search was refined with more terms to yield fewer results, but with higher likelihood of finding relevant studies. Duplicates were removed and a full paper written in English had to be available and obtainable without additional costs, or within the boundaries of library agreements of the University of Groningen. Based on title and abstract screening, manuscripts were considered of potential interest when they described behaviour on familiar routes, reported on behavioural alterations due to increased familiarisation with a route as evolving over time or compared behaviour between an unfamiliar and a familiar route. The remaining manuscripts were read in full and were independently assessed again regarding their potential interest for the current review. Papers using a variety of research methods were included (e.g. real world driving, simulated driving, viewing photos or videos) so long as the papers were captured by our screening process. The process of study selection is displayed in the flow diagram in Fig. 1.

2.4. Selected aspects of paper characteristics, cognition and subsequent behaviour in traffic

Based on topics in transport psychology and of the included abstracts, the range of variables likely to be referenced in the papers was derived. After each paper was read in full, its relevance to each sub-category was documented. All (sub)categories related to aspects of cognition, or as a proxy thereof, are listed in Table 1. Data extracted from the manuscripts included the title, first author, year of publication, the studied mode of transport (driving/ cycling/ walking), how route familiarity had been specified and measured, and how familiarity affected one of the sub-categories of cognition.

The risk of bias in individual studies was addressed by using a predefined data extraction form and following the study protocol (Appendix C). Data was extracted and interpreted independently by two of the researchers (IH and BB). The risk of bias across studies concerns the use of different definitions of familiarity by researchers who explicitly included familiarity in their research design. Another potential source of bias is when researchers have failed to acknowledge familiarity as affecting the way people participate in traffic, while familiarity is implicitly part of the research design, e.g. which may be the case for naturalistic driving studies. Despite efforts to include both explicit and implicit use of familiarity in studies by using a broad set-up for the current systematic search, it is likely that not all available studies on route familiarity will have been included. Finally, for insight in the effects of route familiarity, studies reporting they found a significant effect of route familiarity are equally important as studies that did not find a significant difference. Unfortunately, the latter category is less likely to be published. Moreover, for studies which did not find a significant result it may still be impossible to conclude that there is no effect as sample sizes are often too low to warrant such statements.

2.5. Data analysis method

For analysis and summarising purposes, the content of some subcategories was merged. Based on the content of papers, *change blindness/ inattentional blindness/ looked-but-failed-to-see/ failed-to-look* were merged with *signal detection/ hazard detection*; *motor output tactical level* was merged with *motor output control level*; *compliance* has been merged with *motor output control level* (one study) and with *motor output strategical level* (one study); and of the two papers categorised under *arousal* one was merged with *confidence* and the other with *stress*.

As this was an exploratory search, we included a broad range of research methods. The limitations of this choice are discussed in Section 4.3. In order to summarise and interpret the effects of route familiarity on cognition and behaviour we proposed a rating scheme that focusses on comparisons between familiar and unfamiliar conditions, and which weights various research methods equally. The results were rated by the number of papers pointing in the same direction according to the following rating scheme:

- *convincing evidence*, three papers that compared familiar to unfamiliar conditions plus one or more papers that either compared familiar to unfamiliar conditions or that considered familiar conditions only;
- *good evidence*, three papers that compared familiar to unfamiliar conditions;
- *fair evidence*, two papers that compared familiar to unfamiliar conditions;
- an *indication*, one paper that compared familiar to unfamiliar conditions;
- *mixed results*, equal number of papers that compared familiar to unfamiliar conditions, or with one paper difference, between papers pointing in opposite directions.

Results were interpreted, tallied and rated per modality (i.e., driving, motorcycling, cycling, and walking). Where evidence was based on tallied opposing results, this has been indicated in the text.

Note that when rating the results, this was mainly weighted by the number of papers that compared familiar to unfamiliar conditions.

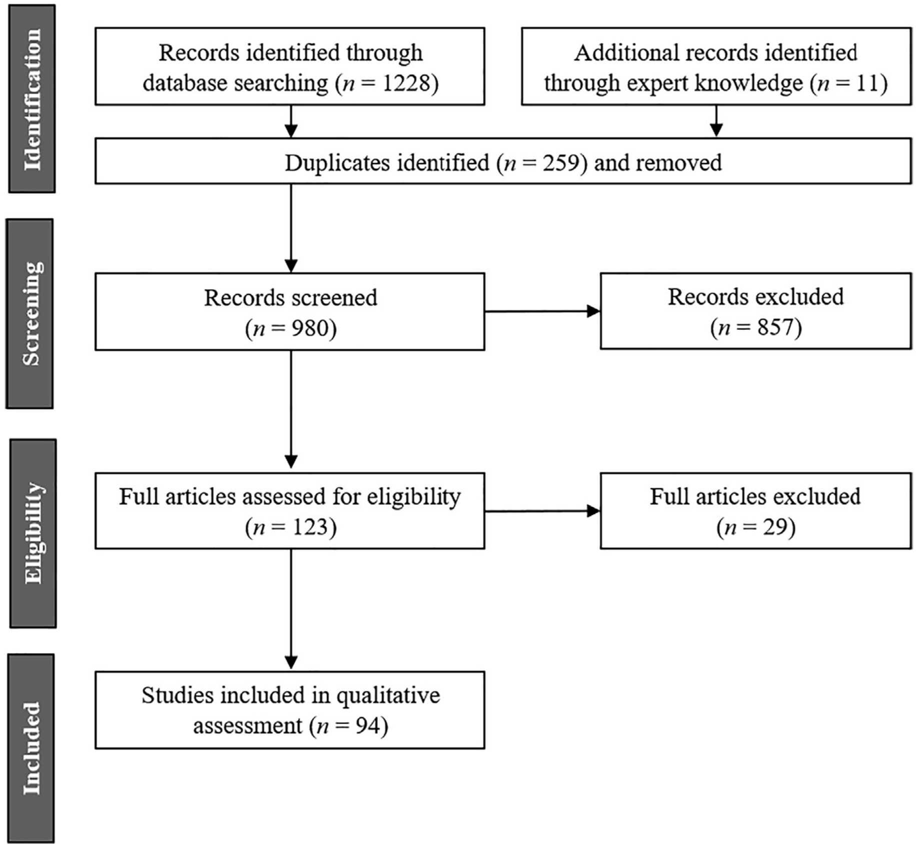

Fig. 1. Flow diagram of the systematic search on route familiarity in traffic, following the PRISMA method.

Table 1
Sub-category terms used to group papers. All subcategories per main category, as used for categorising papers for the current review.

awareness[1]/ attention	memory	judgement	mental state	behavioural performance
signal detection/ hazard detection	temporal memory[2]/ spatial memory/ mental map	risk perception	arousal	senses[3]
change blindness/ inattentional blindness/ looked-but-failed-to-see/ failed-to-look	episodic/ traumatic memory	self-regulation	emotion/ somatic marker	motor output, control level of Michon's task hierarchy[4] (Michon, 1985)
cognitive control/ divided attention/ automaticity/ interaction of conscious and unconscious processes/ self-regulation of attention	mental representation/ scripts/ schemata[5]	rule-based	fatigue	motor output, manoeuvre/ tactical & strategic level of Michon's task hierarchy[6] (Michon, 1985)
mind wandering	STM/ working memory		underload/ overload/ task difficulty	compliance
situation awareness	recall/ recognition		stress	consequences of behavioural performance[7]
			confidence	secondary task performance[8]
				distraction

[1] awareness is defined as an explicit perceptual report throughout this article, similar to e.g. Sandberg et al. (2010) and Spering and Carrasco (2015).
[2] including time estimation.
[3] including glance behaviour; gaze patterns; visual scanning.
[4] including speed selection; lateral position; following distance; braking behaviour; obstacle avoidance; reaction time.
[5] including expectations.
[6] including navigation/ route choice; gap selection.

Papers that considered familiar conditions only, were included in the rating scheme only as part of *convincing evidence*, though they were excluded from the accompanying Tables 3–7 of Sections 3.3 and 3.4, which only consider comparisons of familiar and unfamiliar conditions. Studies that compared familiar to unfamiliar conditions include papers that have used a repeated measures approach; compared familiar and unfamiliar participants; or compared a familiar to an unfamiliar route.

Table 2

Overview of proxies to take route familiarity into account. Per research method and per transport modality (🚗 = car driving, 🚲 = cycling, 🚶 = walking, 🏍 = motorcycling). Where studies combined multiple research methods in one study, for example by comparing participants' performance against their own repeated measures as well as against the performance of unfamiliar participants, they are counted as one study under '# of studies' and are mentioned separately for each research method. N/D stands for no data available about the mode of transport.

	# of studies	Comparing familiar to unfamiliar participants	Comparing against participants' own repeated measures	Using familiar participants only	References
Objective measures of familiarity					
repetitive exposure to the same route	32	18x 🚗 2x 🚲 1x 🚶	16x 🚗 2x 🚲 1x 🚶	1x 🚗	(12,14–44)
commute from home to work or school	12	5x 🚗	1x 🚗 1x 🚶	4x 🚗1x 🚶	(10,14,45–54)
amount of time participants have lived or worked in the researched area	9	4x 🚶	1x 🚶	2x 🚗2x 🚶	(55–63)
distance from home	8	5x 🚗 1x 🚶		2x 🚗	(9,11,64–69)
research area constitutes participants' hometown	5	3x 🚗	1x 🚗	2x 🚗	(15,70–73)
other	6	4x 🚗 1x 🚶		1x 🚗	(3–8)
Subjective measures of familiarity					
rating scale of route familiarity	11	4x 🚗 1x 🚲 1x 🚶 1x N/D	1x 🚗	3x 🚗	(9–11,13,74–80)
dichotomous self-report	7	5x 🚗 1x 🏍		1x 🚗	(81–87)
rating scale of the number of directions needed to get from A to B	1	1x 🚗			(12)
Not defined or unclear	7	3x 🚗 x 🚶	1x 🚲	2x 🚗	(88–94)

A more substantial description per main category for each eligible paper has been included in Appendix B, regardless of whether it considered familiar conditions only or compared them with unfamiliar conditions.

Papers that were composed of summaries of multiple studies – such as a literature review or an editorial foreword – were excluded from categorising and rating paper characteristics regarding cognitive and behavioural effects. Adding summaries of multiple studies to ratings of original papers would unbalance the rating scheme. Hence two studies were excluded from this part of the analysis (Charlton and Starkey, 2018a; Intini et al., 2019).

To improve legibility of the Results and Appendix B, the 94 eligible papers appear with numerical references in these sections. The numerical references have been included in the alphabetical reference list concluding this paper. An overview of all the numerical references, and the papers they refer to, on chronological order of appearance has been provided in Table A.1, in Appendix A.

3. Results

3.1. Selected studies and their characteristics

The flow diagram of all reviewed literature is shown in Fig. 1. The systematic search resulted in 1228 records, of which 259 were duplicates which were removed from the list. Another 11 records were obtained through the authors' knowledge of existing literature and added to the list, resulting in 980 records. After screening the titles and abstracts, 857 articles were excluded. The full texts of the remaining 123 articles were assessed for eligibility, resulting in the exclusion of an additional 29 articles as they appeared not to concern route familiarity after all, leaving 94 eligible articles.

The earliest work found involving route familiarity came from 1969 and focussed on heart rate while driving a familiar route. Thereafter, few researchers included route familiarity as part of their research paradigm, until 2007. As shown in Fig. 2, since 2007, the prevalence of studies considering route familiarity in scientific manuscripts appears to increase. This is reflected by the fact that 47% of studies included in this review were published in 2016 or later. Nevertheless, with a maximum of 13 studies per year in 2019 the subject of route familiarity is only a niche within transport psychology. For reference, the journal Transportation Research Part F (Traffic Psychology and Behaviour) alone published 171 articles on transport behaviour in 2016 and 350 in 2019 (data retrieved from this journal upon request).

Route familiarity is acknowledged across multiple modalities of transport. Although most research regarding route familiarity appears to be focussed on driving ($n = 72$), walking studies are also comparatively well-represented in the search results ($n = 15$). This in contrast to cycling ($n = 6$), and motorcycling ($n = 1$). One study combined both cycling and walking and another did not specify the mode of transport.

The results of any one study could include one or more aspects of cognition, so some articles in this review were included in more than one category. Note that the review study and the editorial foreword (1,2) were excluded from this part of the analysis, as mentioned previously. Of all eligible studies, 33% ($n = 30$) of the studies were categorised as *Judgement*; 24% ($n = 22$) were labelled as *Memory;* 22% ($n = 20$) as *Awareness and attention*; and 15% ($n = 14$), the least, as *Mental state*. Most studies, a total of 63% ($n = 58$), were categorised as *Behavioural performance*. A full overview of the characteristics of each study can be found in Appendix A, Table A.1.

3.2. How route familiarity is studied

Route familiarity has been incorporated in studies in various ways. Some authors studied route familiarity in multiple ways, e.g. reporting on effects due to repeated exposure as well as comparing route-familiar and route-unfamiliar participants. One research method con-

Table 3
Effects of route familiarity on awareness and attention. Per transport modality (🚗 = car driving, 🚲 = cycling, 🚶 = walking) and per research method (transport modality icon without a circle = comparing familiar to unfamiliar participants, with a full circle = comparing against participants' own repeated measures, and with a dotted circle = combining aforementioned methods). N/D stands for no data available.

Awareness and attention		
signal and hazard detection increases • central event/ car braking, marked police car (18,34) • centreline and edgeline road markings (18) • message sign text interpretation (21) • irregular vehicle detection task (17–19) • detection task with target images of locations 1x 🚗, 2x 🚗, 2x 🚗, 1x N/D	*no effect on signal and hazard detection* • 100% obstacle avoidance, regardless of familiarity (13) 1x 🚶	*signal and hazard detection decreases* • peripheral event/ pedestrian walking into the road (34) • road signs, incl. speed limits (17–20,24) • roadside buildings (17,18) • items reported as 'interesting, unusual, or hazardous' (17–19,80) 1x 🚗, 2x 🚗, 3x 🚗
mind wandering increases • very high rates of mind wandering (17,18,23,37,45) • when the familiar route requires less of the traffic participants' attention (14,49) 2x 🚗, 2x 🚗, 2x 🚗, 1x 🚲	*no effect on mind wandering* • many thoughts while walking, incl. mind wandering, regardless of familiarity (13) 1x 🚶	*mind wandering decreases* N/D
cognitive control increases • switch to active control during specific complex or unpredictable situations (40,45) 1x 🚗, 1x 🚗	*no effect on cognitive control* • low awareness towards surroundings, regardless of familiarity (13) 1x 🚶	*cognitive control decreases* • increasing automaticity, decreasing awareness (3,17,18,21,23,36,45) • divided attention and switching between modes of control (monitoring vs. active) (14,40,45) 4x 🚗, 3x 🚗, 2x 🚗, 1x 🚲

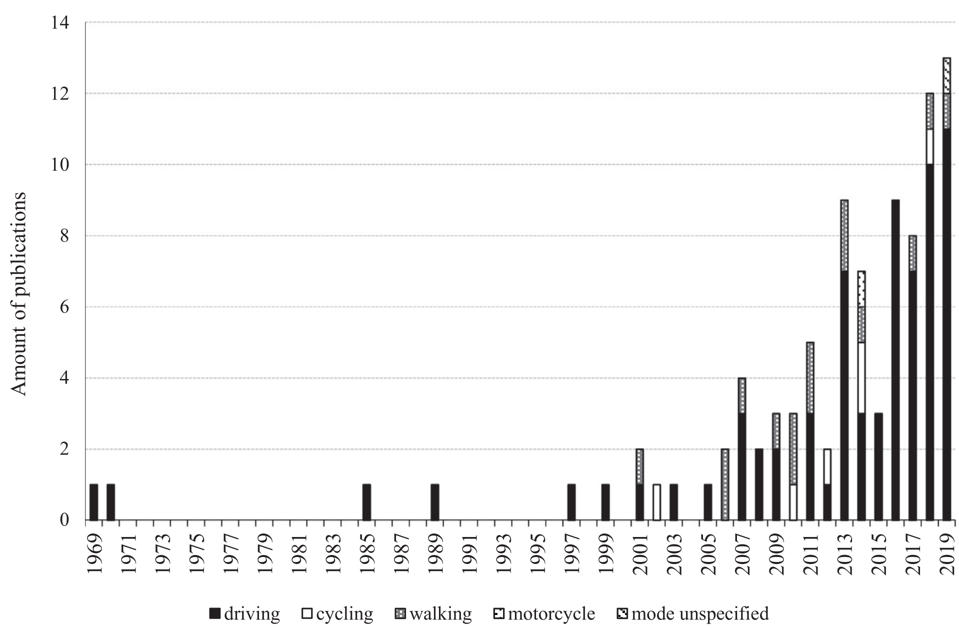

Fig. 2. The number of publications on route familiarity per year, for each mode of transport. Studies from 2020 that have been included in the current review, have been excluded from this graph as the database searching was finalised in April 2020.

sisted of merely including route familiarity as part of a research method to mimic naturalistic circumstances ($n = 27$). Furthermore, the following research designs have been distinguished: comparing a familiar route with an unfamiliar route ($n = 32$); reporting on effects due to increasing route familiarity ($n = 27$); and comparing familiar traffic participants with unfamiliar traffic participants on the same route ($n = 24$). The least used method concerned examining a familiar route that was changed ($n = 5$).

