What Cognitive Mechanisms Predict Travel Mode Choice? A Systematic Review with Meta-Analysis

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Introduction

Increasing reliance on car use is associated with substantial negative impacts on human health and the environment, especially in cities (Gärling & Friman, 2015). For instance, non-car commuting, such as walking and cycling and using public transport (PT) can contribute to daily recommended levels of physical activity (Sahlqvist, Song, & Ogilvie, 2012; Wener & Evans, 2007). Active transport and use of PT also reduces pollution. For instance, use of PT can result in 45% less CO_2 and 48% less nitrogen oxide emissions compared to private vehicle use (Shapiro, Hassett, & Arnold, 2002). Unfortunately, however, the use of cars for school runs (Ulfarsson & Shankar, 2008), leisure purposes (Van Acker, Mokhtarian, & Witlox, 2011), tourism mobility (Ram, Nawijn, & Peeters, 2013) and most notably for commuting to work (Panter, Desousa, & Ogilvie, 2013), is increasing and current trends suggest a doubling of global car ownership by 2040 (IEA, 2015).

To understand how interventions could effectively promote alternative travel mode choices, researchers have investigated several predictors of car use and alternative travel modes including, geographic (Park, Kang, & Choi, 2014), economic (Frank, 2004) and psychological factors (Gardner & Abraham, 2008). Narrative reviews, have synthesised determinants of car use across disciplines, concluding that travel time and cost, socio-demographic and spatial characteristics and car availability are key antecedents of travel mode choice (De Witte et al., 2013; Frank et al., 2008). Identifying psychological changes that could increase use of alternatives to car travel (henceforth abbreviated as 'non-car-use') provides a theoretical basis for so-called 'soft' interventions to promote voluntary behaviour change (Fujii, Gärling, & Kitamura, 2001). Such interventions, can be cost-efficient and quickly implemented compared to, for instance, engineering solutions (Cairns et al., 2008; Richter, Friman, & Gärling, 2010). In reality, policy strikes a balance between the two.

Social-psychological theory has identified a range of potentially-modifiable cognitive mechanisms that can be targeted in travel mode choice interventions (Bamberg, Fujii, Friman, & Gärling, 2011). Most commonly, the Theory of Reasoned Action (Fishbein & Ajzen, 1975) and its successor, including perceived behavioural control (PBC), the Theory of Planned Behaviour (TPB) (Ajzen, 1991) have both been tested. Attitudes, subjective norms and PBC are products of underpinning beliefs and many beliefs related to safety, convenience, time flexibility, practicality, health, accident risk and comfort have been investigated as antecedents of travel mode attitudes (e.g. Mann & Abraham, 2012; Gärling et al., 1998; Bamberg et al., 2007; Heath & Clifford, 2002; Şimşekoğlu et al., 2015).

Understanding of the role of normative beliefs, in particular, has been furthered by development of the Norm Activation Model (NAM) (Schwartz, 1977). This model's core construct is personal norms or the "individual's internalised moral rules" (Parker, Manstead, & Stradling, 1995, p. 129). Dunlap and Van Liere (1978) propose, that "to the extent that concern for the well-being of other humans is aroused, we would expect traditional moral norms which regulate interpersonal behavior to influence environmental behaviors" (p.175). Schwartz (1977) argues for a direct influence of personal norms on behaviour, as opposed to the mediating role for intentions proposed by the TPB. According to the NAM, personal norms influence behaviour when ascription of responsibilities and awareness of consequences are activated. The former refers to a person's self-ascribed responsibility to, for instance, refrain from using the car. The latter describes the level of awareness of environmental damage caused by human influences.

The Value-Belief-Norm (VBN) model (Stern, Dietz, Abel, Guagnano, & Kalof, 1999), clarifies how values are related to behaviour in the NAM. Stern et al. (1999) propose that biospheric, altruistic and egoistic values may all be related to environmentally-relevant behaviour.

It has been argued that these models and other rational choice theories do not adequately represent behaviour patterns that may be regulated by less conscious processes (Sniehotta, Presseau, & Araújo-Soares, 2014; Triandis, 1977). For instance, when behaviours are practiced in stable environments over time, they can be automatically initiated by environmental prompts with little or no conscious deliberation (Strack & Deutsch, 2004). Thus, since daily travel tends to occur in stable contexts, transport mode choice may, over time, become less of a "choice" and more of a habitual response executed with little reflection (Gardner, 2009; Gärling & Axhausen, 2003). Habit was first introduced in Triandis' (1977) Theory of Interpersonal Behaviour and it has been shown that the formation of habits may change the cognitive mechanisms underpinning travel (Verplanken, Aarts, van Knippenberg, & van Knippenberg, 1994).

A limited number of systematic reviews have evaluated interventions that implemented evidence on the importance of a range of cognitive mechanisms to change transport mode choices, but evidence of effectiveness of such interventions is sparse (Arnott et al., 2014; Graham-Rowe, Skippon, Gardner, & Abraham, 2011; Macmillan, Hosking, Connor, Bullen, & Ameratunga, 2013). This implies that our understanding of travel mode choice is incomplete. Reviews of effectiveness may not elucidate which interventions work best under varying circumstances. For instance, as Bamberg (2006) notes, "summarizing and comparing average intervention effects *per se* provides little insight into the conditions and mechanisms mediating these effects" (p. 821). More integrative systematic reviews are needed so that intervention designers can identify relevant cognitive mechanisms linked to driving decisions and circumstances in which those mechanisms might be more susceptible to modification.

So which potentially-modifiable psychological/ cognitive mechanisms should be targeted by interventionists attempting to change travel mode choice? Gardner and Abraham

(2012) provide a useful review of the associations between psychological constructs and car use but were limited to reviewing 23 available studies. We sought to provide a comprehensive review examining associations between modifiable cognitions and both car use and non-car-use. We will use the term "cognitive mechanisms" to refer to a set of psychological measures that have been related to car use and non-car-use across this literature. This includes implicit and explicit measures of beliefs (including normative beliefs), attitudes (including feelings), motives and self-reported habitual action.

The Present Study

We updated and extended the work of Gardner and Abraham (2008) by taking account of a wider range of potentially-modifiable cognitive mechanisms (henceforth abbreviated to "cognitive mechanisms") based on a larger sample of studies. The present review distinguished between correlates of car use and non-car-use (e.g., use of public transport instead of driving) and examined potential moderators. Five questions were addressed: (1) which cognitive mechanisms have been used to explain car use and non-car travel, (2) how methodologically rigorous are available studies, (3) which theories do identified cognitive mechanisms represent, (4) how strong are bivariate associations between specific cognitive mechanisms and car use/ non-car-use, and (5) is strength of these associations moderated by contextual factors such as study location, journey type and travel measure (e.g., 'typical car use' versus 'actual car use').

Methods

Many narrative reviews usefully summarise existing literature but only in relation to specific review questions. In this study we conducted a systematic review to ensure a more comprehensive and transparent summary of the literature (Young et al., 2002; Tranfield et al., 2003). In addition, we conducted a narrative synthesis of identified cognitive mechanisms

and, based on this, a meta-analytic synthesis of (zero order) bivariate correlations between categories of cognitive mechanisms and car use. The review was conducted in accordance with the guidance provided by the University of York, Centre for Reviews and Dissemination for undertaking systematic reviews (Khan, Ter Riet, Glanville, Sowden, & Kleijnen, 2001).

Inclusion Criteria

We included papers that (1) provided at least one quantitative measure of an association between a cognitive mechanism and a measure of car use or non-car-use, (2) were published in English in a peer-reviewed journal, (3) sampled a range of the adult driving population (>18 years), (i.e. excluding studies that investigated only e.g. older adults (>60 years), particular households, people with impaired mental and physical abilities or non-license holders), and (4) focused on any journey type (i.e. excluding studies that focused exclusively on e.g. school runs or holiday travel). No limitations were set on publication date, study design or other socio-demographic population characteristics. When multiple papers reporting results based on a unique data set were identified, the paper with the most comprehensive methodological description was retained for analyses. Where necessary, secondary articles reporting on the same data set were used to complete data extraction. Supplementary File, Chapter 1 provides further explanation of our inclusion criteria.