As route familiarity is subjective by nature, many of the researchers who addressed the concept of route familiarity in transport have used proxy measures to take route familiarity into account. Based on the current review, there has been a clear preference for more objectively measurable proxy measures compared to subjective self-reports of familiarity (see Table 2 for an overview). Of all studies in the current review, 73% used objectively measurable proxies. The most commonly used proxy concerns repetitive exposure to the same route ($n = 32$). Repeatedly travelling along the same route could be anything between two and (at least) fifty-two trials. Other proxies include:

- whether it concerns the commute from home to work or school ($n = 12$);
- the time participants have lived or worked in the researched area ($n = 9$);
- distance from home ($n = 8$);
- whether the research area constitutes participants' hometown ($n = 5$).

Other less-used objectively measurable proxy measures for familiarity include whether the research area constitutes participants' work area – a method used for route familiarity amongst taxi drivers – (3,4); and whether the researched area is the participants home country/ state, or not, (5–8).

The use of subjective measures is less common; they were used by only 19% of the studies in the current review. Subjective measures consisted either of subjective rating scales of route familiarity ($n = 11$); dichotomous self-reports in which participants had to indicate whether they were familiar with a route or not ($n = 7$); or subjective ratings of the number of directions participants needed to get from A to B ($n = 1$). The studies using subjective rating scales used different Likert scales, ranging from 4- to 10-point scales. One study did not mention the number of items on their scale (9). Four of the studies that used a subjective rating scale combined this with another measure for route familiarity, either distance from home (9); commute from home to school/work (10,11); or repeated exposure (12). Whereas Vlahodimitrakou et al. (9) as well as Burdett et al. (11) used their rating scale to confirm the routes from home chosen by respectively their participants or the researcher were indeed familiar, Hamed and Abdul-Hussain (10) related it to route exposure. They found that having driven a commute for a longer time is a contributing factor for higher self-reported familiarity with this route. Although exposure is a contributing factor, Ramachandran et al. (12) reported that on average, repeated exposure – in specific, inferred familiarity based on GPS recordings – showed a relatively low correlation ($r = 0.3$) with self-reported familiarity. Similarly Harms et al. (13) pointed out that the feeling of a route being familiar is likely to be skewed compared to the amount of exposure.

Six of all of the studies in this review used two measures for route familiarity instead of one. Four of them combined an objective measure with a subjective proxy and have already been mentioned above (9–12); the other two used repetitive exposure to the same route and either commuting from home to school/ work (14) or whether the research area constitutes participants' hometown (15), as separate variables. In the seven remaining studies, route familiarity has not been defined or operationalised, or it remained unclear how familiarity of drivers labelled as 'familiar' had been established.

3.3. Effects on cognition

Awareness and attention. Twenty studies addressed various aspects of awareness and attention. These studies provide *convincing evidence* that route familiarity (cf. being unfamiliar) increases mind wandering amongst drivers (11,14,17,18,37,45,49), and enables them to reduce cognitive control and to participate in traffic with little to no awareness of the immediate environment (3,17,18,21,23,36,45,49,60). Participants have also referred to the latter as 'going into autopilot' (17,18,49,60). Additionally, *good evidence* is presented that familiar drivers divide their attention and switch between modes of control – a more passive monitoring mode versus an active control mode – according to momentary demands (11,14,40,45,60).

Similar to driving, mind wandering may increase with practice when cycling (23), while practice might not affect mind wandering when walking (13). Both were rated as an *indication*. Other *indications* reveal that route familiarity might also enable cyclists to reduce cognitive control and to participate in traffic with little to no awareness to the environment (23), similar to familiar drivers; while, in contrast, awareness might not be affected by familiarity when walking (13). Furthermore, an *indication* is added that signal and hazard detection are not affected by route familiarity when walking (13). This contrasts with driving, for which *mixed results* are obtained regarding the effect of familiarity on signal and hazard detection. Dependent on the target object some studies revealed an increase in signal and hazard detection with practice, while others pointed towards a decrease (13,17–20,24,26,34,80).

Table 3 provides an overview of these results. It is apparent that most studies on awareness and attention considered driving, as seventeen studies examined drivers compared to one study on cyclists, another on pedestrians, and one study that did not specify transport mode. The findings regarding signal and hazard detection, mind wandering and cognitive control are described in more detail in Appendix B.

Memory. The twenty-two studies on memory present *convincing evidence* regarding driving that recall and recognition accuracy initially increase (20,21,24,44,75,86), until – with *fair evidence* – the mental image of what is expected becomes so strong that recall and recognition appears to be based on what usually happens or has been seen, rather than the specific instance people had just experienced (19,21,24,75,77). The latter is especially tangible in case the real-life image has changed and does not replicate the mental image anymore (19,21,24,75). For walking, *good evidence* shows that when route familiarity increases, accuracy of memory for spatial orientation increases as well (55,56,93). Regarding spatial memory for walking, there is *fair evidence* that over time, accuracy of walking distance estimates decreases (57,63).

Similar to the *fair evidence* for walking distance estimates, an *indication* is offered that accuracy of walking time estimates decreases as well (57), though for distance and time the loss of accuracy lies in opposite directions: while with practice pedestrians exaggerate the length of highly-familiar paths, they underestimate their travel time. In contrast to distance and time estimates, for spatial orientation an *indication* is added that for cycling – in line with *good evidence* for walking – memory accuracy of spatial orientation increases (31). Additionally, *indications* were obtained that with practice – in line with *convincing evidence* for driving –, recall accuracy initially increases for cycling (31), while in contrast it might not affect recall accuracy when walking (13). *Indications* are also offered that with practice, mental representations of surroundings become stronger and more robust, both for walking as well as for driving (29,74).

An overview of the results is provided in Table 4. Compared to other aspects of cognition, the prevalence of walking studies is striking, especially for spatial and temporal memory. Of all studies categorised as Memory, nine considered walking, twelve examined driving and one involved cycling. More detailed descriptions of the studies on spatial and temporal memory, mental representations, and recall and recognition can be found in Appendix B.

Judgement. The thirty studies that addressed various aspects of judgement offered *convincing evidence* that increased route familiarity provides drivers with increased opportunities for self-regulatory behaviour, both for elderly as well as young drivers (27,32,43,82,84,92). Furthermore, route familiarity results in an increase in rule-based behaviour, with *convincing evidence* for driving (4,12,17,18,50,71,74) and *fair evidence* for walking (55,56). Examples are a preference for navigating easier routes with positive attributes, when driving, and faster judgements of relative spatial positions when walking.

Under familiar conditions, *indications* are presented that with practice – similarly to the *convincing evidence* for driving – opportunities for self-regulatory behaviour increase for walking (59), and that a shift occurs in rules underlying rule-based behaviour, both for walking (56) as well as for driving (15). Specifically, a shift from focussing on negative attributes towards positive attributes takes place in drivers' route choice, and distance estimates shift from egocentric (i.e., viewer oriented) to allocentric (i.e., orientation independent) judgments. *Mixed results* are offered regarding the effect of route familiarity on perceived risk when walking (5,68), cycling (23,78), or driving (7,8,16,34,92), which might reportedly decrease or increase.

Table 5 provides an overview of the results. Studies categorised under Judgement displayed a mix of modalities, with twenty-two studies on driving, six studies on walking and two on cycling. In Appendix

Table 4
Effects of route familiarity on memory. Per transport modality (= car driving, = cycling, = walking) and per research method (transport modality icon without a circle = comparing familiar to unfamiliar participants, with a full circle = comparing against participants' own repeated measures, and with a dotted circle = combining aforementioned methods). N/D stands for no data available.

Memory		
accuracy of spatial & temporal memory increases	*no effect on accuracy of spatial & temporal memory*	*accuracy of spatial & temporal memory decreases*
• spatial representations transition from egocentric (i.e., viewer oriented) to allocentric (i.e., orientation independent) (55,56,93) • from navigational control to movement control for performance on a map-drawing task (31) 3x , 1x	N/D	• path length estimates increase over time (57,63) • travel time estimates decrease over time (57) 1x , 1x
robustness of mental representation increases	*no effect on robustness of mental representation*	*robustness of mental representation decreases*
• stronger and more robust mental representations (29,74) 1x , 1x	N/D	N/D
recall and recognition accuracy increases	*no effect on recall and recognition accuracy*	*recall and recognition accuracy decreases*
• increased accuracy for traffic sign recall and recognition (20,24) • increased amount of memory for the traffic scene just driven (44) • exposure to continuous change increases expectancy of change (21) • shift from no navigational control to movement control for increased landmark recognition (31) 1x , 3x , 1x	• no difference between route-familiar and route-unfamiliar pedestrians' ability to recall a signboard they had just avoided (13) 1x	• reduced accuracy when a priority sign changed into a yield sign (24) • reduced recall accuracy for warning signs (77) 1x , 1x

Table 5
Effects of route familiarity on judgement. Per transport modality (= car driving, = cycling, = walking) and per research method (transport modality icon without a circle = comparing familiar to unfamiliar participants, with a full circle = comparing against participants' own repeated measures, and with a dotted circle = combining aforementioned methods). N/D stands for no data available.

Judgement		
perceived risk increases • discomfort at a familiar freeway exit (92) • driving more slowly in school zones (7) • more accurate judgements to safely enter a roundabout (8) • estimating familiar locations as more dangerous (78) • higher safety margin for gap selection to cross a road (5) 3x , 1x , 1x	*no effect perceived risk* N/D	*perceived risk decreases* • when assessing the risk of an accident in actual high-risk situations (16) • maintaining a shorter headway (34) • feeling relatively competent and safe in traffic (23) • ceasing the waiting time at the pedestrian crossing (68) 1x , 1x , 1x , 1x
opportunities for self regulation increase • young drivers report unfamiliar situations as a barrier to using their smartphone (82) • confining route choice to familiar routes when suffering from cognitive decline (27,32) • avoiding unfamiliar areas with age (84,92) • become aware of, and compensate for or avoid, barriers in the environment (59) 5x , 1x	*no effect on opportunities for self regulation* N/D	*opportunities for self regulation decrease* N/D
rule-based behaviour increases • lower number of turns for which directions were required (12) • more default behaviour regarding route choice (71) • stereotyped responses regarding reports on anything unusual, hazardous or interesting (17,18) • cues for higher speeds take precedence over those for lower speeds (74) • faster judgements for allocentric and egocentric distance estimation (55,56) 3x , 1x , 1x , 2x	*no increase/decrease, but a shift in rule-based behaviour* • those familiar optimise on positive attributes of a road while those unfamiliar focus on negative attributes (15) • higher accuracy for allocentric distance estimation, lower accuracy for egocentric distance estimation (56) 1x , 1x	*rule-based behaviour decreases* N/D

B, the results for perceived risk, self-regulation and rule-based behaviour are described in more detail.

Mental state. The fourteen studies that addressed various aspects of mental state provide *convincing evidence* that for driving, task difficulty decreases when route familiarity increases (8,17,18,49).

The other results found are rated as *indications*. For driving, stress levels might be lower when familiar conditions reduce uncertainty, and everyday driving is associated with fluctuations in stress (47,49,72,76,94). With practice, confidence might increase for cycling (23) and decrease for driving (92), dependent on the immediate situation.

Table 6

Effects of route familiarity on mental state. Per transport modality (= car driving, = cycling) and per research method (transport modality icon without a circle = comparing familiar to unfamiliar participants, with a full circle = comparing against participants' own repeated measures, and with a dotted circle = combining aforementioned methods). N/D stands for no data available.

Mental state		
stress increases N/D	*no effect on stress* N/D	*stress decreases* • lower 'range stress' in battery electric vehicle drivers (76) 1x
task difficulty increases N/D	*no effect on task difficulty* N/D	*task difficulty decreases* • progressive decrease of task difficulty (17,18) • associations with boredom (49) • less demanding to judge whether it was safe to enter a roundabout in a familiar driving context (8) 2x , 2x
confidence increases • feeling relatively competent (23) 1x	*no effect on confidence* N/D	*confidence decreases* • discomfort at a familiar freeway exit (92) 1x

Additionally, two studies on emotions reveal that drivers experience negative emotions when expectations – based on familiarity – are violated (51,60). Since both studies considered highly familiar drivers only, they were not included in Table 6.

An overview is provided in Table 6. Studies categorised under Mental state were mostly car dominated, with thirteen studies on driving and only one study on cycling. More detailed descriptions of the results for stress, task difficulty, confidence and emotions can be found in Appendix B.

3.4. Effects on behavioural performance

Fifty-eight studies related route familiarity to behavioural performance measures. Some researchers used these to measure the effects of route familiarity on behavioural performance itself, while others used behavioural performance as a proxy for cognition. The fifty-eight studies provide *convincing evidence* that for drivers, time spent looking at traffic-related objects decreases with practice (24,25,28,35,42,77); average driving speed increases (18,19,21,24,26,33,38,42,52,74,87); and route-choice behaviour becomes increasingly proceduralised (4,12,15,21,22,32,50,54,85). There was also *convincing evidence* that the probability of crash risk (39,64,65,69,81) and violations (66,70,85,89) increase when driving on familiar roads. For both crash risk as well as violations, this result is obtained by tallying the results of studies of which one study found a decrease while the others reported on increases. *Fair evidence* is offered that familiar drivers spend more time looking at traffic-unrelated objects (33,35,60), decrease driving speed variability (17,18), decrease driving speed near dedicated road infrastructure for vulnerable road users – in specific a school zone and bicycling infrastructure – (7,79), and maintain shorter headways (33,34). Furthermore, in line with the *convincing evidence* for driving, there is *fair evidence* that route choice also becomes proceduralised for pedestrians with familiarity (41,59). There was also *fair evidence* that secondary task engagement increases, for both walking (13,46) and driving (33,82).

Furthermore, the studies that considered behavioural performance measures present *indications* that with practice average speed increases for cycling (30), in line with the *convincing evidence* for driving; that due to perceptual speed regulation, car drivers' speed decreases inside a tunnel (17); and that lane position variability decreases for cycling (30). Other *indications* add that route familiarity does not affect hazard avoidance when walking (13) and that gap selection improved for drivers (8). Further *indications* suggest that the likelihood of errors is higher for driving along familiar roads (64); that under specific aberrant circumstances – e.g. poor alignment, dark without road lights, bad weather such as rain or fog – car drivers' crash risk decreases when the road is familiar, cf. unfamiliar, (69); and that crash risk decreases when motorcycling is done on familiar roads (83); the latter two contrary to *good evidence* for driving which displays increased risk. Additionally, an *indication* offers that higher network familiarity, i.e., drivers' familiarity with an area, can be partly predicted by various variables, such as being familiar with at least one alternative route to one's preferred route and having driven the commute for a longer time (10). Finally, *mixed results* are obtained for lane position variability and car driving (17,18) and for the quality of gap selection of pedestrians (5,68). These studies found gap selection to improve or worsen, and lane position to increase or decrease with practice.

Table 7 provides an overview of these results. As shown in this table, most studies concern driving. Specifically, forty-eight studies regarded drivers, six considered walking, three studied cyclists and one examined motorcyclists. Appendix B describes the results for all behavioural performance measures in more detail.

3.5. Amount of repetition required for effects on cognition and behavioural performance

Results presented in Tables 3–7 show that across areas of awareness and attention, memory, judgment, mental state, and a variety of behavioural performance measures, there were similarities and differences reported by the various studies in terms of how they are affected by familiarity. The standout findings are presented here in terms of how aspects of behaviour manifest, and how long they seem to take to develop.

The amount of exposure to the traffic environments used in the studies contained in the current review differs tremendously between studies. Of the thirty-two studies that used repetitive exposure to the same route as a proxy for route familiarity, twenty studies included the exact amount of repetition, which varied from measurements taken after two and (at least) fifty-two trials.

Across trials, studies either used continuous measurements or they measured cognitive and, or, behavioural aspects in an initial trial and again only after a familiarisation period of several trials. The latter type of studies are referred to as single repeated measurements studies. Fourteen studies performed continuous measurements after each trial (15,17–19,21,24–26,28,30,35,38,39,44), though six of these studies did not report on all interim results for all cognitive or behavioural aspects (19,21,25,26,30,35). Eleven studies (of which some also performed continuous measurements on other aspects) involved single repeated measurements studies (16–21,23,24,33,34,36).

Both types of studies showed that some effects on cognition and, or, behaviour manifested after only few trials, while others required more trials before an effect was shown. For driving, Charlton and Starkey had already noted that the process of driving becoming proceduralised depends on the aspect of the driving task that is considered (17). The

Table 7
Effects of route familiarity on various behavioural performance measures. Per transport modality (🚗 = car driving, 🚲 = cycling, 🚶 = walking, 🏍 = motorcycling) and per research method (transport modality icon without a circle = comparing familiar to unfamiliar participants, with a full circle = comparing against participants' own repeated measures, and with a dotted circle = combining aforementioned methods). N/D stands for no data available.

Behavioural performance		
time spent looking at objects increases • increase of looking at something within or outside the vehicle (33) • increase of time spent looking off the road, unrelated to hazards (35)	*no effect on time spent looking at objects* N/D	*time spent looking at objects decreases* • decrease in looking at traffic signs, information signs and road markings (24,25) • decrease in looking at warning signs (77) • fewer fixations at traffic-related information near and in tunnels (42) • decrease in looking at the road (35) • confining sampling in front of the car to a smaller area (28)
1x 🚗, 1x 🚗		2x 🚗, 3x 🚗, 1x 🚗
increases in measures for speed, lane position, headway, hazard avoidance and gap selection • increase of average speeds (18,19,21, 24,26,30,33,38, 42,52,74,87)	*no effect on measures for speed, lane position, headway, hazard avoidance and gap selection* N/D	*decreases in measures for speed, lane position, headway, hazard avoidance and gap selection* • decrease of speed variability (17,18) • decrease of speeds in tunnel (17) • decrease of speeds near road infrastructure for vulnerable road users (7,79),
• increase of lane position variability (18,30)	N/D	• decrease of lane position variability (17)
N/D	N/D	• shorter headways (33,34)
N/D	• no effect on moment in time to move to avoid the obstacle (13)	N/D
• in unfamiliar conditions gap selection was more unsafe or overtly cautious (5) • improved judgements to safely enter a roundabout (8)	N/D	• shorter waiting times when selecting a gap to cross a road (68)
7x 🚗, 2x 🚗, 3x 🚗, 1x 🚲, 1x 🚶	1x 🚶	4x 🚗, 1x 🚗, 1x 🚗, 1x 🚶
proceduralised route-choice behaviour increases • stick to preferred, easy routes (12,15,32,85) • decreased use of directional signposting and navigational aids (22,54,59) • increased path efficiency and sooner en-route navigational decision making (41) • compliance route instruction without recall (21)	*no effect on proceduralised route-choice behaviour* N/D	*proceduralised route-choice behaviour decreases* N/D
5x 🚗, 2x 🚗, 1x 🚶, 1x 🚶		
likelihood of crashes, violations and errors increases • increase of crash risk (39,64,65,69,81)	*no effect on likelihood of crashes, violations and errors* N/D	*likelihood of crashes, violations and errors decreases* • unfamiliarity contributes to motorcycle crashes (83) • decrease of crash risk under aberrant driving conditions (69) • higher fatality rate for out-of-state drivers (6)
• increase of violations (66,70,85,89)	N/D	N/D
• increase of errors (64)	N/D	N/D
8x 🚗, 1x 🚗		2x 🚗, 1x 🏍
secondary task engagement increases • increase in (smart)phone usage and music listening (33,46,82) • increase in talking and singing (13,33)	*no effect on secondary task engagement* N/D	*secondary task engagement decreases* N/D
1x 🚗, 1x 🚗, 1x 🚶, 1x 🚶		

timeline of Fig. 3 provides an overview of the amount of exposure required, if available, for each effect in the current review to manifest. For this, effects are considered for which *fair* to *convincing evidence* has been provided. *Indications* and *mixed results* are excluded.

3.5.1. After two to five trials

Visual scanning and eye fixations. With practice, time spent looking at traffic-related objects decreased while driving and two continuous measurements studies reported the first effects of this to occur immediately after two to three trials (24,28). Considerable changes in visual sampling strategies were noted after driving the same road three times (28): during the first drive, drivers sampled a wide area in front of them, while during the third drive sampling was confined to a much smaller area. When using more than three trials, it was noted that the largest decrease of glance duration for traffic signs occurred during the first five drives. During the remaining twenty drives glance duration continued to decrease, though reaching asymptote from drive five (24). These studies consisted of either on-road expressway driving or simulated rural and urban desktop driving.

Three other studies were single repeated measurements studies (25,33,35). The first one showed that after twelve trials fixation times and fixation frequency for traffic signs, information signs or road markings decreased, for both on-road and video driving along rural and urban roads (25). After twenty-six trials the time spent looking at the road decreased, and time spent looking off the road, in places unrelated to any observable hazards, had increased, when driving along real-road carriageways, rural roads and suburban roads (35). After fifty-two or more trials participants driving along real-world urban roads were more likely to fixate for longer periods on something within the vehicle compared to in unfamiliar situations (33).

Speed. The increase in driving speed was reported by three continuous measurements studies to occur immediately after the first trial (19,24,38). These studies found the increase to plateau after three to four drives out of six up to twenty-five trials (24,38), or reach asymp-

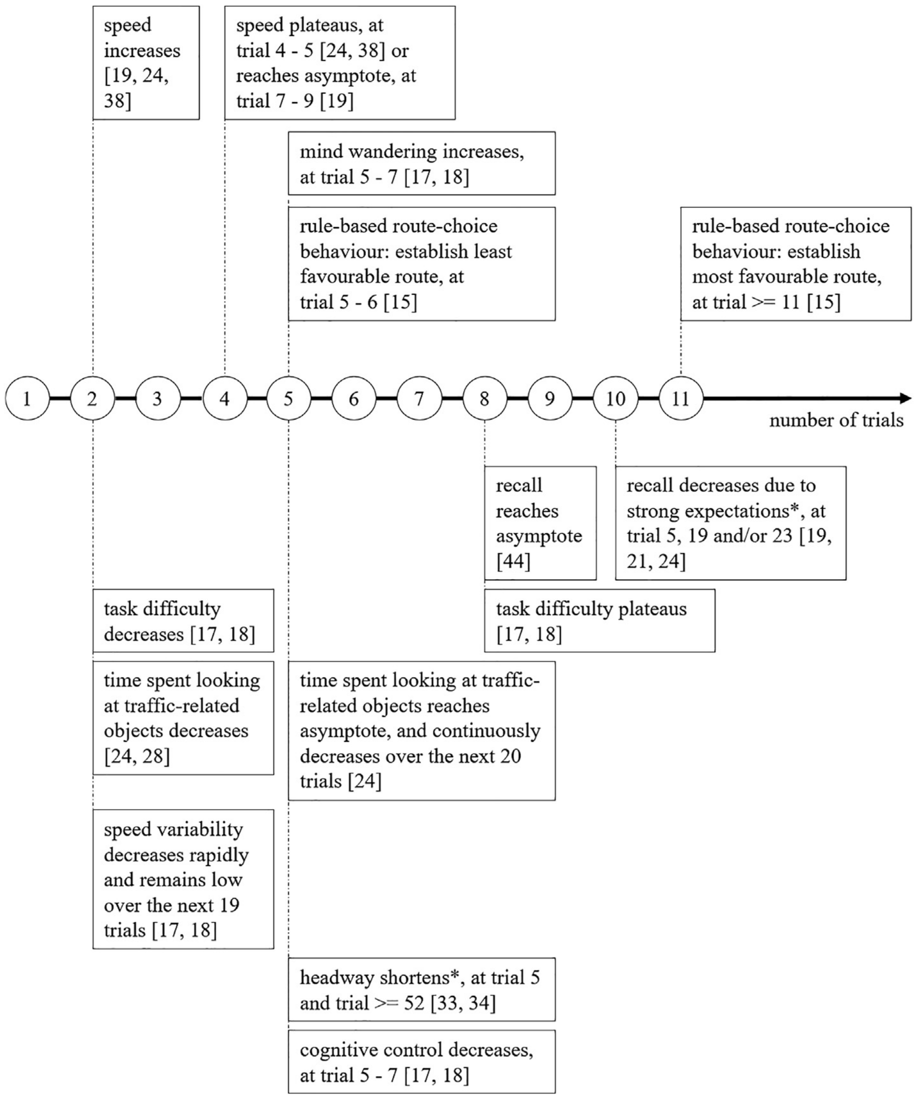

Fig. 3. Timeline displaying the number of trials required for the effect on each cognitive or behavioural aspect to manifest. All studies concern driving. Single repeated measurements studies are marked with an *, to distinguish them from continuous measurements studies.

tote after approximately six to eight drives out of twenty trials (19). These studies consisted of either two-lane two-way rural on-road driving, simulated rural and urban desktop driving, or simulated motorway driving. In contrast, in one other continuous measurements study the increase in driving speed started after five trials. However, it remains unknown what happened to driving speed from drive one to drive two, as drive one concerned the practice drive on the same track and data for it was not included in the paper. Across the trials, driving speed slowly increased though this study found no clear plateau or asymptote reached during the total of ten drives (21). The latter study concerned simulated motorway driving.

Three single repeated measurements studies all confirmed the increase of driving speed over six, eighteen, or over fifty-two trials (18,26,33). These studies concerned simulated driving along rural roads, separate lanes and dual carriageways, and on-road driving along urban roads.

Speed variability. Whereas driving speed increases (almost) immediately within the first few trials, driving speed variability reduces. In a continuous measurements study it was shown that after the first trial, speed variability decreased rapidly and remained low during the remaining nineteen trials, except for the trials in which participants drove along a visually unfamiliar road (only the road geometry remained the same) or were conversing on the phone while driving (17). This finding was confirmed in another study that only reported on measurements taken from trials one, six, eleven and sixteen (18). Both studies concerned simulated driving on a rural road.

Headway. Drivers maintained shorter headways after five and at least fifty-two trials, both in comparison to first time driving, as shown by two single repeated measurements studies (33,34). These studies consisted of simulated rural freeway driving and on-road urban driving, respectively. Given the absence of continuous measurements studies it is unknown whether headway is affected any earlier.

Task difficulty. Ratings of task difficulty while driving decrease immediately after the first trial and continue to decrease until they plateaued after seven trials, as shown by two studies using continuous measurements up to twenty trials (17,18). Both studies concerned driving a simulated rural road.

3.5.2. After five to seven trials

Rule-based route-choice behaviour. Timewise, two distinct turning points were observed in rule-based route-choice behaviour (15). After four to five trials, drivers established their least favourable route based on traffic conditions. Approximately eleven trials or more, marked the point at which they established their most favourable route. This continuous measurements study examined choice distribution for a simulated urban road.

Mind wandering. An increase in mind wandering was reported at trials five to seven, when participants first volunteered they were mind wandering while driving along a simulated rural road (17,18). Participants reported they were 'mostly thinking about food', 'were daydreaming', or were 'driving without thinking about it'. Both studies concerned continuous measurements and consisted of up to twenty trials.

Cognitive control. Contrary to the increase in mind wandering, a decrease in cognitive control was reported at trials five to seven, as part of the same two continuous measurements studies (17,18). While driving, participants volunteered they were on autopilot, which included reports of participants saying that they were 'zoning out' or 'going on autopilot'.

Two single repeated measurements studies confirmed abovementioned reduction of cognitive control for driving. In the first, researchers measured only after seven to twelve trials of video driving on an unknown type of road, and found that brain regions associated with attention and perception were less active compared to the initial trial, suggesting reduced attention with increasing familiarity (36). The other study performed measurements during the ninth trial, on a simulated motorway, and showed that drivers had automated the reading of an overhead variable message sign (displaying various texts in previous trials) to the extent that it required very little to no conscious attention (21).

3.5.3. After seven or more trials

Expectations and recall. The amount recalled for a traffic scene just driven increased from the first drive and reached asymptote after 7.6 trials on average. Both the steepness of memory growth as well as the number of trials required before reaching asymptote varied between participants, with the latter ranging from 5 to 11 trials (44). The other studies on expectations and recall during driving were all measured using a single repeated measurements design, for which the second measurement was performed at ten trials up to twenty-four trials. Regardless of measuring expectations and recall at ten, nineteen, or twenty-three trials, all found that strong expectations resulted in recall reports of seeing what one expected to see and participants failing to become aware of changes (19,21,24). Furthermore, when measuring during the fifteenth trial, recall of a speed limit was better when the speed limit sign had explicitly been displayed in all previous trials compared to it being implicit (20). From measurements taken as part of the twenty-fourth trial, it was noted that exposure or familiarity increases the expectations that subjects have about the content of traffic signs at certain locations (24).

All studies used simulated roads, which consisted of a combination of a rural and an urban road in a desktop simulator (24); a motorway in a driving simulator (19,21); or a motorway in videos (20); or an urban road (44).

4. Conclusion and discussion

This systematic review on the effects of route familiarity on cognition and behaviour in transport has shown that the saying 'practice makes perfect' is misleading. It provides an incorrect summary of the effects of practice, because evidence suggests that the effects of familiarity are much more complicated. Some effects are beneficial, and with practice performance improves, while for other aspects performance worsens with practice.

4.1. How familiarity affects human beings and how this is acknowledged by researchers

Positive effects of familiarity on cognitive aspects of behaviour included increased accuracy of spatial orientation when walking, a general decrease in drivers' task difficulty, an increase in drivers' and pedestrians' rule-based behaviour or a shift in the underlying rules (i.e., an improved consistency of performance), and increased opportunities for self-regulatory behaviour. Furthermore, drivers' recall accuracy for an area increased as long as the surroundings did not change.

In contrast, one of the negative effects of familiarity on cognition was that drivers' mental representations might become so robust that they interfered with perception and recall accuracy, resulting in people seeing and recalling what they had expected to see instead of what could actually be seen. Other negative effects included pedestrians' decreased accuracy for estimates of travel time and distance, and drivers' general tendency to decrease cognitive control – slipping into autopilot – and to increase mind wandering. Results for other aspects remained indicative or inconclusive, such was the case for signal and hazard detection, for which performance increase or decrease appeared to be dependent on the target object.

The cognitive changes associated with familiarity were reflected in transport behaviour, which in turn interacts with cognition. The increase in rule-based judgements was displayed in both pedestrians' as well as drivers' increase in proceduralised route choice, such as familiar drivers' preference for 'easier' routes, minimising complex manoeuvres. These routes might be quicker to proceduralise and might be more predictable. Repeatedly taking these routes would explain why drivers' task difficulty as well as cognitive control reduces. Familiar drivers typically were found to divide their attention between tasks and switch between active control of traffic and passively monitoring it. This context-bound behaviour is reflected for example in familiar drivers' speed choice. Driving speed typically increases compared to unfamiliar drivers, unless driving near specific road infrastructures for vulnerable road users, such as a school zone. In such cases the opposite was found with familiar drivers driving more slowly compared to those unfamiliar. For passive monitoring, familiar drivers can use their increasingly accurate mental representations of the area – as confirmed in recall studies – thus diminishing the need for strenuous processing of the environment. This would explain why with practice, drivers decrease time spent looking at traffic-related objects. Instead, they engage in other activities. In fact, the moment that decreasing task difficulty reaches a plateau is closely related to the moment that reports of mind wandering and being on autopilot manifested. Presumably to pass time, familiar drivers increase the time spent looking at objects not related to traffic and, or, increase engagement in secondary tasks (similar to pedestrians).

Task difficulty also appears to be linked to other driver behaviours. The immediate decrease in task difficulty when repeatedly driving the same route coincides with the immediate increase in driving speed and decrease in driving speed variability. It is also known that headway shortens over the first five trials, though it is currently unknown exactly when this occurs. These changes in speed and headway may suggest that drivers try to compensate for the reduction of task difficulty, induced by practice. Together, these behaviours to remain occupied – either by increasing task difficulty or engaging in other tasks – might explain familiar drivers' increased crash risk and number of violations.

In conclusion, this systematic review has shown that route familiarity affects both cognition as well as behaviour, in particular driver behaviour. Similar to Charlton and Starkey (2018a), this review supports that familiarity-based driver behaviour is generally predictable and 'can be carried out safely with only brief periods of active, focussed attention'. Whether the effects are the same for all transport modalities considered in this review remains unclear. For some aspects of cognition *indications* were found that pointed in the same direction, such as for the reduction of cognitive control in drivers, of which an *indication* was found for cyclists as well. For other aspects results pointed in opposing directions, e.g. for awareness, which reduced for drivers whereas for pedestrians an *indication* was found that it was not affected by familiarity at all, as it was low already. More studies, especially on walking and cycling, are needed to confirm or contradict how familiarity affects cognition for the various transport modalities.

Nevertheless, the current systematic review also pointed out that currently in transportation research, the fact that familiarity affects human cognition and behaviour is not sufficiently acknowledged. Despite increased awareness amongst transportation researchers since 2007, taking into account familiarity is still rather uncommon in research designs.