Search Strategy

The systematic search was closed in September 2015. Ten databases were searched for keywords, abstracts and titles including the meta-databases EBSCO, Web of Knowledge, Transport Research Board and ProQuest. The search used 77 keywords related to travel mode choice (e.g. “modal choice”), transport (e.g. “car”) and social-psychological categories (e.g. “antecedent”). Search terms and Boolean combinations were customised to accommodate

differences across databases. An illustration of one systematic search can be found in Supplementary File, Chapter 1, Table S1. Ancestry and descendency searches were performed by hand-searching reference lists of included key papers and systematic/narrative review articles as well as citation searches using Google Scholar until no new records could be identified.

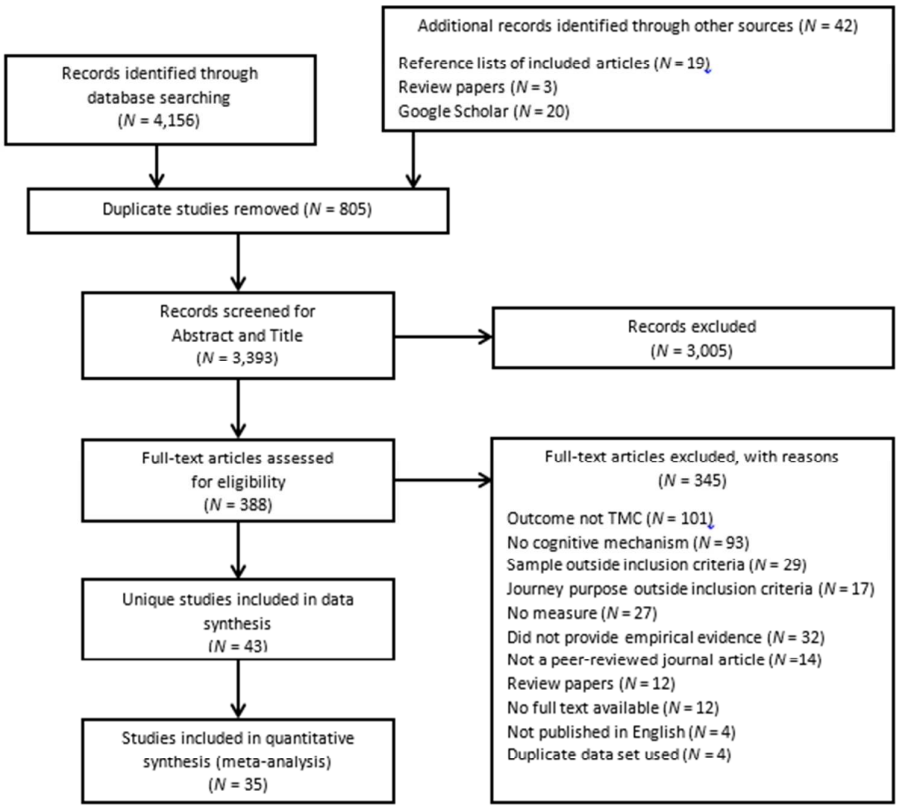
Study Selection and Data Collection

The systematic search strategy identified 4,156 records which were initially screened for title as well as abstracts. A second reviewer independently screened a random selection of 306 (of 3005, 10%) excluded records and agreed, in all cases, that none of those papers should have been included in the review. Full text screening of 388 articles was completed based on the pre-defined inclusion criteria. A final number of 43 studies were deemed eligible for inclusion. Eighty-six studies (43 included and 43 excluded) were independently screened by a second coder. The AC1 statistic (Gwet, 2002) was used to calculate the degree of agreement between two coders and a score of 0.93 indicated good inter-rater reliability. Disagreements were resolved by consensus or in consultations with a third researcher.

Extracted information included measures of cognitive mechanisms, detail of study characteristics, statistical analysis, dependent car use and non-car use measures and methodological quality criteria. Longitudinal data were extracted from the most recent set of measures. Only baseline measures or control group data were extracted from studies with an experimental design. Wherever possible, Pearson's correlation coefficients were extracted; otherwise Spearman's correlation coefficients or point-biserial correlations were used. Authors were contacted if relevant information could not be extracted and studies were excluded from meta-analyses if effect sizes were unobtainable. Of 43 eligible studies, 35 could be included in quantitative synthesis.

Included papers are marked with one asterisk in the reference list and with two asterisks if data was included in meta-analyses. Figure 1 illustrates the steps of the study selection process in more detail.

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flowchart



Methodological Quality Assessment

The majority of included studies were cross-sectional surveys. No suitable quality assessment tool was found to assess such survey studies. We therefore applied three criteria that were highlighted across six previous studies recommending bias assessment in correlational studies (EPHPP, 1998; Gautheir, 2003; NHLBI, 2014; Pace et al., 2012; von Elm et al., 2014; Wong,

Cheung & Hart, 2008). We have adopted the most common criteria across these validated quality assessment tools. First, was the sample size sufficiently large to find the hypothesized effects? Two criteria were used: (1) use of power analyses to guide sample size selection *or*; (2) a sample size greater than 200 if path analysis or structural equation modelling (SEM) were employed (Hoelter, 1983, Kline, 2011, Garver & Mentzer, 1999). Second, was the sample representative of the target population? Third, did the study use reliable and valid measures as assessed by use of previously-validated/tested/used measures and reporting of internal scale reliability (α>0.6) (Gliem & Gliem, 2003). Studies could score 1 point for of the first and second criteria. In assessing question 3, each measure of a cognitive mechanism was assessed separately and contributed to a single ratio of valid//reliable measures for each study. Hence, studies that included multiple measures could score between 0 and 1 point. Single-item measures were deemed not applicable for reliability assessment, hence not included in the score. A score of 0 was assigned if the criteria were inadequately reported, unclear or absent. Studies that achieved an overall score >2, 1-2, <1 were rated as high, medium or low quality, respectively. We did not exclude studies on the basis of low quality scores but used the criteria to highlight areas of potential bias. A detailed definition of assessment criteria can be found in the Supplementary File, Chapter 3, Table S4.

Data Synthesis

A narrative synthesis was conducted (Popay et al., 2006) by qualitatively summarising extracted data to identify categories of cognitive mechanisms. In addition, a meta-analysis of correlation coefficients was undertaken to summarise effect sizes for each identified cognitive mechanism. Random-effects analyses were undertaken, assuming that not all study effects are homogenous (Hunter & Schmidt, 2004).

Effect size analysis and multiple measures

Pearson's correlation coefficient r ($N = 30$), the point-biserial correlation r_{pb} ($N = 4$) and Spearman's rank correlation coefficient ρ ($N = 1$) could be obtained from a total of 35 studies. In order to assign more weight to studies that carry more information, i.e. had larger sample sizes, the meta-analysis produced a weighted average effect size (r_+). A 95% confidence interval was used to infer statistical significance. Pooled effect sizes are interpreted in accordance with thresholds proposed by Cohen (1988) where $r_+ \geq .10$, $r_+ \geq .30$, $r_+ \geq .50$ and $r_+ \geq .70$ qualify as small, medium, large or very large effects, respectively.

Our meta-analytic procedure frequently included more than one effect size per cognitive mechanism that was extracted from the same study (Myrtek, 1995; Pole, 2007; Wolf, 1986). For example, van Vugt et al.'s (1995) study measured the association between subjective importance of the environment and of public health using two different scales. Although the scales produced two different effect sizes, they are not independent of each other. Therefore, we combined those study effects *a priori* to obtain an average effect (Borenstein et al., 2009). Consequently, we only used one (average) effect size for meta-analysis for which we extracted two associations at first. Hence, k refers to the number of unique associations tested. Meta-analysis was performed where $k \geq 3$. While conclusions cannot be drawn from $k = 2$ analyses (Ryan, 2013), all these analyses are presented for comparative purposes.

Test of homogeneity and bias

Chi-squared was used to test for heterogeneity. We expected X^2 to have a value at least as high as its degrees of freedom and $p > .05$ for studies to be considered homogeneous. For ease of interpretation, we also calculated the heterogeneity index I^2 to summarise inconsistencies across studies (Burnette, O'Boyle, VanEpps, Pollack, & Finkel, 2013). This

statistic describes the variation across studies as a result of heterogeneity rather than chance (Higgins & Thompson, 2002) with higher percentage values demonstrating greater heterogeneity of effect sizes. I^2 values were interpreted in accordance with Higgins and Green (2009), whereby values between 0-40%, 30-60%, 50-90% and 75-100% represent no, moderate, substantial and considerable heterogeneity, respectively.