4.2. Defining route familiarity with respect to cognition and exposure

A complicating factor for taking into account familiarity concerns the question of when its effects manifest. Although the daily commute is a classic familiar route, effects of familiarity on cognition and behaviour are exhibited in a much earlier stage. Intini et al. (2019) proposed to identify drivers as familiar after at least four drives. Based on the current review we argue that, depending on the aspect of behaviour or cognition one is studying, four trials might not suffice. We agree with Intini et al. (2019) that route familiarity is not a strictly binary variable. Moreover, we conclude that route familiarity is a gradual process of becoming increasingly acquainted with a route or area and which increase continues to affect different aspects of cognition at subsequent thresholds of exposure. The way familiarity affects cognition and behaviour in transport is very much akin to Fitts and Posner's (1967) model for skill development. They noted that skill development commences with rapid improvements in performance, followed by a more gradual phase in which performance gains accrue much more slowly. The present review shows that with practice various cognitive or behavioural aspects displayed a similar curve, e.g. driving speed and self-rated task difficulty. However, its results also reveal a large variety concerning the instance different aspects of cognition and behaviour are affected and continue to be affected before reaching asymptote or a plateau. For example, it was found that driving speed may plateau after four to five trips along the same road, while self-rated task difficulty requires eight repeated trips to plateau. Hence there appears to be no clear cut-off point for general levels of familiarity.

Next to the amount of repetition, the time elapsed between a single previous event and the instant in which an experience takes place may also be a factor in establishing familiarity. Repetitive exposure with short interval times may result in the experience being more firmly stored in the subject's memory compared to a very long interval between repetitions. Unfortunately the current research on route familiarity does not provide enough studies that describe time intervals for conclusions to be drawn in this review. The section on the limitations of this review addresses this in further detail.

The studies eligible for the current review displayed a clear preference for defining route familiarity by objectively measurable proxy measures compared to subjective self-reports of familiarity (used by 73% compared to 19%, respectively). However, there are indications that subjective self-reports of familiarity and proxy measures of familiarity are not interchangeable measures for familiarity. Although exposure is indeed a contributing factor to feelings of familiarity, it was found that repeated exposure is only moderately correlated to self-reported familiarity (Ramachandran et al., 2013) and that the feeling of a route being familiar is likely to be skewed compared to the amount of exposure (Harms et al., 2019). A possible explanation for this may be provided by predictability. In this review it was shown that route familiarity induced robustness of mental representations and expectations, which included components of the physical surroundings as well as what was likely to happen there. Predictability ties the occurrence of specific events to particular features of the built and natural environments. This characteristic is for example applied within the concept of 'self-explaining roads', which builds on the notion that drivers form expectations based on repeated exposure to a specific kind of road and environment. By using the same road features to categorise similar roads, it is possible to tap into these well-learned expectations (Theeuwes and Godthelp, 1995). Therefore, a route could feel familiar 'at first sight'. This is important because drivers report driving without awareness – strongly connected to route familiarity (Charlton and Starkey, 2011) – some of the time even on unfamiliar roads (Burdett et al., 2016). In that case it is arguable that the 'look and feel' of the road can be familiar even if the actual route has never been encountered before. In conclusion, what is considered as being familiar is therefore highly subjective. Although there are challenges studying the effects of a concept as difficult to define as familiarity on road user behaviour, results suggest that the variety of methods used to tackle this issue are valid and important.

Beyond relative familiarity, and extremes (very familiar versus not at all familiar), there appears to be little use in defining grades of familiarity. Instead, we want to emphasise 'a general context familiarity' as the normal baseline for everyday behaviour in transport.

4.3. Limitations of this review

To obtain a first insight in the effect of route familiarity on cognition and behaviour, various types of research methods were included in the current review. As a result, actual on-road driving has been given equal weight as for example driving simulator studies or video-based studies. When more studies take route familiarity into account and the amount of research on this topic is more substantial, in the future it may be possible to discern between various methods, filtering out methodological effects. This might also shed light on the amount of exposure required for various effects to exhibit, as current reported variations might also be partially contributed to the methods used (e.g. on-road, simulator, video).

Furthermore it is important to observe that behaviour is not only conditioned by the amount of exposure to the same environment, but perhaps also by the time elapsed between events of exposure. Unfortunately the time elapsed between events of exposure varied so widely across the eight studies that used a repeated measures paradigm and reported on results after each trial, that none were alike. There were variations of testing participants at fixed time intervals between trials, to a focus on the total time period in which all trials needed to be executed regardless of time elapsed between trials, to not mentioning the exact interval time between trials at all. Due to this large variety it was not possible to extract time elapsed between trials as a separate factor in the analysis on the effects of route familiarity.

Another limitation of the current review concerns the possible bias that studies which did not find a meaningful difference between familiar and unfamiliar participants might not have been published, and consequently are not part of this review. Given that in the current review very few studies reported no effect of familiarity, this may well have occurred.

4.4. How to proceed within transport psychology

Familiarity appears to have large effects on how people attend to and process the environment. Given the proportion of time people spend travelling in familiar situations, this low attention, high familiarity state should be considered the default mode and as a more integral context for experimental, naturalistic and observational research in transport psychology. To take familiarity into account, various methods can and have been used, as shown in the current review. The method of choice – opting for a subjective measure or an objectively-measured proxy for familiarity – will in part be defined by the research materials. A naturalistic study provides ample opportunities for subjective measures, whereas a non-routine context such as a simulator may prove to be more challenging. The latter can be solved by controlling the amount of practice, such that the amount of repetition required to take familiarity into account depends largely on the cognitive aspects one wishes to study. Including the effects of exposure enables the research focus to shift from traffic participation as a single, stand-alone task to regarding traffic participation as an integral part of people's daily life. Taking familiarity into account as a baseline context for research designs, would improve the ecological validity of studies on transport behaviour.

We also recommend that research into cognition while driving, cycling, and walking is critiqued in light of the findings of this review. In particular, one-off simulator studies of driver behaviour (for example) are useful to compare drivers' choices in different situations, such as with different kinds of road markings or signage. They are less useful as means to explore drivers' thoughts (e.g. the proportion of time spent mind wandering) or performance issues such as headway or reaction times, because those variables are affected by context familiarity. Repeated exposure to the simulated context can overcome these difficulties somewhat.

Road safety practitioners, engineers and policy makers can benefit from knowledge on the effects of route familiarity by designing the road transport system to better support how people actually drive, cycle and walk. The links between road user behaviour and road safety are a step beyond the scope of this review, so more research is warranted to provide specific advice for road safety engineers tasked with designing safe and forgiving environments. Benefitting from route-familiar behaviour relies strongly on tapping into predictable, automatised behaviours by meeting expectations, and preparing road users for occasions in which expectations cannot be met. By collecting more data on everyday driving, cycling and walking we should not only further improve the physical environment, we could also promote safety in the design of connected, automated and autonomous vehicle technologies.

Acknowledgements

An earlier version of this review (till 2018) appeared as a chapter in the PhD thesis of Ilse Harms (to be defended in 2021). Therefore the authors wish to express their gratitude to Dick de Waard and Karel Brookhuis from the University of Groningen for supervising this PhD study. The authors also wish to thank the internet for enabling this online search and providing multiple means for long-range communication. Last but certainly not least we thank Vanessa Beanland and the anonymous reviewers for their helpful feedback to further improve this paper.

Funding and declaration of interest

Declarations of interest: none.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Instead it has been performed as part of the part-time PhD study of Harms.

Appendix A. Overview of study characteristics

See Table A1 for an overview of the study characteristics of all 94 studies considered in this systematic review, in accordance with the PRISMA method.

Appendix B. Study descriptions for each subcategory, per main category

Awareness and attention

Ten studies regarded *signal and hazard detection*. The six studies which found that specific aspects of signal and hazard detection improved with practice either concerned driving (17–19,21,34) or transport mode had not been specified (80). For driving it was reported that under familiar conditions (cf. unfamiliar conditions), changes in centreline and edgeline road markings were more readily detected and that detection of salient events such as the addition of a marked police car or a severely braking pace car was also better (18,34). Familiarity with texts on a variable message sign aided drivers' ability to interpret a critical route instruction, compared to drivers unfamiliar with the sign displaying texts (21). Finally, repeated

Table A1

Overview of the study characteristics of all 94 studies considered in this systematic review, in accordance with the PRISMA method. In brackets the numerical references, together with the reviewed papers they refer to, as used in the Results chapter and in Appendix B. Aw. = Awareness and attention; Mem. = Memory; Jud. = Judgement; Ment. = Mental state; Beh. = Behavioural performance. Some studies consisted of multiple experiments. These have been labelled sequentially as exp1, exp2, etc. Research methods were labelled as U = comparing familiar to unfamiliar participants, R = comparing against participants' own repeated measures, and F = using familiar participants only. Some studies used multiple methods, dependent on the aspects of cognition and behaviour measured. N/A stands for not applicable and concerns both the literature review and the editorial foreword.

Numerical reference, author and year	Number of participants	Research method			Mode of transport	Aw.	Mem.	Jud.	Ment.	Beh.
[1] Charlton and Starkey, 2018a	N/A	N/A	N/A	N/A	driving	N/A	N/A	N/A	N/A	N/A
[2] Intini et al., 2019	N/A	N/A	N/A	N/A	driving	N/A	N/A	N/A	N/A	N/A
[3] Grabner et al., 2003	31	U	–	–	driving	x	–	–	–	–
[4] Yao et al., 2013	211 (trips)	–	–	F	driving	–	–	x	–	x
[5] Johnston and Peace, 2007	12	U	–	–	walking	–	–	x	–	x
[6] Sivak and Schoettle, 2011	49,304 (fatal crashes)	U	–	–	driving	–	–	–	–	x
[7] Valdés et al., 2020	72	U	–	–	driving	–	–	x	–	x
[8] Thompson and Sabik, 2018	28	U	–	–	driving	–	–	x	x	–
[9] Vlahodimitrakou et al., 2013	33	–	–	F	driving	–	–	–	–	x
[10] Hamed and Abdul-Hussain, 2001	498	U	–	F	driving	–	–	–	–	x
[11] Burdett et al., 2019	25	–	–	F	driving	x	–	–	–	–
[12] Ramachandran et al., 2013	22	U	–	–	driving	–	–	x	–	x
[13] Harms et al., 2019	234	U	–	–	walking	x	x	–	–	x
[14] Berthié et al., 2015	128	U	–	–	driving	x	–	–	–	–
[15] Lotan, 1997	25	U	R	–	driving	–	–	x	–	x
[16] Bragg and Finn, 1985	50	–	R	–	driving	–	–	x	–	–
[17] Charlton and Starkey, 2011	20	U	R	–	driving	x	–	x	x	x
[18] Charlton and Starkey, 2013	54	–	R	–	driving	x	–	x	x	x
[19] Harms and Brookhuis, 2016	24	–	R	–	driving	x	x	–	–	x
[20] Harms and Brookhuis, 2017	255	U	R	–	driving	x	x	–	–	–
[21] Harms et al., 2019	32	U	R	–	driving	x	x	–	–	x
[22] Knapper et al., 2016	21	U	–	–	driving	–	–	–	–	x

(*continued on next page*)

Table A1 (*continued*)

Numerical reference, author and year	Number of participants	Research method			Mode of transport	Aw.	Mem.	Jud.	Ment.	Beh.
[23] Larsen, 2014	1	U	R	F	cycling	x	–	x	x	x
[24] Martens and Fox, 2007a	36	U	R	–	driving	x	x	–	–	x
[25] Martens and Fox, 2007b	28	–	R	–	driving	–	–	–	–	x
[26] Martens, 2018	78	U	R	–	driving	x	–	–	–	x
[27] Mauri et al., 2014	198	U	–	F	driving	–	–	x	–	–
[28] Mourant and Rockwell, 1970	8	–	R	–	driving	–	–	–	–	x
[29] Neidhardt and Popp, 2010	140	U	–	–	walking	–	x	–	–	–
[30] Vansteenkiste et al., 2014	25	–	R	–	cycling	–	–	–	–	x
[31] von Stülpnagel and Steffens, 2012	62 (exp1); 65 (exp2)	U	–	–	cycling	–	x	–	–	–
[32] Wallace et al., 2013	2	U	–	–	driving	–	–	x	–	x
[33] Wu and Xu, 2018	155	U	–	–	driving	–	–	–	–	x
[34] Yanko and Spalek, 2013	20 (exp1); 26 (exp2); 20 (exp3)	U	–	–	driving	x	–	x	x	x
[35] Young et al., 2018	1	–	R	–	driving	–	–	–	–	x
[36] Mader et al., 2009	16	–	R	–	driving	x	–	–	–	–
[37] Burdett et al., 2016	502	U	R	–	driving	x	–	–	–	–
[38] Colonna et al., 2016	19	U	–	–	driving	–	–	–	–	x
[39] Intini et al., 2017	19	U	R	–	driving	–	–	–	–	x
[40] Markkula, 2014	nil	U	–	–	driving	x	–	–	–	–
[41] Brunyé et al., 2018	50 (exp1); 32 (exp2)	–	R	–	walking	–	–	–	–	x
[42] Hu et al., 2019	32	U	–	–	driving	–	–	–	–	x
[43] Roe et al., 2019	20	–	–	F	driving	–	–	x	–	x
[44] Li et al., 2018	20	–	R	–	driving	–	x	–	–	–
[45] Burdett et al., 2018	11	–	R	F	driving	x	x	–	–	–
[46] Liikkanen and Lahdensuo, 2010	27,241 (exp1); 11,509 (exp2)	–	R	–	walking; cycling	–	–	–	–	x
[47] Riener et al., 2009	1	–	–	F	driving	–	–	–	x	–
[48] Rõivas et al., 2011	85	–	–	F	walking	–	–	x	–	–
[49] Steinberger et al., 2016	24	U	–	F	driving	x	–	–	x	–
[50] Venigalla et al., 2017	44	–	–	F	driving	–	–	x	–	x
[51] Wurhofer et al., 2015	9	–	–	F	driving	–	–	–	x	–
[52] Richard et al., 2014	164	U	–	F	driving	–	–	–	–	x
[53] Gaspar and Carney, 2019	10	–	–	F	driving	–	–	–	–	x
[54] Samson and Sumi, 2019	17	U	–	–	driving	–	–	–	–	x
[55] Iachini et al., 2009	34	U	–	–	walking	–	x	x	–	–
[56] Iachini et al., 2011	40	U	–	–	walking	–	x	x	–	–
[57] Jafarpour and Spiers, 2017	20	U	–	–	walking	–	x	–	–	–
[58] Meilinger et al., 2014	23	–	–	F	walking	–	x	–	–	–
[59] Phillips et al., 2013	44	U	–	–	walking	–	–	x	–	x
[60] Spiers and Maguire, 2008	20	–	–	F	driving	x	x	–	x	x
[61] Meilinger et al., 2013	23	–	–	F	walking	–	x	–	–	–
[62] Peruch et al., 1989	48	–	–	F	driving	–	–	x	–	x
[63] Crompton, 2006	140	–	R	–	walking	–	x	–	–	–
[64] Burdett et al., 2018	3,901 (crashes); 4,143 (trips)	U	–	–	driving	–	–	–	–	x
[65] Burdett et al., 2017	9,315 (31,102 trips)	U	–	–	driving	–	–	–	–	x
[66] Chevalier et al., 2016	344	U	–	F	driving	–	–	–	–	x
[67] Intini et al., 2018	633 (crashes)	U	–	–	driving	–	–	–	–	x
[68] Hamed, 2001	350	U	–	F	walking	–	–	x	–	x
[69] Wen and Xue, 2020	4098 (crashes)	U	–	–	driving	–	–	–	–	x
[70] Rosenbloom et al., 2007	38	U	–	–	driving	–	–	x	x	x
[71] Lotan and Koutsopoulos, 1999	25	U	–	–	driving	–	–	x	–	–
[72] Charlton and Starkey, 2017a	64	–	–	F	driving	–	x	x	x	x
[73] Charlton and Starkey, 2016	75 (exp1); 42 (exp2)	–	–	F	driving	–	–	x	–	–
[74] Charlton and Starkey, 2017b	55 (exp1); 13 (exp2)	U	–	F	driving	–	x	x	–	x
[75] Charlton and Starkey, 2018b	75	–	–	F	driving	–	x	–	–	–
[76] Franke et al., 2016	74	–	R	–	driving	–	–	–	x	–
[77] Inman et al., 2013	26	U	–	–	driving	–	x	–	–	x
[78] von Stülpnagel and Krukar, 2018	15 (exp1); 28 (exp2	U	–	–	cycling	–	–	x	–	–
[79] Fournier et al., 2020	48	U	–	–	driving	–	–	–	–	x
[80] Guilbert et al., 2019	64 (exp1); 49 (exp2)	U	–	–	not specified	x	–	–	–	–
[81] Chen et al., 2005	3,939	U	–	F	driving	–	–	–	–	x
[82] Gauld et al., 2016	26	U	–	F	driving	–	–	x	–	x
[83] Shaker et al., 2014	246	U	–	–	motorcycle	–	–	–	–	x
[84] Molnar and Eby, 2008	68	U	–	–	driving	–	–	x	–	–
[85] Payyanadan et al., 2019	29	U	–	–	driving	–	–	–	–	x
[86] Dua and Charlton, 2019	25	–	–	F	driving	–	x	–	–	–
[87] Shen and Wang, 2019	402	U	–	–	driving	–	–	–	–	x
[88] Caird, 2015	nil	–	–	F	driving	–	–	–	–	x
[89] Horvath et al., 2012	398	U	–	–	driving	–	–	–	–	x
[90] Andersson and Bunketorp, 2002	207	–	R	–	cycling	–	–	–	–	x
[91] Valdés et al., 2017	36	U	–	–	driving	–	–	–	–	x
[92] Vardaki and Karlaftis, 2011	40	U	–	–	driving	–	–	x	x	–
[93] Ruggiero and Iachini, 2006	not specified	U	–	–	walking	–	x	–	–	–
[94] Taggart et al., 1969	32	–	–	F	driving	–	–	–	x	–

exposure to the same route resulted in drivers becoming proficient in a vehicle detection task in which they had to detect irregularly appearing target vehicles in the oncoming traffic stream (17–19). Without specifying the transport mode, it was found that in a detection task targets were visually processed sooner if the target concerned an image of a familiar location compared to it being a location unfamiliar to the participants (80).