Egger's regression test (Egger, Smith, Schneider, & Minder, 1997) and interpretation of funnel plots was used, wherever possible, to detect evidence of publication bias (Rosenthal, 1979; Begg & Mazumdar, 1994). Bias was considered to be present if the intercept significantly ($p < 0.1$) differed from 0. Some analyses had insufficient numbers of studies for the test to be carried out so that results cannot be reported consistently.

Results

Study Characteristics

Included studies ($N = 43$) were predominantly cross-sectional surveys ($N = 26$, 60.5%) that recruited, on average, 584 participants, with a slight over-representation of female participants (54%). Across all studies, a minority ($N = 7$, 16.3%) used student-only samples. The majority of studies were conducted in Europe ($N = 36$, 83.7%) with contributions primarily from Germany ($N = 13$), the Netherlands ($N = 8$) and the UK ($N = 7$). Other studies were conducted in USA ($N = 3$), Australia ($N = 3$) and Canada ($N = 1$). Approximately one quarter of the studies ($N = 10$, 23.3%) were conducted before the year 2000. Detailed information on individual study characteristics can be found in the Supplementary File, Chapter 2, Tables S2 and S3.

Setting, Journey Characteristics and Dependent Measures

Thirty-eight studies (88.4%) reported geographic settings ($N = 38$), of which 27 (71%) were

conducted in urban areas, three used rural samples and eight mixed rural, suburban and urban samples. Studies that included rural, suburban or a mix were aggregated and entered as non-urban studies in meta-analyses.

Various journey types were considered. A large number of studies focused on commuting trips only (N = 19, 44.2%). The remaining 24 studies were aggregated as non-commuting journeys, of which shopping (N = 7, 30.4%) and leisure trips (N = 6, 26.1%) were the most frequent.

A variety of simple self-report car use and non-car-use measures were considered. A continuous measure of "typical car use" was employed by 30 studies (69.8%), e.g. "how many times during the last week have you used the car?" (5-point scale *seldom – always*) or "In the last week, how many of your journeys were made using a car?" (5-point scale *all journeys – no journeys*). Thirteen studies (30.2%) used self-administered travel diaries (over several days or weeks) to log multiple trips and modes and were summarised as "actual car use" studies. Continuous measures were derived by calculating a ratio, e.g. the sum of reported journeys made by car divided by the total number of reported journeys. Dichotomous measures (N = 7, 16.3%) were used where, e.g. a value of 1 was given if a participant used PT and zero for car use.

Measures of Potentially-Modifiable Cognitive Mechanisms (Research Question 1)

Overall, 333 associations were found between (1) a cognitive mechanism measure and (2) a measure of car use/ non–car-use frequency or intensity. The number of associations reported per study ranged from one (Davidov, 2007; Tischer & Phillips, 1979; Verplanken, Walker, Davis, & Jurasek, 2008) to 20 (Mann & Abraham, 2012) per dependent variable with an average of seven. One study tested 36 associations across three different car use measures (Van Acker et al., 2011). Later studies tended to measure more cognitive mechanisms per

dependent measure (see Supplementary File, Chapter 4, Figure S2).

Operationalisations of non-car-use cognitive mechanisms varied considerably. For example, considering attitudes towards non-car-use travel, some studies concentrated only on one mode such as train travel (Verplanken et al., 1994) or PT in general (Nilsson & Kuller, 2000), while others measured attitudes towards using PT instead of the car (Bamberg, 2006; Matthies, Klöckner, & Preissner, 2006). Studies also concentrated on attitudes towards reducing the number of journeys (Abrahamse, Steg, Gifford, & Vlek, 2009), not using the car (Gardner & Abraham, 2010), or using other forms of transport instead of the car (Harland, Staats, & Wilke, 1999). Two studies measured attitudes towards the use of active modes, e.g. cycling (Haustein & Hunecke, 2007) and walking/ cycling (Van Acker et al., 2011) as separate variables in addition to PT use.

This range of conceptually and psychometrically different measures of cognitive mechanisms was aggregated into meaningful categories. We applied a similar coding scheme as used in previous meta-analyses (e.g. Hagger, Chatzisarantis, & Biddle, 2002) in order to maintain continuity and transparency of categorisation. A second independent researcher categorised 65% of all measures and coders agreed on 88% of classified measures. Disagreements were resolved through discussion. The number of studies and reported associations per cognitive mechanism can be found in the Supplementary File, Chapter 4, Table S6. Supplementary Table S7 (Chapter 4 in the Supplementary File) shows an overview of the emerged categories including a more detailed definition and examples.

Methodological Quality Assessment (Research Question 2)

Study quality was assessed for 43 studies and a mean score of 1 (range: 0 to 3) indicated a low to medium overall study quality. Seven studies (16.3%) could be classified as high quality, 18 studies (41.9%) as medium and the remaining 18 (41.9%) as low quality. Detailed

scores for individual studies can be found in Supplementary File, Chapter 3, Table S5.

Sample size

Only 9 of 12 studies which performed SEM or path analysis used a sufficient sample of 200 or more. Of those that did not perform SEM or path analysis, only three of 31 (9.7%) reported undertaking a power calculation prior to data collection of which two achieved the required sample size.

Sample representativeness

Seven studies (16.3%) used a representative sample of the target population. One third of included studies ($N = 14$, 32.5%) acknowledged having used samples that could not be described as representative and 22 (51.2%) did not discuss sample representativeness.

Validity/reliability

The most frequent previously-validated measure used was the Response Frequency Measure (RFM) of habit (Verplanken et al., 1994) used in ten (23.3%) studies. Overall 32 (74.4%) studies used at least one previously-validated/tested/used measure. Of 214 measures eligible for reliability evaluation, 87 (40.6%) achieved acceptable internal reliability (Cronbach's alpha >0.6). We were unable to determine scale reliability for half of these measures ($N = 108$, 50.47%) due not reported data.

Use of Theoretical Frameworks (Research Question 3)

Twenty four studies (55.8%) were explicitly based on an underlying theoretical framework and eight multi-component theories were applied. Studies used measures derived from Ajzen's (1991) TPB ($N = 16$, 66.7%), the habit-extended Theory of Interpersonal Behaviour by Triandis (1977) ($N = 1$, 4.2%), Schwartz' (1977) NAM ($N = 6$, 2%), Stern et al.'s (1999)

modified VBN model ($N = 1$), Stryker's (1980) Identity Theory ($N = 1$), Kelley and Thibaut's (1978) Interdependence Theory ($N = 1$), Dittmar's (1992) Model on the Meaning of Material Possessions ($N = 1$), and Frey's (1988) Ipsative Theory of Behaviour ($N = 2$, 8.3%). Authors rarely used theories in combination ($N = 3$, 12.5%), but more frequently extended the TPB ($N = 8$, 33.3%) and NAM ($N = 2$) by measuring additional cognitive mechanisms, predominantly habit ($N = 4$, 16.7%) and personal norms ($N = 2$).

Meta-analytic Results (Research Questions 4 and 5)

Data were available from 35 studies for inclusion in the meta-analyses (see Supplementary File, Chapter 5 for further explanations and more detailed results). We performed meta-analysis separately for: (1) cognitive mechanisms associated with car use (i.e. frequency or intensity of car use), and (2) cognitive mechanisms associated with non-car-use (i.e., how much car use had been replaced by an alternative mode). Moderator analyses (research question 5) were conducted when there were at least two studies and three associations in the smallest of the comparison groups. Results of these analyses are included in Tables 1 and 2. Below we only highlight significant dissimilarities between moderator groups, based on comparisons of confidence interval overlap.

A low number of studies testing each cognitive mechanism only allowed to perform bias assessment for 22 (out of 53) meta-analyses, of which seven were significant. We could not find any evidence suggestive of publication bias for most of the TPB measures and habit measures. However, results of Egger's tests suggested that for Car Use Attitude there may be "missing studies".

Cognitive mechanisms associated with car use

Table 1 presents meta-analytic results for associations with car use ($N = 27$, $k = 87$) for a total sample of 35,645. Car use was mainly operationalised as driving or using a private motorised

vehicle but occasionally included taxi journeys (Gardner & Abraham, 2010), taxi and motorcycle use (Verplanken et al., 2008), or car share and rental cars (Hunecke, Haustein, Grischkat, & Bohler, 2007). One study specified car use as single occupancy driving (Golob & Hensher, 1998).

Table 1. Results of the meta-analysis of car use

Cognitive mechanism (sub-groups)	*n*	*k*	*r*+	95% CI	I^2 (%)	*Egger's test*
Car Use Attitudes	**4647**	**38**	**0.22*** **	**0.13, 0.30**	**91.6**	**6.8 (*p* = 0.01)**
non-urban	3186	29	0.14***	0.06, 0.23	87.2	8.8 (*p* = 0.07)
urban	1461	9	0.31***	0.21, 0.41	83.2	3.6 (*p* = 0.17)
non-commuting journeys	3019	24	0.15**	0.05, 0.25	92.4	9.4 (*p* = 0.12)
commuting journeys	1628	14	0.34***	0.26, 0.42	78	4.2 (*p* = 0.11)
non-European	927	3	0.37***	0.26, 0.48	83.9	7.8 (*p* = 0.10)
European	3720	35	0.18***	0.09, 0.27	90.8	6.3 (*p* = 0.04)
typical car use	4218	28	0.21***	0.12, 0.30	92.3	6.5 (*p* = 0.01)
actual car use	429	10	0.28*	0.06, 0.50	92	-
TPB measures	1290	6	0.33***	0.20, 0.46	89.3	2.8 (*p* = 0.62)
Beliefs	3586	32	0.19***	0.09, 0.29	92.2	9.2 (*p* = 0.01)
Non-car-use Attitudes	**812**	**3**	**-0.23****	**-0.40, -0.06**	**90.7**	**-**
Attitudes - Travel in General	**1486**	**10**	**0.05**	**-0.05, 0.15**	**84.6**	**-**
Attitudes - Environment & Health	**4097**	**9**	**-0.10****	**-0.17, -0.03**	**86.2**	**-**
non-urban	2804	3	-0.09	-0.18, 0.00	89	-
urban	1293	6	-0.13*	-0.25, 0.00	87.4	-
Attitudes - Transport Environment	**4811**	**12**	**-0.28*****	**-0.41, -0.15**	**97.5**	**-**
non-urban	1759	8	-0.17***	-0.23, -0.11	70.5	-
urban	3052	4	-0.35***	-0.52, -0.17	98.6	-
Car Use Subjective Norms	**1455**	**6**	**0.20****	**0.05, 0.35**	**91.3**	**12.2 (*p* = 0.20)**
Non-car-use Subjective Norms	**944**	**3**	**-0.15*****	**-0.20, -0.11**	**0**	**-**
Car Use Descriptive Norms	**532**	**3**	**-0.07**	**-0.35, 0.21**	**94.2**	**-**
Car Use PBC	**1605**	**9**	**0.39*****	**0.18, 0.60**	**97.1**	**-6.3 (*p* = 0.75)**
Non-car-use PBC	**1200**	**5**	**-0.42*****	**-0.57, -0.28**	**93**	**-**
PBC - Environment	**324**	**4**	**-0.08****	**-0.17, -0.05**	**52.8**	**-**
Car Use Intentions	**2375**	**7**	**0.50*****	**0.31, 0.68**	**98.3**	**8.3 (*p* = 0.33)**
non-urban	844	3	0.34	-0.04, 0.71	99.2	-
urban	1531	4	0.59***	0.47, 0.70	95.6	9.1 (*p* = 0.01)
non-commuting journeys	1438	3	0.50***	0.33, 0.67	96.7	-
commuting journeys	937	4	0.50**	0.15, 0.85	98.9	26.4 (*p* = 0.24)
typical car use	1839	4	0.47***	0.26, 0.67	97.9	6.2 (*p* = 0.62)
actual car use	536	3	0.62***	0.25, 0.98	98.7	-

Cognitive mechanism (sub-groups)	*n*	*k*	*r*+	95% CI	I^2 (%)	*Egger's test*
Non-car-use Intentions	**943**	**3**	**-0.38***	**-0.68, -0.09**	**98.1**	**-**
Non-car-use Personal Norms	**793**	**5**	**-0.35*****	**-0.42, -0.28**	**69.3**	**-**
Ascription of Responsibilities	**642**	**3**	**-0.14**	**-0.31, 0.03**	**87.7**	**-**
Awareness of Consequences	**2139**	**6**	**-0.22*****	**-0.29, -0.16**	**69.1**	**-**
Altruistic Value Orientation	**184**	**3**	**-0.32*****	**-0.34, -0.29**	**0**	**-**
Identity Anti-Car	**1609**	**11**	**-0.08****	**-0.11, -0.02**	**39.1**	**-**
Identity Pro-Car	**4229**	**11**	**0.05*****	**0.04, 0.07**	**0**	**-**
Social Comparison	**1247**	**6**	**0.16****	**0.06, 0.26**	**84.5**	**-**
Car Use Habit - RFM	**2058**	**6**	**0.47*****	**0.39, 0.56**	**89**	**2.7 (p = 0.42)**
typical car use	445	3	0.53***	0.39, 0.66	87.9	-
actual car use	1613	3	0.46***	0.35, 0.57	92.1	-
Car Use Habit - Other Measures	**2160**	**7**	**0.38*****	**0.20, 0.56**	**97.8**	**7 (p = 0.48)**
past behaviour	1248	2	0.58***	0.37, 0.78	97.7	-
SRHI	523	2	0.28	-0.08, 0.64	98.6	-
latent variable	1437	2	0.49***	0.29, 0.69	98.6	-
*p<.05, **p<.01, ***p<.001						

Car use Attitudes were the most studied cognitive mechanism with 38 associations tested. The meta-analysis suggested that the relationship between (positive) attitudes and car use was positive, and of a small to medium size (r_+ = .22, CI: 0.13;0.30). There was considerable heterogeneity across studies (I^2 = 91.6%).

Moderator analysis, to explore this heterogeneity further, showed that the link between attitudes and car use was stronger for commuting journeys (r_+ = .34, CI: 0.26;0.42, k = 14, I^2 = 78%) than for non-commuting journeys (r_+ = .15, CI: 0.05;0.25, k = 24, I^2 = 92.4%). Attitudinal scales using TPB measures were relatively stronger predictors (r_+ = .33, CI: 0.20;0.46, k = 6, I^2 = 89.3%) while those employing car use beliefs showed smaller effects (r_+ = .19, CI :0.09;0.29, k = 32, I^2 = 92.2%).

Non-car-use Attitudes. Favourable attitudes towards alternative transport modes were negatively associated with car use (r_+ = -.23, CI: -0.40;-0.06, k = 3, I^2 = 90.7%). Despite

continued heterogeneity, moderator analysis was not performed due to a limited number of associations.

Attitudes - Travel in General. The relationship general evaluations about travel and car use was not significant (r_+ = .05, CI: -0.05;0.15, k = 10, I^2 = 84.6%). The result was underpinned by only three studies of varying effect sizes. Attitudinal measures varied, assessing the subjective importance of flexibility or time (Joireman, Van Lange, Kuhlman, Van Vugt, & Shelley, 1997; Van Vugt, Meertens, & Van Lange, 1995), stress (Cao & Mokhtarian, 2005) or comfort (Joireman et al., 1997). Inconsistent operationalisations may have created this variability.

Attitudes - Environment & Health. Drivers' concern about environmental protection and public health showed small negative associations with car use (r_+ = -.10, CI: -0.17;-0.03, k = 9, I^2 = 86.2).

Attitudes - Transport Environment. Positive perceptions of the built environment such as proximity to shops (Scheiner & Holz-Rau, 2007), walkability or cyclability (Panter et al., 2013) or concerns about traffic congestion (Golob & Hensher, 1998) were also negatively associated with car use (r_+ = -.28, CI: -0.41;-0.15, k = 12, I^2 = 97.5%).