In contrast, six studies – four of the aforementioned studies, together with two other driving studies that compared familiar with unfamiliar conditions – pointed out aspects for which signal and hazard detection decreased with increased familiarity. It was noted that response time was slower to detect a pedestrian walking into the street or to detect a speed limit decrease and that the likelihood to report the removal of, or changes to, road signage – including speed limits – and roadside buildings in the roadside environment decreased as well (17,19,20,24,34). Moreover, the more experience drivers gained with a route, the lower the likelihood they detected new, unusual warning signs (18). Additionally, with practice, the number of items drivers reported as 'interesting, unusual, or hazardous' steadily declined, although the decline was remarkably slower for comments regarding other road users compared to other items (17–19).

One study found no effect on signal and hazard detection. This concerned a walking study which compared familiar to unfamiliar conditions. With sufficient power it found no difference in pedestrians' ability to detect and avoid an obstacle placed on the pavement (13). Two studies are not considered for this part of the review as their sample sizes were considered too low to draw conclusions; in both studies no significant difference on signal detection was found between route-familiar and route-unfamiliar drivers (26,34). Together, the nine studies offer *mixed results* on signal and hazard detection for driving, dependent on the target object (13,17–20,24,26,34,80), and an *indication* that signal and hazard detection is not affected when walking (13).

Nine studies regarded *mind wandering* and all but one compared familiar to unfamiliar conditions. Seven of these studies found that both drivers (6 studies) as well as cyclists (1 study) experienced very high rates of mind wandering on familiar roads (17,18,23,37,45); particularly when the familiar route required less of the traffic participants' attention (14,49). These findings were supported by the one study that concerned drivers in familiar surroundings only (11). In contrast, one study found that – with sufficient power – mind wandering did not differ between route-familiar and route-unfamiliar pedestrians, indicating that walking might deviate from the other modalities (13). This was explained by proposing that walking is in fact such skilled behaviour that there is already enough free attentional capacity to allow for mind wandering, even along unfamiliar routes. Together, these studies provide *convincing evidence* that with practice mind wandering increases when driving (11,14,17,18,37, 45,49), and an *indication* this is also true for cycling (23) but not for walking (13).

Fourteen studies included *cognitive control*. Twelve studies found that cognitive control decreased, of which five (also) reported on situational dependency (11,14,40,45,60). Ten of the twelve studies addressed cognitive control in general and concerned two driving studies considering familiar conditions only (11,60) and eight studies that compared familiar with unfamiliar conditions, of which one concerned cycling (23) and the other seven driving (3,17,18,21,36,45,49). These studies showed that with practice, skills were developed to reduce allocation of attention and to automatically process and act upon environmental input (3,17,21,23,36); even to the point that drivers fail to recall the stimuli they have just acted upon or that they retrospectively report being on autopilot (17,18,21,45,49,60). The latter was reported as a very common state to be in for route-familiar drivers. The five studies that reported on decreased cognitive control, dependent on situational demands, all concerned driving studies, of which three compared familiar to unfamiliar conditions (14,40,45) and two considered familiar conditions only (11,60). These studies showed that drivers divided attention and switched between modes of control – a more passive monitoring mode versus an active control mode – according to momentary demands (11,14,40,45,60).

Additionally, four of these five studies also reported on increased cognitive control, dependent on situational demands. Examples of situations that enticed switching to a mode of more active cognitive control include when in response to actions of other road users (probably as these responses are not proceduralised); during situations that were complex, critical or unpredictable (including specific locations and types of traffic); when drivers thought they ought to pay attention; or when expectations were violated (11,40,45,60).

One study found no effect of familiarity on awareness, with sufficient power. This study considered walking and examined pedestrians' awareness of an object which they had just interacted with. It found that most pedestrians were walking in a state of 'walking without awareness', regardless of familiarity (13). One study was not considered for this part of the review. This study found no difference between familiar and unfamiliar drivers regarding the freeing up of attentional resources, though sample size could not warrant the conclusion there was no effect (34). Together these fourteen studies present *convincing evidence* that familiarity with a route enables drivers to reduce cognitive control and to participate in traffic with little to no awareness (3,17,18,21,23,36,45,49,60), and an *indication* this is also the case for cycling (23). Furthermore, an *indication* is offered that awareness is not affected by familiarity when walking (13) and *good evidence* is provided that drivers divide attention and switch between modes of control – a more passive monitoring mode versus an active control mode – according to momentary demands (11,14,40,45,60).

Memory

Seven studies addressed *spatial and temporal memory*. Two of them reported on decreased accuracy of spatial and temporal memory in familiar conditions, cf. unfamiliar conditions (57,63). Both studies considered walking. Two of these studies found that walking distance estimates increased over time: pedestrians were likely to exaggerate the length of highly-familiar paths compared to less-familiar paths (57,63). One of these studies also considered travel time and reported that, in contrast to travel length, travel time is underestimated with practice (57).

Four studies found increased accuracy for spatial orientation (31,55,56,93). All compared familiar to unfamiliar conditions. Three of these studies examined walking and showed that with increasing experience with an environment, spatial representations of this location transition from egocentric to allocentric (55,56,93). In other words, they shift from being oriented by the position of the viewer in space to orientation independent. The other of the four studies concerned a cycling study, in which it was observed that in a map-drawing task of the route just ridden, cyclists familiar with the area benefitted from having had movement control, i.e., having had control over the bicycle's handlebar, while unfamiliar cyclists benefitted from navigational control. The latter performed best when they had to find their own route. For familiar cyclists navigational control was only observed as an interaction effect; those without control over the bicycle's handlebar and who had to follow the marked route, performed worse than those in the other conditions (31).

The sole study of all seven that examined familiar participants only, showed that spatial memory regarding knowledge to navigate along a familiar route root in a separate memory of the same environment, compared to knowledge to determine a target's metric location, e.g. by pointing (61). Together, these seven studies showed that route familiarity contributes to a shift in spatial and temporal memory, providing *fair evidence* that over time, accuracy of walking distance estimates decrease (57,63) and indicating that accuracy of walking time estimates decrease as well (57). Furthermore, *good evidence* shows that with practice, accuracy of spatial orientation increases for walking

(55,56,93) and an *indication* is added that it increases for cycling too (31).

Six studies addressed the building and usage of *mental representations*, though only two of them compared familiar to unfamiliar conditions. These two studies considered either walking or driving, and they offer an *indication* that with practice, mental representations of surroundings become stronger and more robust, both for walking as well as for driving (29,74). The driving study found that drivers' mental categories and expectations took precedence over their immediate experience, which may imply that drivers use stored schemata to maintain and guide their performance on familiar roads (74). The walking study showed that children experienced with walking to their kindergarten were better at performing a task in which they had to point towards the location of their kindergarten while taken on a walk in its neighbourhood, and that this experience even benefitted their ability to point out the starting point of a walk in an unfamiliar setting (29).

The remaining four studies on mental representations all concerned participants in familiar surroundings only and corroborated the *indications* described above. These studies showed that drivers used their mental representation of an area to continuously make real-time comparisons between the real world and their expectations (45,60); and that they appear to include driving demand in their mental representation (72). The latter is based on the finding that drivers used road geometry – including narrow bridges and intersections with other roads – to distinguish roads on which they would display the same behaviour, instead of other roadside features that may change the visual appearance of a road, such as poles and vegetation. Additionally, in a walking study under solely familiar pedestrians, it was noticed that when planning a route, pedestrians tended to focus on turning intersections, i.e., intersection where they had to turn left or right, instead of on both turning and straight-walking intersections. It was suggested this strategy to build a mental representation might be adopted to reduce memory load. However, it remains unclear whether this strategy was an effect of route familiarity, as a similar result was found in another study with unfamiliar pedestrians, though both studies have not been statistically compared (58).

Accuracy of *recall and recognition* was addressed by ten studies. Five studies found that recall and recognition accuracy decreased with practice (19,21,24,75,77). All five studies concerned driving, two of them compared familiar with unfamiliar conditions (24,77), while the other three tested recall and recognition under familiar conditions only (19,21,75). Four of these five studies observed decreased recall and recognition under the specific circumstance that the target object had changed, for example changes in traffic signs – i.e., variable speed limit signs, priority and yield signs and texts on variable message signs – and specific events (19,21,24,75). One study found decreased recall accuracy of warning signs for familiar drivers, cf. unfamiliar drivers, regardless of change (77).

Next to decreased accuracy, seven of the ten studies also found beneficial effects of practice on recall and recognition accuracy. Two of these studies, on driving, considered familiar conditions only (75,86), while the other five compared familiar to unfamiliar conditions; four of them concerned driving (20,21,24,44) and one examined cycling (31). Of the latter five studies, two reported on drivers' increased accuracy for traffic sign recall and recognition with practice (20,24); one found the amount of drivers' recall about the traffic scene they had just passed increased with exposure (44); another showed that drivers' exposure to continuous changes in variable message signs increased expectancy of change (21); and yet another found that for cyclists familiar with the area, landmark recognition increased if they had movement control over the bicycle, irrespective of navigational control (in contrast, for unfamiliar cyclists recognition was best without navigational control, i.e., when they followed a marked route on a map, regardless of having had movement control) (31). The two studies that concerned familiar participants only reported that drivers accurately remembered locations they had driven through (in contrast to specific events) (75) and that memories for the route were more available for recall and accessible when a good recall cue, such as music, was used (86).

One study found no effect of practice on recall and recognition accuracy. This study examined walking under familiar and unfamiliar conditions, and found no difference in pedestrians' ability to recall a signboard they had just avoided and which 53.8% of them had failed to recall (13). Another study also found no effect of familiarity, however it was not considered for this part of the review as its sample size was too low to warrant the conclusion that recall of speed limit signs was high regardless of familiarity (77).

Two of the eight studies also noted a dissociation between recall and displayed behaviour, although no evidence was provided that this was associated with familiarity (13,21). Together, the ten studies display *convincing evidence* that for driving, with practice, accuracy initially increases (20,21,24,44,75,86), until – with *fair evidence* – the mental image of what is expected becomes so strong that recall and recognition appears to be based on what usually happens or has been seen, rather than the specific instance people had just experienced (19,21,24,75,77). The latter is especially tangible in case the real-life image has changed and does not replicate the mental image anymore (19,21,24,75). *Indications* are offered that with practice, recall accuracy initially increases for cycling as well (31), while in contrast it might not affect recall accuracy when walking (13).

Judgement

Thirteen studies included *perceived risk*, of which nine studies addressed the development of perceived risk in relation to route familiarity. In these nine studies perceived risk was mostly derived from behavioural performance measures, such as headway and red-light waiting times, or through interpretation of other output, such as interviews (5,7,8,23,34,68,78,92); one study measured perceived risk through a risk questionnaire (16). All nine compared familiar to unfamiliar conditions.

Four out of nine studies reported that perceived risk decreased when exposure increased, for cycling (23), walking (68), and driving (16,34). They derived decreased perceived risk from maintaining a shorter headway when driving, ceasing the waiting time at a pedestrian crossing and feeling relatively competent and safe in traffic when cycling (23,34,68); or when assessing the risk of an accident in actual high-risk driving situations (16).

In contrast, five out of nine studies found that perceived risk increased with exposure, for walking (5), cycling (78), and driving (7,8,92). These studies found that the more familiar cyclists were with a location, the more dangerous it was estimated to cycle there (78); and that elderly drivers were more likely to report discomfort at a familiar freeway exit (92). Additionally, local drivers were found to drive more slowly in school zones compared to foreign drivers unfamiliar with the school zone road layout, though both driver groups reduced their speeds similarly in response to a pedestrian inside the school zone (7). Furthermore it was reported that participants' familiarity (with the direction of traffic) resulted in pedestrians maintaining a higher margin of safety when selecting a gap in which to cross the road (in a virtual reality simulated environment) (5) and drivers making more accurate, i.e., less risky, judgements regarding whether or not it was safe to enter a roundabout (8). These outcomes were interpreted as an increase in perceived risk. It must be noted that in three of the five studies (5,8,92) subjects consisted of a very specific target group (drivers aged 65 to 74, and participants for whom traffic came from the direction opposite of the convention in their country of origin), which might prevent generalising these results to the whole population of drivers and pedestrians.

The remaining four studies (out of the initial thirteen) provided accounts of risk perception while driving or walking along a familiar route, without comparing to unfamiliar conditions (48,72,73); or hypothesised a negative correlation between route familiarity and perceived risk without measuring it in their study (70). The two car driving studies found that drivers' speed choice correlated negatively with perceived risk (72,73). The walking study, in which children were questioned about their route to school, showed that perceived risk along a familiar route is location dependent (48).

Together, the thirteen studies revealed *mixed results* regarding the effect of route familiarity on perceived risk when walking (5,68), cycling (23,78), or driving (7,8,16,34,92), which might reportedly decrease or increase.

Seven studies addressed *self-regulation*. One of these studies, on driving, considered familiar conditions only (43), while the other six compared familiar to unfamiliar conditions, of which five considered driving (27,32,82,84,92) and one examined walking (59). It was found that along familiar routes, young drivers tended to engage in other activities such as smartphone use, while they were less tended to do so along unfamiliar routes (82); whereas elderly drivers used familiar situations – and limiting their movements to these areas – to compensate for decreased driving abilities, e.g. due to cognitive decline (27,32,84,92). The latter is supported by similar results found in the one study that considered familiar driving conditions only (43). These studies suggest subjective demand is lower for familiar routes. Additionally it was found that pedestrians reported that familiar environments, cf. unfamiliar environments, enabled them to become aware of barriers in the environment and to compensate for them or avoid them altogether (59). Together, these studies provide *convincing evidence* that increased route familiarity provides drivers with increased opportunities for self-regulatory behaviour, both for elderly as well as young drivers (27,32,43,82,84,92). An *indication* is offered that this is also the case when walking (59).

Eleven studies addressed *rule-based behaviour*. One of them compared rule-based behaviour between two kinds of route-familiar drivers, without comparing to an unfamiliar condition and without pointing in any particular direction regarding rule-based behaviour itself (62). The other ten studies showed that rule-based behaviour amongst route-familiar drivers and pedestrians affected various types of behaviour in traffic. They consisted of two studies that compared familiar to unfamiliar conditions for pedestrians (55,56), six that compared familiar to unfamiliar conditions for drivers (12,15,17,18,71,74) and two that examined driving under familiar conditions only (4,50).

For driving, familiar drivers displayed a preference for 'easier' routes: the number of turns they needed directions for was lower cf. unfamiliar routes (12), and they tended to choose the route with the lowest frequency of left turns (in a right-hand side driving context), instead of routes that are 'rationally' (i.e., shortest in time or distance) (4,50). Default behaviour regarding route choice was more apparent among drivers familiar with the area than those unfamiliar with it (71). Furthermore, when asking drivers to report on anything unusual, hazardous or interesting, the responses obtained became stereotyped with repeated exposure (17,18). Familiar drivers tended to focus on 'positive' attributes of a road: cues for higher speeds – such as a high level of delineation – appeared to take precedence over those for lower speeds, such as the prominence of footpaths, residential housing, or even speed signs in a residential street (74). The increased interest in positive attributes was also present in route choice, where familiar drivers attributed more importance to good traffic conditions; while unfamiliar drivers attributed more importance to bad traffic conditions hence avoiding the least favourable streets (15). The latter, however, is more indicative of a shift in rule-based behaviour, rather than an increase.

The two walking studies showed that familiar pedestrians' judgements of relative spatial positions between buildings (i.e. allocentric distance) as well as between a building and themselves (i.e. egocentric distance) were faster compared to pedestrians unfamiliar with the area. Furthermore, the accuracy of familiar pedestrians' judgements is higher for allocentric distance, while it is lower for egocentric distance, in comparison to unfamiliar pedestrians (55,56). The latter is indicative of a shift in rule-based behaviour, rather than an increase or decrease.