Car Use Subjective Norms. A small to medium-sized positive association was observed between driving and drivers' perceptions of others' approval of driving (r_+ = .20, CI: 0.05;0.35, k = 6). Effect sizes varied considerably across studies (range from r = .03 to r = .52, I^2 = 91.3%) with half of the studies including subjective norm measures (N = 3) reported non-significant associations with car use.

Non-car-use Subjective Norms. Combining effect sizes from three studies generated a small negative, homogeneous average association (r_+ = -.15, CI: -0.20;-0.11, I^2 = 0%).

Car Use Descriptive Norms. Although there was a small negative relationship between self-reported car use and perceptions about other people's car use behaviour, this was not significant (r_+ = -.07, CI: -0.35;0.21, I^2 = 94.2%).

Car use PBC. Control beliefs (e.g. freedom or confidence) were positively associated with car use (r_+ = .30, p = .021, k = 10) and this was increased (r_+ = .39, CI: 0.18;0.60, k = 9) when an anomalous negative association (Gardner & Abraham, 2010, r_+ = -.33) was removed from further analysis. Heterogeneity was again high (I^2 = 97.1%) reflecting the combination of measures of feasibility, (Verplanken, Aarts, van Knippenberg, & Moonen, 1998), confidence, (Panter et al., 2013) and perceptions of parking problems and accident risks (Mann & Abraham, 2012).

Non-car-use PBC. A negative heterogeneous association was observed between perceived difficulty of driving and car use (r_+ = -.42, CI: -0.57;-0.28, k = 5, I^2 = 93%).

PBC - Environment. People's beliefs about the capability of reducing environmental damage showed a very small negative, though relatively homogenous, negative association with car use (r_+ = -.08, CI: -0.17;-0.05, k = 4, I^2 = 52.8%).

Car Use Intentions showed a large, positive, heterogeneous association with car use (r_+ = .50, CI: 0.31;0.68, k = 7, I^2 = 98.3%). See Supplementary File, Chapter 5.1 for further details about effect size variability.

Non-car-use Intentions produced a weaker, negative, heterogeneous association with car use (r_+ = -.38, CI: -0.68;-0.09, k = 3, I^2 = 98.1%).

Non-car-use Personal Norms. Feeling a moral obligation not to drive had a negative medium association with car use (r_+ = -.35, CI: -0.42;-0.28). This result was underpinned by five studies with substantial heterogeneity (I^2 = 69.3%).

Awareness of Consequences. Combining effect sizes generated a small to medium negative effect (r_+ = -.22, CI: -0.22;-0.16, k = 6, I^2 = 69.1%), such that people who were more aware of the environmental consequences of car use, also reported driving less frequently. See Supplementary File, Chapter 5.2 for for further details about effect size variability.

Ascription of Responsibilities. The relationship between car use and the perceived responsibility to reduce environmental impacts was negative but not significant (r_+ = -.14, CI: -0.31;0.03, k = 3, I^2 = 87.7%).

Altruistic Value Orientation. Consistent with theory, there was a negative, moderate association between altruistic values and car use (r_+ = -.32, CI: -0.34;-0.29, k = 3). Meta-analysis was performed on two homogeneous studies (I^2 = 0%).

Identity. A very small, negative association was observed between car use and anti-car identity measures (r_+ = -.08, CI: -0.11;-0.02, k = 11), while a very small positive association was observed between car use and pro-car identities (r_+ = .05, CI: 0.04;0.07, k = 11). Both effects were homogeneous (I^2 = 39.1% and I^2 = 0%, respectively).

Social Comparison. A small positive effect of $r_+ = .16$ (CI: 0.06;0.26, $k = 6$, $I^2 = 84.5\%$) showed that people who consider driving as a means of self-evaluation and self-enhancement are also more likely to use the car.

Car Use Habit – RFM. Verplanken et al.'s (1994) Response Frequency Measure of habit was employed by six studies (a tool to assess habit strength of travel mode choices across different travel situations, drawing on automaticity component of habit). Meta-analysis suggested that car use was positively, associated with strong car use habits, though the effect was considerably heterogeneous ($r_+ = .47$, CI: 0.39;0.56, $k = 6$, $I^2 = 89\%$).

Car Use Habit – Other Measures. Five studies reported a total of seven associations that used other measures of car use habit based on different conceptualisations of habit (see Supplementary File, Chapter 5.3). Meta-analysis produced a medium to large, positive heterogeneous, effect of $r_+ = .38$ (CI: 0.20;0.56, k = 7, $I^2 = 97.8\%$). Moderator analyses for the different conceptualisations of habit identified the largest effect for "past behaviour" ($r_+ = .58$, CI: 0.37;0.78, $k = 2$, $I^2 = 97.7\%$). Whilst generating the largest effect size, this result was based on only two studies.

Cognitive mechanisms of non-car-use

Table 2 presents results for the meta-analysis of non-car-use studies with an overall sample size of $n = 12{,}335$. Only nine studies were available for inclusion, so few moderator analyses could be undertaken. Moreover, these studies used varying operationalisations of alternatives to car use. Specifically, (1) use of other forms of transport in general (Harland et al., 1999), (2) use of PT (Bamberg, 2006; Yang-Wallentin, Schmidt, Davidov, & Bamberg, 2004), (3) use of environmentally friendly transport modes (incl. walking, cycling, bus, tram/subway, regional train, long-distance train) (Haustein & Hunecke, 2007) and (4) use of the subway

instead of the car (Hunecke, Blöbaum, Matthies, & Hoeger, 2001). Aggregating these operationalisations is not ideal and high levels of heterogeneity suggests caution in interpretation.

Table 2. Results of the meta-analysis of non-car-use

Cognitive mechanism (sub-groups)	*n*	*k*	*r*+	95% CI	I^2 (%)	*Egger's test*
Non-car-use Attitudes	**2597**	**7**	**0.36*** **	**0.21, 0.51**	**97.1**	**11.3 (*p* = 0.19)**
Non-car-use Subjective Norms	**2745**	**6**	**0.28*** **	**0.14, 0.41**	**95.6**	**5.1 (*p* = 0.41)**
Non-car-use PBC	**3500**	**9**	**0.49*** **	**0.41, 0.57**	**93.9**	**8.3 (*p* = 0.14)**
typical non-car-use	2347	4	0.49***	0.39, 0.59	93.3	-
actual non-car-use	1153	3	0.50***	0.34, 0.66	97.2	-
Non-car-use Intentions	**3493**	**8**	**0.48*** **	**0.35, 0.61**	**97.3**	**11.8 (*p* = 0.18)**
* $p < .05$, ** $p < .01$, *** $p < .001$						

Non-car-use Attitudes. Positive attitudes towards alternative travel modes was associated with a medium-level, though heterogeneous, positive relationship with non-car-use ($r_+ = .36$, CI: 0.21;0.51, $k = 7$, $I^2 = 97.1\%$).

Non-car-use Subjective Norms. Non-car-use was positively associated with stronger subjective norms towards *not* driving, though the effect was small to medium and heterogeneous ($r_+ = .28$, CI: 0.14;0.41, $k = 6$, $I^2 = 95.6\%$).

Non-car-use PBC. A large, positive effect between the perceived ease of using alternative travel modes and the reported use of alternatives to the car ($r_+ = .49$, CI: 0.41;0.57, $k = 9$) was considerably heterogeneous ($I^2 = 93.9\%$).

Non-car-use Intentions. A large, positive association between non-car-use and the intention *not* to drive was observed, though yielded a heterogeneous effect ($r_+ = .48$, CI: 0.35;0.61, $k = 8$, $I^2 = 97.3\%$).

Discussion

This systematic review of 25 years of research into measures of potentially-modifiable cognitive mechanisms associated with transport mode choice identified 43 relevant studies of which 35 generated data that could be included in meta-analyses. The mechanisms assessed in these studies could be grouped into 22 conceptually-coherent categories of cognitive mechanisms related to car use and 4 categories of cognitive mechanisms related to non-car-use. Our results support and extend those of previous reviews, in particular Gardner and Abraham (2008), who summarised results from 23 studies identifying 18 unique potentially-modifiable correlates of car use and car use intentions.

Included studies were assessed to be of low to moderate methodological quality. Few studies conducted an *a priori* power analyses (Cohen, 2013) and few samples could be regarded as representative of particular populations of drivers. In many instances study quality indicators received low scores because important information for assessing quality was not reported. In part, this reflects the multi-disciplinary roots of the field, where reporting standards may vary. We also acknowledge that many studies were conducted before it was common practice to include supplementary materials in digital format. We would therefore urge future researchers in this field to provide comprehensive methodological details in supplementary materials, to aid future reviews. Further work could also validate a quality assessment tool, suitable for cross-sectional studies or systematic reviews with mixed study design. In addition, the range of cognitive mechanisms assessed strongly suggests that use of standardised measures would facilitate data syntheses in this field. In particular, development of validated self-report measures of the extent of car use and use of alternative transportation modes to replace car use could accelerate progress in identifying intervention targets. In achieving coherence of measurements we suggest adopting items recommended by Ajzen or

Francis et al. (2004) and encourage the use of already published measures that were identified in this review.

Our findings identify a clear pattern. Two theories, the Theory of Planned Behaviour (TPB) and the Norm Activation Model (NAM) were widely applied and results support continued use of the TPB but offer less support for NAM because, measures of PBC, intentions and habit generated consistently higher average effect sizes than measures of norms. This does not mean that normative beliefs are inconsequential but that unless higher activation levels can be reached, they may not be the most effective change targets for interventions seeking to reduce car use. Interestingly too, TPB-derived attitude measures generated somewhat higher average effect sizes than other attitudinal measures. Attitudinal measures incorporating affective components showed the weakest individual effect sizes in both categories of non-car-use attitudes (Armitage, Reid, & Spencer, 2013; Haustein & Hunecke, 2007).

The range of attitude and car use/ non-car-use-measures emphasises that the importance of attitudes critically depends on what type of car use/ car use reduction is being predicted. For example, attitudes may be better predictors of urban and commuting journeys than of other journey types. Thus targeting reductions in particular types of car journey may be more effective than planning reductions in driving *per se* (Graham-Rowe et al., 2011). While our results generally support the important role often assigned to attitudes (e.g., Boarnet & Crane, 2001; Fujii & Gärling, 2003; Sunkanapalli, Pendyala, & Kuppam, 2000), they also advocate greater specificity of cognition measures.

People can evaluate transport mode choices as both positive and negative depending on the journey type and the transport environment. For example, cycling may be viewed as good exercise (attitudes – environment and health) but also impractical when faced with high volumes of traffic (attitudes – transport environment). It is notable too, that drivers'

environmental and health-related attitudes did not have strong associations with car use. Hence, clarification of the complex structure of attitudes in measurement methods could clarify intervention targets.

It is unsurprising to note that people's perceived feasibility of alternatives and confidence in being able to use these alternatives is important to driving reduction (see non-car-use PBC) (Klöckner & Friedrichsmeier, 2011). Constraints may be imposed by job or family responsibilities or by infrastructure limitations. Acknowledging this, Haustein and Hunecke (2007) have defined a measure of perceived mobility necessities. Klöckner and Blöbaum (2010) included perceived mobility necessities items in their perceived behavioural control measure and this study yielded the largest individual effect size (r = .72) between a measure of a potentially-modifiable cognition and reported car use, suggesting that perceived mobility necessities may well be an important adjunct to controllability measures.

Meta-analyses of intentions and habits supported previous findings (Gardner & Abraham, 2008) emphasizing both the importance of intentions not to drive and the challenges of translating such motivation into action by those who habitually and perhaps unthinkingly drive to travel (Gardner, 2009). Identifying interventions capable of breaking habits may, therefore, be as important as employing persuasive interventions targeting motivation. For instance, a series of studies by Verplanken and colleagues (Verplanken & Roy, 2015; Verplanken et al., 2008; Walker, Thomas, & Verplanken, 2015) into the habit discontinuity hypothesis have demonstrated how contextual changes, e.g. moving home or offices, can weaken habits. Likewise, the formation of if-then plans or implementation intentions to change travel mode amongst a sample with strong car use habits has proven to be effective in a driving reduction experiment (Eriksson, Garvill, & Nordlund, 2008).

We were disappointed that so few moderator analyses could be conducted. Insufficient reporting and aggregation of journey types and location limited our ability to

draw conclusions about possible change targets in different contexts. Hence, moderator analysis remains exploratory in this review. Variations between study findings may be explained by factors not investigated in this review (e.g. other confounders or the use of different measurement scales for cognitive mechanisms). Journeys may also be helpfully categorised by length (Harland et al., 1999) as mode choice behaviour changes with varying travel distance (Sustrans, 2014). Both purpose and length may moderate changeability and possible key change mechanisms. The review also highlighted that geographical journey location categories need careful specification. For example, rural as opposed to urban journeys may – or may not – indicate poorer PT accessibility (Mann & Abraham, 2012). PT accessibility as well as walkability and cyclability may be critical to behaviour change and indexes such as the Transport for London's Public Transport Accessibility measures may be helpful in this regard (Chng, White, Abraham, Alcock & Skippon, under review).

Study limitations

Due to the inconsistent methodological quality and heterogeneity of the primary studies, the current review was unable to provide clear and unambiguous findings. Variations in individual effect sizes are considerable due, no doubt, in part to the wide range of different measures used across studies. Thus, we acknowledge that interpretation of our findings should be cautious because we include similar but not identical measures of cognitive mechanisms across samples. Also, as with other meta-analytic reviews of this literature (e.g. Gardner & Abraham, 2008; Neoh, Chipulu, & Marshall, 2015), the number of included studies for moderator analyses was sometimes very small. This limits our ability to draw meaningful conclusions and generalise across populations.

The data we have summarised is correlational, more detailed analyses of carefully designed controlled intervention studies would provide a more definitive and causal guide to

which cognitive mechanisms can and cannot be easily changed in which populations and what impact this has on which journey types in specified contexts. Unfortunately, current intervention evaluations do not permit such analyses (Arnott et al., 2014; Graham-Rowe et al., 2011). Likewise, the analyses of bivariate relationships as investigated in this review do not identify inverse associations, e.g. a person's attitudes or PBC might be a result of that person's choice of transport rather than a determinant thereof.

The quality assessment sought to detect potential confounders by applying core criteria common across all studies in this review. However, this does not exclude the possibility of other confounding variables (e.g. walkability, access to a car or accessibility of PT) which vary across studies and time.

Conclusion

The current systematic review summarises the evidence of associations between specific cognitive mechanisms and both, car use and non-car-use. The review highlights the wide range of such mechanisms and the limited number of theories used to conceptualise these. In particular, the use of theories other than rational choice models could advance our understanding of the motivation (not) to drive. Our meta-analyses show that the strongest correlates of car use and non-car-use were intentions, perceived behavioural control and attitudes with habit also being a strong predictor of car use. Development of standardised measures, both of change mechanisms and of driving and use of alternative transport modes could help accelerate identification of optimal change targets. Most importantly, heterogeneity of attitudinal measurement needs urgent attention and we propose greater specificity and consensus of measures. Careful categorisation of journey type and length as well as descriptions of the geographical setting could also facilitate intervention design. We recommend that a consensual, validated quality assessment tool is developed for cross-

sectional studies, to be used by both primary researchers and reviewers. We considered methodological criteria identified across six such tools and found that study quality was moderate to weak. Finally, we suggest that researchers make extensive use of supplementary materials to clarify study methodology.

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Supplementary File for: What Cognitive Mechanisms Predict Travel Mode Choice? A Systematic Review with Meta-Analysis

The systematic review appraises transportation research that investigates potentially-modifiable cognitive determinants (cognitive mechanisms) of travel mode choice. This supplementary file provides further details about methods used and shows all information extracted from the studies that formed the basis for quantitative and qualitative synthesis. Table S1 in Chapter 1 illustrates search methods. Tables S2 and S3 in Chapter 2 display quantified study characteristics as well as data extracted from all included studies. Chapter 3 provides additional information with regards to the assessment of study quality. Tables S6 and S7 in Chapter 4 show a detailed overview of identified cognitive mechanisms together with a definition and the relative prevalence of investigation into these. Finally, Chapter 5 gives further clarification into decisions with regards to meta-analyses. To be directed to a specific table, please press Ctrl and click on the relevant link in the table of contents. Press Ctrl+Home to get back to this page.