On a side note, the study that compared between two kinds of route-familiar drivers found that taxi drivers were no different from other, familiar local drivers in estimations of crow-flies and travel time distances between familiar landmarks. This suggests that familiarity affects wayfinding in similar ways, and taxi drivers are not 'expert' or 'expertly familiar' (62).

Together, the studies on rule-based behaviour show that route familiarity results in an increase in rule-based behaviour, with *convincing evidence* for driving (4,12,17,18,50,71,74) and *fair evidence* for walking (55,56). Additionally, *indications* are presented for a shift in rule-based behaviour with practice, both for walking (56) as well as for driving (15).

Mental state

Although five studies – all on car driving – touched upon experienced *stress*, only one study compared familiar to unfamiliar conditions (76). The other four studies reported on stress in familiar conditions only (47,49,72,94). The study that compared familiar to unfamiliar conditions found that higher route familiarity was linked to lower 'range stress' in battery electric vehicle drivers (76). 'Range stress' concerns stress invoked by concerns about whether the amount of fuel suffices the distance that needs to be covered, and which relates to the psychological concept of stress. The findings of this study were explained by suggesting that stress levels had lowered as higher route familiarity reduces uncertainty (76). However, as 'range stress' is a phenomenon generally exclusively related to battery electric vehicles, it is difficult to generalise these findings to stress related to route familiarity in general. The other four studies were not after effects on stress due to familiarity. Instead, they provided descriptions of how stress is experienced during route-familiar driving. The picture that emerges from these studies is that driving along a familiar route is not stressful by itself, but that stress levels and arousal may fluctuate during the drive, dependent on situational demands. For example, more comfort was associated with higher rated speed choice, while stress and arousal increased during route sections of higher traffic volume and sections with a number of hazardous curves that require manoeuvring, or when feeling 'stuck' in busy traffic (47,49,72,94). Together, the five studies on stress add an *indication* that for driving, stress levels might be lower when familiar conditions reduce uncertainty and that fluctuations in stress, probably linked to attention, are normal during everyday driving (47,49,72,76,94).

Six studies – all on car driving as well – addressed *task difficulty*. Four of them examined the effect of familiarity on task difficulty, by comparing familiar to unfamiliar conditions. These studies found that with repeated exposure to the same route, driving difficulty was rated progressively lower and it was also significantly lower compared to driving an unfamiliar route (17,18). Task difficulty has even been reported to drop to the point that driving a familiar route resulted in boredom (49). On another level of familiarity - in which an unfamiliar right-hand driving context was compared with a familiar left-hand driving context - it was found that judging whether it was safe to enter a roundabout was considered significantly more difficult and demanding in the unfamiliar context compared to the familiar context (8). Together, these studies present *convincing evidence* that for driving, task difficulty decreases when route familiarity increases (8,17,18,49).

The other two studies also addressed task difficulty, though not as a result of route familiarity. One study reported that on familiar roads, higher rated speed choice was associated with lower levels of driving difficulty and that ratings of driving difficulty were more closely associated with rated speed choice than was rated risk (72). The other study further reduced the task load of driving in a familiar context by artificially maintaining a constant headway to a pace car and found this might lead to underload, decreasing task performance (34). When increasing task performance again (by the enforced instruction to maintain a fixed speed) and while still driving behind the constant-headway pace car, no significant difference between familiar and unfamiliar drivers for hazard detection performance was found. However, sample size was low ($n = 10$ per group), which means it is likely this experiment does not have enough power to warrant the conclusion that there is no difference.

Three studies touched upon the topic of *confidence* and familiarity, though one of them only hypothesised that increased route familiarity would result in increased confidence in (or even overconfidence for) drivers' own driving skills, though this has never been measured in their study (70). The other two studies pointed in different directions, dependent on modality. The cycling study reported initial feelings of intimidation and anxiousness, which changed into feeling relatively competent with increased exposure (23). In contrast, the car driving study found that older drivers were more likely to report discomfort at a familiar freeway exit, cf. less familiar peers (92). The reduced confidence at the freeway exit might be related to previous experiences in that complex environment, though this has not been addressed in the paper. Consequently, these studies offer *indications* that with practice, confidence might increase for cycling (23) and decrease for driving (92), dependent on the immediate situation.

The two studies on *emotions* consisted of car-driving studies with highly familiar participants only. In both studies a link was displayed between emotions and having strong expectations, which in turn are closely related to familiarity, as pointed out earlier. The studies revealed that participants experienced negative emotions when expectations were violated, for example when a selected street appeared to be blocked or congestion was unexpected; while meeting expectations coincided with positive emotions (51,60). Given that both studies considered familiar conditions only, they are not regarded as evidence for any effects of route familiarity.

Effects on behavioural performance

Eleven studies concerned *visual scanning and eye fixations*; six of them addressed traffic-related objects and three examined traffic-unrelated objects. The six studies concerning traffic-related objects provide *convincing evidence* that with practice, time spent looking at traffic-related objects decreases while driving, compared to unfamiliar conditions (24,25,28,35,42,77). They reported on decreased time spent looking at traffic signs, information signs and road markings (24,25,77); fewer fixations at traffic-related information just before as well as after entering a tunnel (42); decreased time spent looking at the road (35); and sampling in front of the car confined to a smaller area (28). The three studies investigating traffic-unrelated objects present *fair evidence* that, while driving, with practice time spent looking at traffic-unrelated objects increases (33,35,60). They reported that compared to unfamiliar conditions, with practice, the total frequency of looking at something within or outside the vehicle increased (33), as well as time spent looking off the road, in places unrelated to any observable hazards (35). Additionally, under familiar conditions only, it was observed that most trip time was spent on visual inspection of the environment (53,60). On average, drivers spent 74% of driving time looking up at the forward roadway, 13% looking at the instrument panel/steering wheel, and just 3% looking at the vehicle's touchscreen, regardless of vehicle automation that assisted with the car's longitudinal and lateral control being engaged or not (53). According to the retrospective verbal reports, visual inspection related partly to keeping oriented in the environment but also to generally look at features out of interest (60).

Of all eleven studies, during successive trials, two studies found no difference in looking at the car mirrors, or at near features on the road in rural (dual and multi lane) environments (35) or in dwell time percentage of the eyes to all specific 'areas of interest' while cycling (30). One study compared familiar to unfamiliar conditions and found no effect of car drivers' self-reported familiarity with various types of bicycling infrastructure on their glance behaviour (79). Sample sizes of all three studies were not large enough to conclude that finding no difference translates into no effect of familiarity. Hence, these results were not considered for this part of the review.

Of the twenty-three studies that measured *speed, lane position, headway, hazard avoidance and gap selection*, fifteen studies examined speed relative to familiarity. They provide *convincing evidence* that in general average speeds increase with practice for car driving (18,19,21,24,26,33,38,42,52,74,87), and an *indication* they do so as well for cycling (30). Regarding dedicated road infrastructure for vulnerable road users – in specific a school zone and bicycling infrastructure – two studies provided *fair evidence* that familiarity with these driving contexts resulted in reduced driving speeds (7,79). For the school zone this meant more compliant speed choice behaviour. One study found no significant difference of driving speed over drives (17), though it was not considered for this part of the review since its sample size was too low to warrant the conclusion that speed is not affected. Two studies considered speed variability and present *fair evidence* that with practice, driving speed variability decreases (17,18). One of these studies also reported on perceptual speed regulation and offers an *indication* that with progressing experience with driving through a 400 m simulated tunnel, drivers' speeds inside the tunnel decreases (17). This finding was explained by proposing an increased effect of optic flow information related to reduced explicit attention resulting from repeated practice. The final study that concerned speed included only familiar drivers and provided a possible explanation for aforementioned effects on speed, as they found that ratings of speed choice highly correlated with ratings of safe speed and estimated speed limits (72).

The two headway studies present *fair evidence* that over time, drivers maintain shorter headways (33,34), this in contrast to the six studies on lane position measures. Two of these studies – one on car driving, the other on cycling – reported on an increase of lane position variability (18,30), while another car study indicated a decrease of lane position variability (17). Yet another study recorded no significant difference between route-familiar and route-unfamiliar drivers regarding lateral position in three sub-experiments, though this finding is not considered for this review as for sub-experiments sample sizes were too low to conclude there was no effect (34). Together these studies provide *mixed results* for car driving and an *indication* that with progressing experience lane position variability decreases for cycling. Other findings regarding lane position were provided by three of the six studies, which found that previous experiences with a location resulted in cycling significantly more towards the centre of a bend when cycling through around a curve (30); and enabled drivers to improve lane position with a new layout for a toll plaza or near bicycling infrastructure (79,91).

Two studies regarded hazard avoidance and add an *indication* that route familiarity does not affect hazard avoidance when walking. This *indication* concerns the study that found no statistically significant difference between route familiarity and the moment pedestrians moved to avoid a signboard, with sufficient sample size (13). The other study reported that differences in route-familiar and route-unfamiliar drivers' reactions to a road hazard were largely due to differences in initial driving speed, rather than drivers' reaction time. However, the study did not conclude there was no effect of hazard avoidance as sample size was too low to warrant such a conclusion (17).

The remaining three studies of all twenty-three considered gap selection. Two studies concerned walking and compared familiar with unfamiliar conditions, though they found *mixed results* regarding the quality of gap selection. While one study found that waiting times were shorter when pedestrians were familiar with the crossing, making their crossing more unsafe (68), the other study indicated that in unfamiliar conditions, pedestrians' gap selection was more unsafe (i.e., had lower safety ration, or a lower margin of error), or overtly cautious (i.e., waiting for all traffic to have passed) (5). The third study concerned driving, also compared familiar with unfamiliar conditions, and provided an *indication* that familiarity improved gap selection when driving. Familiarity (with the direction of traffic) enhanced judgements regarding whether or not it was safe to enter the roundabout (8).

Of the sixteen studies that concerned *route choice*, eleven addressed proceduralised route-choice behaviour. Six of these studies showed drivers familiar with the area have a tendency to stick to preferred, easy routes (4,12,15,32,50,85); such as routes with fewer left turns (in a righthand-side driving context), as reported by the two studies that considered familiar conditions only (4,50). All but one of these six studies have already been described in more detail under Judgement, as part of rule-based cognition and self-regulation. Three other studies reported decreased use of directional signposting (one study) and navigational aids (two studies) for familiar trips compared to unfamiliar trips (22,54,59); one study concerned walking, the other two considered driving, respectively. For walking, it was also found that path efficiency increased over trials and that decisions on whether to turn or continue straight are made far in advance of an intersection when navigating a familiar environment, compared to walking along unfamiliar paths (41). Regarding driving, another study found that after repeated exposure participants complied with a route instruction sign without access to this text in recall (21). Next to this, without comparing to unfamiliar conditions, a tendency was reported under taxi drivers to opt for routes with a higher driving speed, unless congested (4). Together, these eleven studies present *convincing evidence* that amongst drivers proceduralised route-choice behaviour increases with practice and *fair evidence* it does so as well for pedestrians.

Of the remaining five out of sixteen studies, one distinguished between route-familiar and route-unfamiliar drivers and offers an *indication* that higher network familiarity, i.e., drivers' familiarity with an area, can be predicted by them being familiar with at least one alternative route to their preferred route; receiving en-route traffic information; having a shorter commute; using alternative routes to avoid congestion (instead of leaving earlier); having driven the commute for a longer time; having a higher number of vehicles per household (assumed to correlate with route flexibility); and belonging to a household with more young children (<5 years) (10). The other four of these five studies concerned studies that considered familiar conditions only. They found that wayfinding was similarly affected by familiarity for both taxi drivers and the general public (62), as already mentioned under Judgement; and that wayfinding amongst taxi drivers followed four distinct, consecutive stages (60): 1) the destination's location must be retrieved, 2) the direction to the location must be determined, 3) retrieval/ selection of the streets to form the route, 4) en route filling-in of a plan for the next stage of the journey or re-planning part of the route (e.g. because of obstructions). Regarding elderly drivers it was found that they spent the majority of time during everyday driving trips on 50 and 60 km/h roads, instead of on roads with higher speeds (9); and that elderly drivers with preclinical Alzheimer's disease were more likely to stick to familiar routes (43). The latter two might be the case as part of self-regulation.

Fourteen studies addressed route familiarity and *crashes, violations and errors*. Of the seven studies that reported on how crash risk relates to familiarity, five car driving studies reported increased crash risk for familiar roads (39,64,65,69,81), while two other studies – one on car driving, the other on motorcycling – found decreased crash risk (6,83). Furthermore, it was found that under specific aberrant circumstances – e.g. poor alignment, dark without road lights, bad weather such as rain or fog – familiar car drivers were less likely to be involved in crashes (69). Together, they provide *convincing evidence* that crash risk increases when driving a car on familiar roads and *indications* that route familiarity decreases crash risk for motorcycling and is protective when driving a car under aberrant driving conditions. Increased crash risk for car driving was found regardless of gender, age or having child passengers in the vehicle (65,81).

Five of the fourteen studies examined how violations related to familiarity. The four studies that compared familiar to unfamiliar roads all reported violations to increase when driving a car on familiar roads, regardless of gender or age (66,70,85,89), while the one study that considered familiar conditions only, reported on a low tendency to speed amongst older drivers (9). Amongst the violations were speeding (66,70,85,89); hard braking and accelerating, cornering (85); crossing in red light, hand-held phone usage, and dangerous behaviours such as eating while driving, tuning the radio and listening to loud music (70). Considered together, these studies present *convincing evidence* to assume that violations increase when driving on familiar roads.

One out of the fourteen studies one study considered errors when comparing familiar and unfamiliar conditions and adds an *indication* that the likelihood of errors is higher for driving along familiar roads (64).

The two remaining studies out of all fourteen focussed on discerning between specific circumstances for crashes on familiar versus unfamiliar routes. One found that in cycling accidents, cyclists under the influence of alcohol were not so familiar with the route compared with sober cyclists (90); which may suggest that travelling along a familiar route is more easy, even when impaired (in this case by alcohol consumption). The other found a complex web of weak associations, in which familiar drivers were e.g. more likely to be involved in accidents at minor intersections/driveways, and with speed limits < 80 km/h, while unfamiliar drivers were more likely to be involved in accidents involving e.g. head on/rear end-angle crashes, heavy vehicles and, or, young drivers (67).

Six studies touched upon *secondary task engagement* related to route familiarity, five of them were experimental studies and one concerned a peer commentary. The five experimental studies provide *fair evidence* that with practice, secondary task engagement increases both for walking and driving. Amongst route-familiar drivers and pedestrians these secondary tasks included increased (smart)phone usage and music listening (33,46,82), which have also been reported as common behaviour amongst commuting cyclists (23). Though only the latter study was without comparison to unfamiliar circumstances. Other behaviour that increased with route familiarity – both for drivers as well as pedestrians – involved talking and singing (13,33). The peer commentary addressed secondary task engagement and everyday driving and stressed the importance of natural circumstances – as used in all five aforementioned studies –, as performance decrements associated with secondary tasks in laboratory studies do not necessarily generalise to everyday driving behaviour (88).

Appendix C. Study protocol

Objective

The main objective of this systematic review is twofold: 1) to explore how researchers have described and examined familiarity as a context for driving, cycling, and walking performance; and 2) to obtain a better insight into the cognitive processes, and transport behaviour (e.g., driving, cycling, and walking) that occur in familiar road environments.

Search strategy

The title, abstract and keywords of the manuscripts contained in the database Scopus were searched systematically for combinations of search terms. The search terms were defined by selecting a few well-cited manuscripts on route familiarity and working backwards by varying search terms until they returned both the selected manuscripts as well as a broad variety of other manuscripts. The resulting terms are provided in Table C.1 and were used in combination. These combinations consisted of terms from each column until all 125 possible meaningful combinations were made (excluding combination of two blank terms). For example, TITLE-ABS-KEY (driv* AND 'route familiarity'), TITLE-ABS-KEY (driv* AND 'naturalistic driving'), TITLE-ABS-KEY (driv* AND 'naturalistic driving' AND 'route familiarity'), and so on.

Table C1
Overview of all terms that made up the search combinations used for this review. Search combinations consisted of systematically combining entries from the first, second and third column, with the exception of combining both < leave blank > entries.

Mode of transport	Type of experiment	Words associated with route familiarity
driv*	<leave blank>	<leave blank>
(bicycle OR cyclist)	naturalistic < insert driving/cycling/walking>	route familiarity
(pedestrian OR walk*)	observational	road familiarity
	field operational test	familiar
		familiar AND road
		familiar AND path
		familiar AND route
		everyday < insert driving/cycling/walking>
		Daily
		routine < insert driv*/cycl*/ walk*>
		commut*

For cycling, the search term (bicycle OR cyclist) was used instead of cycl*, because cycl* yielded a large number of hits of which many were not about mobility. For example, searching for TITLE-ABS-KEY (cycl* AND familiar) yielded 2842 results on March 6, 2018, of which Scopus labels most (33%) in the area of Medicine.