Contents

2

1. Systematic Search and Screening

The systematic review searched ten databases: Applied Social Sciences Index and Abstracts, ABI/Inform Complete, ProQuest Sociology, Sociological Abstracts, Web of Science Core Collection, Business Source Complete, Environment Complete, PsychINFO, Psychology and Behavioural Science Collection and Transport Research Information Services Database. Table S1 shows an example of an applied search strategy for the database Web of Science.

Table S1. Illustration of a systematic review search strategy

Database: Web of Science Limiters: English, Document Type=Article, Abstract of published item
TS=((Mode NEAR/3 choice$) OR (Choice$ NEAR/2 modes) OR (Modal NEAR/2 choice$) OR (Transport*5 NEAR/3 decision$) OR (Transport*5 NEAR/3 choice$) OR (Travel NEAR/3 decision$) OR (Travel NEAR/3 choice$) OR (Modal NEAR/2 switch*3) OR (Mode NEAR/2 switch*3) OR (Modes NEAR/2 switch*3) OR (Mode NEAR/2 shift$) OR (Modes NEAR/2 shift$) OR (Modal NEAR/2 shift$) OR (Modal NEAR/2 split) OR (Mode NEAR/2 split) OR (Modes NEAR/2 split) OR (Mode NEAR/2 share) OR (Modes NEAR/2 share) OR (Modal NEAR/2 share) OR (Multimodal NEAR/2 transport*5) OR (Transport*5 NEAR/3 mode) OR (Transport*5 NEAR/3 modes) OR (Travel NEAR/3 mode) OR (Travel NEAR/3 modes) OR (Mode NEAR/3 change$) OR (Modes NEAR/2 change$) OR (Modal NEAR/3 use) OR (Mode NEAR/3 use) OR (Modes NEAR/3 use) OR (Mode NEAR/3 select*3) OR (Modal NEAR/2 selection) OR (travel NEAR/10 behavio$r) OR (commut*3 NEAR/10 behavio$r) OR (transport*5 NEAR/10 behavio$r))
AND
TS=(((Cogniti*2) OR (Antecedent$) OR (Determin*3) OR (Correlate$) OR (Expla*7) OR (Motivat*3) OR (Cause$) OR (Causing) OR (Predict*3) OR (Effect$) OR (Mechanism$) OR (Regulat*3) OR (Influen*4) OR (Control*4) OR (Mediat*2) OR (Moderat*2) OR (affects) OR measure$) OR relationship OR role$ OR factor$ OR psychol*4)
AND
TS=((Public N/2 transport*5) OR (Private N/2 travel) OR (Private N/2 transport*5) OR Driving OR Automobile$ OR (Car N/2 driver$) OR (Car N/2 dependenc$) OR (Car N/2 use) OR car OR cars OR (Car N/2 owner*4))

Overall, 4,156 records were initially identified. After removing 805 duplicates 3,393 unique citations remained for title and abstract screening. 3,005 were deemed not relevant, leaving 388 references for further investigation of full texts. If necessary, authors were contacted to request the full text of inaccessible studies (N = 19). Following these inclusion criteria, a full text screening identified 47 studies to be eligible for inclusion. Four data sets were found to underpin more than one paper, leading to the exclusion of four studies to avoid double-counting. Frequently, studies only test a relationship between a cognitive mechanism and

intention or measured a non-cognitive or affective mechanism. Some publications focussed on elderly or children only. A few studies were excluded on the basis of not representing travel in general. Reduced chauffeur trips to school is an important behaviour change target as it can contribute to increased physical activity in children (Cooper et al., 2010). School runs cannot be looked at in isolation but interdependencies with travel patterns of parents should be taken into account (McDonald, 2008). Likewise, the decision to drive children to school is often a result of intra-household interactions, composition and shared responsibilities rather than individual intrinsically-motivated travel mode choice (Yarlagadda & Srinivasan, 2007). It can therefore be argued that school runs can be classified as an agent of socialisation (Baslington, 2008). As a result, different cognitive mechanisms underpin school travel mode choice of parents, e.g. worry about safety (Ahlport, Linnan, Vaughn, Evenson, & Ward, 2008; DiGuiseppi, Roberts, Li, & Allen, 1998). We therefore did not include school runs in our systematic review and recommend separate analysis of such studies.

2. Characteristics of Included Studies

Based on 42 studies that reported the sample size, the mean was 584, ranging from 56 to 2000 participants. Only 32 studies (74.42%) reported the mean age of their sample (min 24.5, max 50.8, average 38.29) and even less specified the SD ($N = 9$, 20.94%). No information could be extracted from six studies with regards to gender distribution so that, based on 37 studies, the average percentage of female participants was 54%. In 15 studies (40.54%) the proportion of the female population was 55% and above and 60% or more in seven out of 37 studies (19.92%). Seven studies (16.28%) sampled students only. Information concerning car ownership or access and driver's licence varied across studies, with participants consisting of only drivers or only commuters, but also a mixed population with non-car owners. For example, 23 out of 38 studies (60.53%) reported that their sample consisted of driver's license holders only, with at least frequent access to a car. Five studies did not report details with regards to driver's licence or car access. The majority of studies applied a cross-sectional design ($N = 26$, 60.47%). Experimental studies ($N = 7$; 16.28%) and prospective studies ($N = 6$; 13.95%) were conducted less frequently. A longitudinal approach was the least frequently employed study design ($N = 4$, 9.3%). Only 16.28% ($N = 7$) of all studies were conducted outside of Europe with the majority of these from the USA ($N = 3$) and Australia ($N = 3$). Within Europe, Germany ($N = 13$) and the Netherlands ($N = 8$) were major contributors to the TMC literature, accounting for 48.84% of all included studies. Table S2 summarises the extracted study characteristics and shows the number of incidences for different sub-groups. The more detailed evidence table can be found in Table S3, presenting summarised characteristics of each individual study.

Table S2. Study characteristics of different sub-groups

	All studies included in the review	Studies that applied a theoretical framework	Studies that applied TPB	Studies included in Meta-Analysis
	Number and % of $N = 43$	Number and % of $N = 24$	Number and % of $N = 16$	Number and % of $N = 35$
Study design				
Cross-sectional	26 (60.47)	13 (54.17)	9 (56.25)	22 (62.86)
Experimental	7 (16.28)	5 (20.84)	2 (12.5)	6 (17.14)
Longitudinal	4 (9.3)	1 (4.17)	1 (6.25)	3 (8.57)
Prospective	6 (13.95)	5 (20.84)	4 (25)	4 (11.43)
Study Context				
Commuting	19 (44.19)	10 (41.67)	6 (37.5)	14 (40)
General Purpose	23 (53.49)	14 (58.34)	10 (62.5)	20 (57.14)
Not reported	1 (2.33)	-	-	1 (2.86)
Study Setting				
Urban	27 (62.79)	17 (70.84)	10 (62.5)	20 (57.14)
Mixed	8 (18.60)	4 (16.67)	3 (18.75)	7 (20)
Rural	3 (6.98)	2 (8.34)	2 (12.5)	3 (8.57)
Not reported	5 (11.63)	1 (4.17)	1 (6.35)	4 (11.43)
Geographical Location				
UK	7 (16.28)	5 (20.84)	4 (25)	7 (20)
Germany	13 (30.23)	10 (41.67)	7 (43.75)	9 (25.71)
Australia	3 (6.98)	2 (8.34)	1 (6.25)	2 (5.71)
Netherlands	8 (18.60)	4 (16.67)	2 (12.5)	7 (20)
Canada	1 (2.33)	1 (4.17)	1 (6.25)	1 (2.86)
Switzerland	2 (4.65)	2 (8.34)	1 (6.25)	2 (5.71)
Sweden	4 (9.30)	-	-	4 (11.43)
USA	3 (6.98)	-	-	2 (5.71)
Spain	1 (2.33)	-	-	1 (2.86)
Belgium	1 (2.33)	-	-	-
Dependent Variable				
Car-use	32 (74.42)	16 (66.67)	11 (68.75)	26 (74.29)
Non-car-use	11 (25.58)	8 (33.34)	5 (31.25)	9 (25.71)
Unclear	1 (2.33)	-	-	-
Population				
Total Sample Size	24517	11584	10130	18770
Average % female	54	54.95	60.66	54.64
Age (grand mean)	38.29	39.61	39.2	39.2
Min mean age	24.5	24.5	24.5	24.7
Max mean age	50.77	50.77	50.77	50.77