For walking, the search term (pedestrian OR walk*) was used instead of walk* to increase the number of results for this mode of transportation. Inclusion of the word 'pedestrian' increased the number of (useful) results. For example, TITLE-ABS-KEY (walk* AND familiar AND road) resulted in 18 hits of which most were not about walking as a mode of transport. Adding the word 'pedestrian', TITLE-ABS-KEY ((pedestrian OR walk*) AND familiar AND road), resulted in 35 hits of which a few were even of potential interest for this research.

Study selection and eligibility criteria

Studies from searches that yielded a maximum of 160 results were considered for screening. If a search yielded more than 160 results, none of these studies were considered, but the search was refined with more terms to yield fewer results, but with higher likelihood of finding relevant studies. The number of hits per search combination and date of search were documented, together with per study the title, first author, year of publication, whether the study was on mobility, mode of transport, research method, number of participants, type of road, research questions, keywords and any additional reviewer comments. All search combinations received a final update in April 2020. Identification was completed by additional records identified through the authors' knowledge of existing literature.

For study eligibility, the following criteria applied:

- No duplicates
- Full paper available and obtainable without additional costs, or within the boundaries of library agreements of the University of Groningen
- Full paper must be written in English

Based on title and abstract screening, in duplicate, two researchers (IH and BB) assessed whether manuscripts were of potential interest for this review, using three response options 'yes', 'no', and 'maybe'. Records were excluded if rated 'no' twice, or 'no' and 'maybe'. Manuscripts were considered of potential interest when they:

- described behaviour on familiar routes;
- reported on behavioural alterations due to increased familiarisation with a route as evolving over time;
- or, compared behaviour between an unfamiliar and a familiar route.

Selected aspects of paper characteristics, cognition and subsequent behaviour in traffic

A list of (sub)categories of cognition and behaviour was compiled by the three authors based on their understanding of topics in transport psychology, expanded with variables they extracted from a selection of this review's full papers, and finalised with unanimous agreement. The final list of (sub)categories has been provided in Table 1.

After title and abstract screening, all papers of interest were read in full, were briefly summarised and were independently assessed again regarding their potential interest for the current review by IH or BB, following the criteria mentioned above. The process of study selection is displayed in the flow diagram in Fig. 1. For papers of interest it was extracted how route familiarity had been specified and measured, and how it affected one of the sub-categories of cognition. Papers using a variety of research methods were included (e.g. real world driving, simulated driving, viewing photos or videos) so long as the papers were captured by our screening process. In case of methodological concerns papers were flagged, and any missing data was completed. In particular, claims related to familiarity and behaviour in transport were critiqued according to the study limitations, as described by paper authors, and determined by IH and BB. For papers that were excluded from the current review a brief motivation was documented.

References

The numerical reference as used in the Results chapter and in Appendix B is listed in bold in brackets [ ] at the end of each of the 94 references which were part of the systematic review.

Aarts, H., Dijksterhuis, A., 2000. The automatic activation of goal-directed behaviour: The case of travel habit. J. Environ. Psychol. 20 (1), 75–82. https://doi.org/10.1006/jevp.1999.0156.

Andersson, A.-L., Bunketorp, O., 2002. Cycling and alcohol. Injury 33 (6), 467–471. ***[90]***.

Avni-Babad, D., Ritov, I., 2003. Routine and the perception of time. J. Exp. Psychol.: Gen. 132 (4), 543–550. https://doi.org/10.1037/0096-3445.132.4.54.

Bargh JA, Gollwitzer PM. Environmental control of goal-directed action: automatic and strategic contingencies between situations and behavior. In: Spaulding WD, editor. Nebraska symposium on motivation, Vol. 41. Integrative views of motivation, cognition, and emotion Lincoln, NE, US: University of Nebraska Press; 1994. p. 71-124.

Berthié, G., Lemercier, C., Paubel, P.-V., Cour, M., Fort, A., Galéra, C., Lagarde, E., Gabaude, C., Maury, B., 2015. The restless mind while driving: Drivers' thoughts behind the wheel. Accid. Anal. Prev. 76, 159–165. ***[14]***.

Bragg, B.W.E., Finn, P., 1985. Influence of safety belt usage on perception of the risk of an accident. Accid. Anal. Prev. 17 (1), 15–23. https://doi.org/10.1016/0001-4575(85)90004-1. ***[16]***.

Brewer, W.F., Treyens, J.C., 1981. Role of schemata in memory for places. Cognit. Psychol. 13 (2), 207–230. https://doi.org/10.1016/0010-0285(81)90008-6.

Brunyé, T.T., Gardony, A.L., Holmes, A., Taylor, H.A., 2018. Spatial decision dynamics during wayfinding: intersections prompt the decision-making process. Cognitive Res.: Principles. Implications 3 (1). https://doi.org/10.1186/s41235-018-0098-3. ***[41]***.

Burdett, B.R.D., Charlton, S.G., Starkey, N.J., 2019. Mind wandering during everyday driving: An on-road study. Accid. Anal. Prev. 122, 76–84. https://doi.org/10.1016/j.aap.2018.10.001. ***[11]***.

Burdett, B.R.D., Charlton, S.G., Starkey, N.J., 2018a. Inside the commuting driver's wandering mind. Transp. Res. Part F: Traffic Psychol. Behav. 57, 59–74. https://doi.org/10.1016/j.trf.2017.11.002. ***[45]***.

Burdett, B.R.D., Charlton, S.G., Starkey, N.J., 2016. Not all minds wander equally: The influence of traits, states and road environment factors on self-reported mind wandering during everyday driving. Accid. Anal. Prev. 95, 1–7. https://doi.org/10.1016/j.aap.2016.06.012. ***[37]***.

Burdett, B.R.D., Starkey, N.J., Charlton, S.G., 2018b. Characteristics of the close to home crash. Saf. Sci. 105, 222–227. https://doi.org/10.1016/j.ssci.2018.02.020. ***[64]***.

Burdett, B.R.D., Starkey, N.J., Charlton, S.G., 2017. The close to home effect in road crashes. Saf. Sci. 98, 1–8. https://doi.org/10.1016/j.ssci.2017.04.009. ***[65]***.

Caird, J.K., 2015. On the effects of listening and talking to humans and devices on driving. Hum Factors 57 (8), 1325–1327. https://doi.org/10.1177/0018720815575942. ***[88]***.

Charlton, S.G., Starkey, N.J., 2018a. Attention and awareness in everyday driving. Transp. Res. Part F: Traffic Psychol. Behav. 57, 1–3. https://doi.org/10.1016/j.trf.2018.04.014. ***[1]***.

Charlton, S.G., Starkey, N.J., 2018b. Memory for everyday driving. Transp. Res. Part F: Traffic Psychol. Behav. 57, 129–138. https://doi.org/10.1016/j.trf.2017.06.007. ***[75]***.

Charlton, S.G., Starkey, N.J., 2017a. Drivers' mental representations of familiar rural roads. J Environ Psychol 50, 1–8. https://doi.org/10.1016/j.jenvp.2017.01.003. ***[72]***.

Charlton, S.G., Starkey, N.J., 2017b. Driving on urban roads: How we come to expect the 'correct' speed. Accid. Anal. Prev. 108, 251–260. https://doi.org/10.1016/j.aap.2017.09.010. ***[74]***.

Charlton, S.G., Starkey, N.J., 2016. Risk in our midst: Centrelines, perceived risk, and speed choice. Accid. Anal. Prev. 95, 192–201. https://doi.org/10.1016/j.aap.2016.07.019. ***[73]***.

Charlton, S.G., Starkey, N.J., 2013. Driving on familiar roads: Automaticity and inattention blindness. Transp. Res. Part F: Traffic Psychol. Behav. 19, 121–133. https://doi.org/10.1016/j.trf.2013.03.008. ***[18]***.

Charlton, S.G., Starkey, N.J., 2011. Driving without awareness: The effects of practice and automaticity on attention and driving. Transp. Res. Part F: Traffic Psychol. Behav. 14 (6), 456–471. https://doi.org/10.1016/j.trf.2011.04.010. ***[17]***.

Chase, W.G., Simon, H.A., 1973. Perception in chess. Cognit. Psychol. 4 (1), 55–81. https://doi.org/10.1016/0010-0285(73)90004-2.

Chen, I.G., Durbin, D.R., Elliott, M.R., Kallan, M.J., Winston, F.K., 2005. Trip characteristics of vehicle crashes involving child passengers. Injury Prevention 11 (4), 219–224. https://doi.org/10.1136/ip.2004.006767. ***[81]***.

Chevalier, A., Coxon, K., Chevalier, A.J., Wall, J., Brown, J., Clarke, E., Ivers, R., Keay, L., 2016. Exploration of older drivers' speeding behaviour. Transp. Res. Part F: Traffic Psychol. Behav. 42, 532–543. https://doi.org/10.1016/j.trf.2016.01.012. ***[66]***.

Colonna, P., Intini, P., Berloco, N., Ranieri, V., 2016. The influence of memory on driving behavior: How route familiarity is related to speed choice. An on-road study. Saf. Sci. 82, 456–468. https://doi.org/10.1016/j.ssci.2015.10.012. ***[38]***.

Crompton, A., 2006. Perceived distance in the city as a function of time. Environ. Behav. 38 (2), 173–182. https://doi.org/10.1177/0013916505276743. ***[63]***.

De Groot, A.D. Het denken van den schaker: een experimenteel-psychologisch experiment. PhD dissertation. University of Amsterdam, Amsterdam, The Netherlands; 1946.

Dicke-Ogenia, M. Psychological aspects of travel information presentation: a psychological and ergonomic view on travellers' response to travel information. PhD dissertation. Technische Universiteit Delft, Delft, The Netherlands; 2012. doi: 10.4233/uuid:bb928d00-fd70-420a-8536-462bb22368d9.

Dua, M.J., Charlton, S.G., 2019. Audio on the go: The effect of audio cues on memory in driving. Transportation Research Interdisciplinary. Perspectives 1, 100004. https://doi.org/10.1016/j.trip.2019.100004. ***[86]***.

Fitts, P.M., Posner, M.I., 1967. Human performance. Brooks/Cole, Oxford, England.

Fournier, N., Bakhtiari, S., Valluru, K.D., Campbell, N., Christofa, E., Roberts, S., Knodler, M., 2020. Accounting for drivers' bicycling frequency and familiarity with bicycle infrastructure treatments when evaluating safety. Accid. Anal. Prev. 137, 105410. https://doi.org/10.1016/j.aap.2019.105410. ***[79]***.

Franke, T., Rauh, N., Krems, J.F., 2016. Individual differences in BEV drivers' range stress during first encounter of a critical range situation. Appl Ergon 57, 28–35. https://doi.org/10.1016/j.apergo.2015.09.010. ***[76]***.

Gaspar, J., Carney, C., 2019. The effect of partial automation on driver attention: a naturalistic driving study. Hum. Factors 61 (8), 1261–1276. https://doi.org/10.1177/0018720819836310. ***[53]***.

Gauld, C.S., Lewis, I.M., White, K.M., Watson, B., 2016. Key beliefs influencing young drivers' engagement with social interactive technology on their smartphones: A qualitative study. Traffic Inj. Prev. 17 (2), 128–133. https://doi.org/10.1080/15389588.2015.1047014. ***[82]***.

Grabner, R.H., Stern, E., Neubauer, A.C., 2003. When intelligence loses its impact: Neural efficiency during reasoning in a familiar area. Int. J. Psychophysiol. 49 (2), 89–98. https://doi.org/10.1016/S0167-8760(03)00095-3. ***[3]***.

Guilbert, D., Most, S.B., Curby, K.M., 2020. Real world familiarity does not reduce susceptibility to emotional disruption of perception: evidence from two temporal attention tasks. Cogn. Emot. 34 (3), 450–461. https://doi.org/10.1080/02699931.2019.1637333. ***[80]***.

Hamed, M.M., 2001. Analysis of pedestrians' behavior at pedestrian crossings. Saf. Sci. 38 (1), 63–82. https://doi.org/10.1016/S0925-7535(00)00058-8. ***[68]***.

Hamed, M.M., Abdul-Hussain, A.A., 2001. Driver's familiarity with urban route network layout in Amman. Jordan. Cities 18 (2), 93–102. https://doi.org/10.1016/S0264-2751(00)00061-5. ***[10]***.

Harms, I.M., Brookhuis, K.A., 2017. Traffic management: Assessing various countermeasures to improve detection failure of changes in speed limit signals. Appl. Ergon. 61, 44–52. https://doi.org/10.1016/j.apergo.2016.12.005. ***[20]***.

Harms, I.M., Brookhuis, K.A., 2016. Dynamic traffic management on a familiar road: failing to detect changes in variable speed limits. Transp. Res. Part F: Traffic Psychol. Behav. 38, 37–46. https://doi.org/10.1016/j.trf.2016.01.005. ***[19]***.

Harms, I.M., Dijksterhuis, C., Jelijs, B., de Waard, D., Brookhuis, K.A., 2019. Don't shoot the messenger: Traffic-irrelevant messages on variable message signs (VMSs) might not interfere with traffic management. Transp. Res. Part F: Traffic Psychol. Behav. 65, 564–575. https://doi.org/10.1016/j.trf.2018.09.011. ***[21]***.

Harms, I.M., van Dijken, J.H., Brookhuis, K.A., de Waard, D., 1846. Walking without awareness. Front. Psychol. 2019 (10), 1–12. https://doi.org/10.3389/fpsyg.2019.01846. ***[13]***.

Horvath, C., Lewis, I., Watson, B., 2012. The beliefs which motivate young male and female drivers to speed: A comparison of low and high intenders. Accid. Anal. Prev. 45, 334–341. https://doi.org/10.1016/j.aap.2011.07.023. ***[89]***.

Hu, Y., Liu, H., Zhu, T., 2019. Influence of spatial visual conditions in tunnel on driver behavior: Considering the route familiarity of drivers. Adv. Mech. Eng. 11 (5). https://doi.org/10.1177/1687814019853661. ***[42]***.

Iachini, T., Ruotolo, F., Ruggiero, G., 2009. The effects of familiarity and gender on spatial representation. J. Environ. Psychol. 29 (2), 227–234. https://doi.org/10.1016/j.jenvp.2008.07.001. ***[55]***.

Iachini, T., Ruggiero, G., Ruotolo, F. Spatial memory and large-scale ecological environments. In: Eklund LC, Nyman AS, editors. Learning and memory developments and intellectual disabilities Happague, NY: Nova Science Publishers; 2011. p. 187-205. [56]

Inman, V.W., Balk, S.A., Perez, W.A. Traffic control device conspicuity. Traffic Sign Conspicuity: Selected Analyses 2013; FHWA-HRT-13-044:1-70. McLean, VA: Federal Highway Administration. [77]

Intini, P., Berloco, N., Colonna, P., Ranieri, V., Ryeng, E., 2018. Exploring the relationships between drivers' familiarity and two-lane rural road accidents. A multi-level study. Accid. Anal. Prev. 111, 280–296. ***[67]***.

Intini, P., Colonna, P., Berloco, N., Ranieri, V. Measuring trade-offs between risk and travel time based on experimental speed data. In: Stanton N, Landry S, Di Bucchianico G, Vallicelli A, editors. Advances in intelligent systems and computing, vol. 484. Proceedings of the AHFE 2016 International Conference on Human Factors in Transportation Cham, Switzerland: Springer International Publishing; 2017. p. 1103-1116. doi:10.1007/978-3-319-41682-3_90 [39]

Intini, P., Colonna, P., Olaussen, R.E., 2019. Route familiarity in road safety: A literature review and an identification proposal. Transp. Res. Part F: Traffic Psychol. Behav. 62, 651–671. https://doi.org/10.1016/j.trf.2018.12.020. ***[2]***.

Jafarpour, A., Spiers, H., 2017. Familiarity expands space and contracts time. Hippocampus 27 (1), 12–16. https://doi.org/10.1002/hipo.v27.110.1002/hipo.22672. ***[57]***.

Johnston, L., Peace, V., 2007. Where did that car come from?: Crossing the road when the traffic comes from an unfamiliar direction. Accid. Anal. Prev. 39 (5), 886–893. https://doi.org/10.1016/j.aap.2006.12.010. ***[5]***.

Kaptein, N.A., Theeuwes, J., van der Horst, R., 1996. Driving simulator validity: some considerations. Transp Res Rec 1550, 30–36. https://doi.org/10.3141/1550-05.

Knapper, A., Nes, N.V., Christoph, M., Hagenzieker, M., Brookhuis, K., 2016. The use of navigation systems in naturalistic driving. Traffic Inj. Prev. 17 (3), 264–270. https://doi.org/10.1080/15389588.2015.1077384. ***[22]***.

Larsen, J., 2014. (Auto)Ethnography and cycling. Int. J. Soc. Res. Methodol. 17 (1), 59–71. https://doi.org/10.1080/13645579.2014.854015. ***[23]***.

Li, X., Li, Z., Cao, Z., Zhao, X., 2018. Modeling drivers' memory of daily repetitive stimuli in traffic scenes. Cogn. Technol. Work 20 (3), 389–399. https://doi.org/10.1007/s10111-018-0476-0. ***[44]***.

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gøtzsche, P.C., Ioannidis, J.P., et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339:b2700. doi:10.1136/bmj.b2700

Liikkanen, L.A., Lahdensuo, M. Observing the mobile music phenomenon: One in nine commuters is wired. DIS 2010 - Proceedings of the 8th ACM Conference on Designing Interactive Systems 2010:348-351. doi:10.1145/1858171.185823. [46]

Lopez, A.J., Astegiano, P., Gautama, S., Ochoa, D., Tampère, C.M.J., Beckx, C., 2017. Unveiling e-bike potential for commuting trips from GPS traces. ISPRS Int. J. Geo-Inf. 6 (7), 190. https://doi.org/10.3390/ijgi6070190.

Lotan, T., 1997. Effects of familiarity on route choice behavior in the presence of information. Transp. Res. Pt C-Emerg. Technol. 5 (3–4), 225–243. https://doi.org/10.1016/S0968-090X(96)00028-9. ***[15]***.

Lotan, T., Koutsopoulos, H.N., 1999. Modeling default behavior in the presence of information and its application to the route choice problem. Int. J. Intell. Syst. 14 (5), 501–533. ***[71]***.

Mader, M., Bresges, A., Topal, R., Busse, A., Forsting, M., Gizewski, E.R., 2009. Simulated car driving in fMRI-Cerebral activation patterns driving an unfamiliar and a familiar route. Neurosci. Lett. 464 (3), 222–227. https://doi.org/10.1016/j.neulet.2009.08.056. ***[36]***.

Markkula, G., 2014. Modeling driver control behavior in both routine and near-accident driving. Proc. Hum. Factors Ergon. Soc. 58 (1), 879–883. https://doi.org/10.1177/1541931214581185. ***[40]***.

Martens, M.H., 2018. The failure to respond to changes in the road environment: Does road familiarity play a role? Transp. Res. Part F: Traffic Psychol. Behav. 57, 23–35. https://doi.org/10.1016/j.trf.2017.08.003. ***[26]***.

Martens, M.H., Fox, M.R.J., 2007a. Do familiarity and expectations change perception? Drivers' glances and response to changes. Transp. Res. Part F: Traffic Psychol. Behav. 10 (6), 476–492. https://doi.org/10.1016/j.trf.2007.05.003. ***[24]***.

Martens, M.H., Fox, M.R.J., 2007b. Does road familiarity change eye fixations? A comparison between watching a video and real driving. Transp. Res. Part F: Traffic Psychol. Behav. 10 (1), 33–47. https://doi.org/10.1016/j.trf.2006.03.002. ***[25]***.

Mason, M.F., Norton, M.I., Van Horn, J.D., Wegner, D.M., Grafton, S.T., Macrae, C.N., 2007. Wandering minds: The default network and stimulus-independent thought. Science 315 (5810), 393–395. https://doi.org/10.1126/science.1131295.

Mauri, M., Cuzzoni, M.G., Bono, G., Sinforiani, E., Zucchella, C., 2014. Driving habits in patients with dementia: A report from Alzheimer's disease assessment units in northern Italy. Funct. Neurol. 29 (2), 107–112. https://doi.org/10.11138/FNeur/2014.29.2.107. ***[27]***.

Meilinger, T., Frankenstein, J., Bülthoff, H.H., 2014. When in doubt follow your nose-a wayfinding strategy. Front. Psychol. 5 (1363), 1–7. https://doi.org/10.3389/fpsyg.2014.01363. ***[58]***.

Meilinger, T., Frankenstein, J., Bülthoff, H.H., 2013. Learning to navigate: Experience versus maps. Cognition 129 (1), 24–30. https://doi.org/10.1016/j.cognition.2013.05.013. ***[61]***.

Michon, J.A., 1985. A critical view of driver behavior models: What do we know, what should we know? In: Evans, L., Schwing, R.C. (Eds.), Human behavior and traffic safety. Plenum Press, New York, pp. 485–520.

Miller, G.A., 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol. Rev. 63 (2), 81–97. https://doi.org/10.1037/h0043158.

Molnar, L.J., Eby, D.W., 2008. The relationship between self-regulation and driving-related abilities in older drivers: An exploratory study. Traffic Inj. Prev. 9 (4), 314–319. https://doi.org/10.1080/15389580801895319. ***[84]***.

Mourant, R.R., Rockwell, T.H., 1970. Mapping Eye-Movement Patterns to the Visual Scene in Driving: An Exploratory Study. Human Factors: The Journal of Human Factors and Ergonomics Society 12 (1), 81–87. https://doi.org/10.1177/001872087001200112. ***[28]***.

Mucelli Rezende Oliveira, E., Carneiro Viana, A., Sarraute, C., Brea, J., Alvarez-Hamelin, I., 2016. On the regularity of human mobility. Pervasive Mob. Comput. 33, 73–90. https://doi.org/10.1016/j.pmcj.2016.04.005.

Neidhardt, E., Popp, M., 2010. Spatial tests, familiarity with the surroundings, and spatial activity experience: How do they contribute to children's spatial orientation in macro environments? J. Individ. Differ. 31 (2), 59–63. https://doi.org/10.1027/1614-0001/a000010. ***[29]***.

Payyanadan, R.P., Sanchez, F.A., Lee, J.D., 2019. Influence of familiarity on the driving behavior, route risk, and route choice of older drivers. IEEE Trans. Hum.-Mach. Syst. 49 (1), 10–19. https://doi.org/10.1109/THMS.2018.2874180. ***[85]***.

Pendyala, R.M. Measuring day-to-day variability in travel behavior using GPS data, Final Report. Washington, D.C.: FHWA; 1999; DTFH61-99-P-00266.

Peruch, P., Giraudo, M.-D., Garling, T., 1989. Distance cognition by taxi drivers and the general public. J. Environ. Psychol. 9 (3), 233–239. ***[62]***.

Phillips, J., Walford, N., Hockey, A., Foreman, N., Lewis, M., 2013. Older people and outdoor environments: Pedestrian anxieties and barriers in the use of familiar and unfamiliar spaces. Geoforum 47, 113–124. https://doi.org/10.1016/j.geoforum.2013.04.002. ***[59]***.

Ramachandran, D., Karpov, I.V., Gupta R, Raux A. Driver familiarity modeling for generating navigation directions. Proceedings of the 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, Netherlands 2013:2193-2200. doi:10.1109/ITSC.2013.6728553 [12]

Rasmussen, J., 1983. Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. IEEE Transactions on Systems, Man and Cybernetics SMC-13 (3), 257–266. https://doi.org/10.1109/TSMC.1983.6313160.

Richard, C.M., Campbell, J.L., Lichty, M.G., Brown, J.L., Chrysler, S., Lee, J.D., et al. Motivations for speeding, volume i: Summary report. In: Breckenridge C, editor. The Need to Speed: A Study of Behavior and Motivation New York: Nova Science Publishers, Inc.; 2014. p. 1-31. [52]

Riener, A., Ferscha, A., Aly, M. Heart on the road: HRV analysis for monitoring a driver's affective state. Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI 2009, Essen, Germany 2009:99-106. doi:10.1145/1620509.1620529 [47]

Roe, C.M., Stout, S.H., Rajasekar, G., Ances, B.M., Jones, J.M., Head, D., et al. A 2.5-year longitudinal assessment of naturalistic driving in preclinical Alzheimer's disease. J Alzheimer's Dis 2019;68(4):1625-1633. doi: 10.3233/JAD-181242 [43]

Rõivas, T., Antov, D., Oja, T., Abel, K., Sepp, E., 2011. Children's risks on their way to school: The example of Tallinn. WIT Trans. Ecol. Environ. 148, 529–538. https://doi.org/10.2495/RAV110481. ***[48]***.

Rosenbloom, T., Perlman, A., Shahar, A., 2007. Women drivers' behavior in well-known versus less familiar locations. J. Saf. Res. 38 (3), 283–288. https://doi.org/10.1016/j.jsr.2006.10.008. ***[70]***.

Ruggiero, G., Iachini, T., 2006. The effect of familiarity on egocentred and allocentred spatial representations of the environment. Cogn. Process. 7 (SUPPL. 1), 88–89. https://doi.org/10.1007/s10339-006-0081-7. ***[93]***.

Samson, B.P.V., Sumi, Y. Exploring factors that influence connected drivers to (not) use or follow recommended optimal routes. Proceedings of the Conference on Human Factors in Computing Systems, CHI 2019, Glasgow, United Kingdom 2019:1-14. doi: 10.1145/3290605.3300601. [54]

Sandberg, K., Timmermans, B., Overgaard, M., Cleeremans, A., 2010. Measuring consciousness: Is one measure better than the other? Conscious Cogn 19 (4), 1069–1078. https://doi.org/10.1016/j.concog.2009.12.013.

Schneider, W., Shiffrin, R.M., 1977. Controlled and automatic human information processing: I. Detection, search, and attention. Psychol Rev 84 (1), 1–66. https://doi.org/10.1037/0033-295X.84.1.1.

Schönfelder, S., 2006. Urban rhythms: Modelling the rhythms of individual travel behaviour PhD dissertation. Eidgenössische Technische Hochschule, Zürich, Switzerland.

Shaker, R.H., Eldesouky, R.S., Hasan, O.M., Bayomy, H., 2014. Motorcycle Crashes: Attitudes of the Motorcyclists Regarding Riders' Experience and Safety Measures. J. Community Health 39 (6), 1222–1230. https://doi.org/10.1007/s10900-014-9883-1. ***[83]***.

Shen, J., Wang, H., 2019. Effects of urban road variable message signs on driving behavior. Adv. Mech. Eng, 11 (4). https://doi.org/10.1177/1687814019841843. ***[87]***.

Shiffrin, R.M., Schneider, W., 1977. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. Psychol. Rev. 84 (2), 127–190. https://doi.org/10.1037/0033-295X.84.2.127.

Sivak, M., Schoettle, B., 2011. A preliminary analysis of traffic crashes by out-of-state drivers. Traffic Inj. Prev. 12 (3), 220–222. https://doi.org/10.1080/15389588.2011.553975. ***[6]***.

Sobková, L.F., Čertický, M., 2018. Urban mobility and influence factors: A case study of Prague. WIT Trans. Built Environ. 176, 207–217. https://doi.org/10.2495/UT170181.

Spering, M., Carrasco, M., 2015. Acting without seeing Eye movements reveal visual processing without awareness. Trends Neurosci. 38 (4), 247–258. https://doi.org/10.1016/j.tins.2015.02.002.

Spiers, H.J., Maguire, E.A., 2008. The dynamic nature of cognition during wayfinding. J. Environ. Psychol. 28 (3), 232–249. https://doi.org/10.1016/j.jenvp.2008.02.006. ***[60]***.

Steinberger, F., Moeller, A., Schroeter, R., 2016. The antecedents, experience, and coping strategies of driver boredom in young adult males. J. Saf. Res. 59, 69–82. https://doi.org/10.1016/j.jsr.2016.10.007. ***[49]***.

Taggart, P., Gibbons, D., Somerville, W., 1969. Some Effects of Motor-car Driving on the Normal and Abnormal Heart. Br Med. J. 4 (5676), 130–134. https://doi.org/10.1136/bmj.4.5676.130. ***[94]***.

Theeuwes, J., Godthelp, H., 1995. Self-explaining roads. Saf Sci 19 (2–3), 217–225. https://doi.org/10.1016/0925-7535(94)00022-U.

Thompson, C., Sabik, M., 2018. Allocation of attention in familiar and unfamiliar traffic scenarios. Transp. Res. Part F: Traffic Psychol. Behav. 55, 188–198. https://doi.org/10.1016/j.trf.2018.03.006. ***[8]***.

Tuan YF. Space and Place: The Perspective of Experience. Minneapolis, MN: University of Minnesota Press; 1977.

Turing, A.M., 1950. Computing machinery and intelligence. Mind 59 (236), 433–460. https://doi.org/10.1093/mind/LIX.236.433.

Valdés, D., Colucci, B., Knodler, M., Fisher, D., Ruiz, B., Ruiz, J., García, R., Colón, E., Hajiseyedjavadi, F., 2017. Comparative analysis of toll plaza safety features in Puerto Rico and Massachusetts with a driving simulator. Transp. Res. Rec.: J. Transp. Res. Board 2663 (1), 1–11. https://doi.org/10.3141/2663-01. ***[91]***.

Valdés, D., Knodler, M., Colucci, B., Figueroa, A., Rojas, M., Colón, E., et al. Speed Behavior in a Suburban School Zone: A Driving Simulation Study with Familiar and Unfamiliar Drivers from Puerto Rico and Massachusetts. Advances in Human Factors of Transportation 2020;964. doi: 10.1007/978-3-030-20503-4_30 [7]

Vansteenkiste, P., Van Hamme, D., Veelaert, P., Philippaerts, R., Cardon, G., Lenoir, M. Cycling around a curve: The effect of cycling speed on steering and gaze behavior. PLoS ONE 2014;9(7):1-11. doi:10.1371/journal.pone.0102792 [30]

Vardaki, S., Karlaftis, M.G. An investigation of older driver road safety perceptions and driving performance on freeways. Advances in Transportation Studies 2011(Special Issue):7-18. doi:10.4399/97888548465792 [30]

Venigalla, M., Zhou, X., Zhu, S., 2017. Psychology of route choice in familiar networks: Minimizing turns and embracing signals. J. Urban Plann. Dev. 143 (2), 04016030. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000364. ***[50]***.

Vlahodimitrakou, Z., Charlton, J.L., Langford, J., Koppel, S., Di Stefano, M., Macdonald, W., Mazer, B., Gelinas, I., Vrkljan, B., Porter, M.M., Smith, G.A., Cull, A.W., Marshall, S., 2013. Development and evaluation of a Driving Observation Schedule (DOS) to study everyday driving performance of older drivers. Accid. Anal. Prev. 61, 253–260. https://doi.org/10.1016/j.aap.2013.03.027. ***[9]***.

von Stülpnagel, R., Krukar, J., 2018. Risk perception during urban cycling: An assessment of crowdsourced and authoritative data. Accid. Anal. Prev. 121, 109–117. https://doi.org/10.1016/j.aap.2018.09.009. ***[78]***.

von Stülpnagel, R., Steffens, M.C., 2012. Can active navigation be as good as driving? A comparison of spatial memory in drivers and backseat drivers. J. Experimental Psychol.: Appl. 18 (2), 162–177. https://doi.org/10.1037/a0027133. ***[31]***.

Wallace B, Goubran R, Knoefel F. Cognitive change measurement through driving navigation ability sensing and analysis. Proceedings of IEEE International Symposium on Medical Measurements and Applications (MeMeA 2013) 2013:164-169. doi:10.1109/MeMeA.2013.6549728 [32]

Wang, Y., Mehler, B., Reimer, B., Lammers, V., D'Ambrosio, L.A., Coughlin, J.F., 2010. The validity of driving simulation for assessing differences between in-vehicle informational interfaces: A comparison with field testing. Ergonomics 53 (3), 404–420. https://doi.org/10.1080/00140130903464358.

Wen, H., Xue, G., 2020. Exploring the relationships between single-vehicle traffic accident and driver's route familiarity on the mountainous highways. Cogn. Technol. Work 22 (4), 815–824. https://doi.org/10.1007/s10111-019-00603-1. ***[69]***.

Wu, J., Xu, H., 2018. The influence of road familiarity on distracted driving activities and driving operation using naturalistic driving study data. Transp. Res. Part F: Traffic Psychol. Behav. 52, 75–85. https://doi.org/10.1016/j.trf.2017.11.018. ***[33]***.

Wurhofer, D., Krischkowsky, A., Obrist, M., Karapanos, E., Niforatos, E., Tscheligi, M. Everyday commuting: prediction, actual experience and recall of anger and frustration in the car. Proceedings of the 7th International Conference on automotive user interfaces and interactive vehicular applications (AutomotiveUI '15) 2015:233-240. doi:10.1145/2799250.2799251 [51]

Yanko, M.R., Spalek, T.M., 2013. Route familiarity breeds inattention: A driving simulator study. Accid. Anal. Prev. 57, 80–86. https://doi.org/10.1016/j.aap.2013.04.003. ***[34]***.

Yao, E.J., Pan, L., Yang, Y., Zhang, Y.S., 2013. Taxi driver's route choice behavior analysis based on floating car data. Appl. Mech. Mater. 361–363, 2036–2039. https://doi.org/10.4028/www.scientific.net/AMM.361-363.2036. ***[4]***.

Young, A.H., Mackenzie, A.K., Davies, R.L., Crundall, D., 2018. Familiarity breeds contempt for the road ahead: The real-world effects of route repetition on visual attention in an expert driver. Transp. Res. Part F: Traffic Psychol. Behav. 57, 4–9. https://doi.org/10.1016/j.trf.2017.10.004. ***[35]***.