6

Table S3. Summary of study characteristics

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
Abrahamse et al. (2009).	Canada (*N* = 241; 66.5%; 18-65 years)	Urban	Commuting	Cross-sectional *[Multiple regression analyses]*	Car use ratio (typical)	1.0
Armitage et al. (2013)	UK (*N* = 423; 57.2%; 50.77 [14.33] years)	Rural	General Purpose	Panel *[Hierarchical regression analysis]*	Car use frequency (typical)	1.5
Baldassare (1991)	USA	NR	Commuting	Cross-sectional *[Regression analysis]*	Car use (SOV) preference (typical)	1.0
Bamberg (2006)	Germany (*N* = 241; 53%; 28.6 [13.9], 17-58 years)	Urban	Commuting, Shopping, Leisure	Experimental *[SEM]*	PT vs. car use proportion (actual)	0.1
Bamberg et al. (2003)	Germany (*N* = 592; 58%; 25, 20-37 years)	Urban	Commuting	Experimental *[SEM]*	Car use proportion (actual) [DV]	1.0
Bamberg & Schmidt (2003)	Germany (*N* = 254; 24.5 years)	Urban	Commuting	Prospective *[SEM]*	Car use proportion (actual) [DV]	1.1
Bergstad et al. (2011)	Sweden (*N* = 1127; 53.7%; 46.3 [12.4] years)	Mixed	General Purpose	Cross-sectional *[Regression Analysis]*	Car vs. other mode use frequency (typical)	1.0

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
Cao & Mokhtarian (2005)	USA (*N* = 1283; 50.9%)	Mixed	Commuting	Cross-sectional *[Binary logit model]*	Car use preference (typical) [DV]	1.0
Collins & Chambers (2005)	Australia (*N* = 205; 50%; 18-58 years)	Urban	Commuting	Cross-sectional *[Multiple regression analysis]*	PT vs. Car use preference (typical)	0.9
Davidov (2007)	Germany (*N* = 123; 44%)	Urban	NR	Experimental *[Binary logit regression analysis]*	Car use vs. PT use frequency (actual) [DV]	0.5
Friedrichsmeier et al. (2013)	Germany (*N* = 1048; 53.4%)	Urban	Commuting, Shopping, Leisure	Prospective *[Correlation analysis]*	Car use ratio (actual)	0.3
Gardner (2009)	UK (*N* = 107; 69.16%; 27.53 [9.69], 18-55 years)	NR	Commuting	Prospective *[Hierarchical regression analysis]*	Car use vs. non-car mode use ratio (actual)	1.8
Gardner & Abraham (2010)	UK (*N* = 190; 60.53%; 36.9 [18.2], 18-86 years)	Urban	General purpose	Cross-sectional *[Multiple regression analysis]*	Car (incl taxi) vs. other mode use ratio (typical)	2.0
Gärling et al. (2001)	Sweden (*N* = 60; 50%; 27.4 [6.9], 20-49 years)	NR	Commuting	Cross-sectional *[SEM]*	Car use frequency (typical)	0.8
Golob & Hensher (1998)	Australia (*N* = 963)	Urban	Commuting	Cross-sectional *[SEM]*	Car use (SOV) frequency (typical)	1.0
Harland et al. (1999)	Netherlands (*N* = 198; 78.7%; 47 years)	NR	Short distance	Cross-sectional *[Hierarchical regression analysis]*	Non-car use frequency (typical)	0.8

8

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
Haustein & Hunecke (2007)	Germany (*N* = 1545; 50%; 46.5, 18-80 years)	Urban	Commuting, Shopping, Leisure	Cross-sectional *[SEM]*	Environmentally friendly mode use (incl. walking, cycling, PT [bus, tram/subway, regional train, long-distance train]) vs. car use (inlc. Motorcycle, car share,rental car, taxi) ratio (typical)	3.0
Hunecke et al. (2001)	Germany (*N* = 160; 46.3%)	Urban	City centre	Experimental, prospective *[ANOVA]*	Subway vs car use ratio (actual)	0.9
Hunecke et al. (2007)	Germany (*N* = 1991; 53%)	Urban	General purpose	Cross-sectional *[Hierarchical regression analysis]*	Car use (incl. Motorcycle, car share, rental cars, taxis) vs. environmentally friendly mode use (Walking, cycling, PT [bus, tram/subway, regional train, long-distance train]) ratio (typical)	2.0
Joireman et al. (1997),	Netherlands (*N* = 102; 37.25%; 33.2 years)	Urban	Commuting	Cross-sectional *[Correlation Analysis]*	Car vs PT use preference (typical)	0.0
Kaiser & Gutscher (2003)	Switzerland (*N* = 895; 46.4, 18-79 years)	Mixed	City centre	Cross-sectional *[Multiple regression analysis]*	Non-car use frequency (typical)	1.0
Kerr et al. (2010)	Australia (*N* = 186; 79%)	Urban	Commuting	Cross-sectional *[Hierarchical*	Car use frequency (typical)	1.0

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
				regression analysis]		
Klöckner & Blöbaum (2010)	Germany (*N* = 389; 60.7%; 24.7, 19-52 years)	Urban	General purpose	Prospective *[SEM]*	Car use ratio (actual)	2.0
Klöckner & Matthies (2004)	Germany (*N* = 160; 36.9%; 38.5, 19-78 years)	Urban	Commuting	Prospective *[Binary logistic regressions analysis]*	PT vs car use ratio (actual) [DV]	0.6
Lois & Lopez-Saez (2009)	Spain (*N* = 284; 50.3%; 34.4 [10.43] years)	Urban	Shopping visiting friends/family commuting leisure trips	Cross-sectional *[SEM]*	Car use frequency (typical) - Shopping Car use frequency (typical) - visiting friends/family Car use frequency (typical) - commuting Car use frequency (typical) - leisure trips	2.0
Mann & Abraham (2012)	UK (*N* = 229; 49.78%; 40.59, 19-76 years)	Mixed	Commuting	Prospective *[Hierarchical regression analyses]*	Car use ratio (actual)	2.0
Matthies et al. (2006)	Germany (*N* = 297; 37.7%; 45 years)	Urban	General purpose	RCT *[Multiple logistic regression analysis]*	Car-use ratio (actual)	0.3
Murtagh et al. (2012)	UK (*N* = 419; 62%; 40, 20-61 years)	Urban	Commuting General Purpose	Cross-sectional *[Multiple regression analysis]*	Car use ratio (typical)	3.0
Nilsson & Küller (2000)	Sweden (*N* = 157; 58%; 40	Urban	General Purpose	Cross-sectional [*Hierarchical*	Mode use frequency (typical)	0.7

10

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
	years)			*regression analysis]*		
Panter et al. (2013)	UK (*N* = 137; 76.6%; 43.7 [11.9] years)	Mixed	Commuting	Panel *[logistic regression]*	Car use frequency (typical) [DV]	0.7
Polk (2003)	Sweden (*N* = 1145; 18-80 years)	Mixed	Commuting, General purpose	Cross-sectional *[Correlation analysis]*	Car use frequency (typical)	1.0
Scheiner & Holz-Rau (2007)	Germany (*N* = 2690)	Urban	General purpose	Cross-sectional *[SEM]*	Car vs PT use (incl. motorcycle) ratio (typical) PT vs. Car use ratio (typical)	1.0
Steg (2005)	Netherlands (*N* = 113; 27%; 42 years)	Urban	Commuting	Cross-sectional *[Multiple regression analysis]*	Car use ratio (typical)	2.0
Steg & Sievers (2000)	Netherlands (*N* = 413)	NR	General purpose	Cross-sectional *[Correlation Analysis]*	Car use frequency (typical)	0.5
Tanner (1999)	Switzerland (*N* = 153; 33%; 46 years)	Mixed	Commuting, Shopping, Leisure	Cross-sectional *[Multiple regression analyses]*	Car (incl. motorcycle) use frequency index (typical)	1.0
Tischer & Phillips (1979)	USA (*N* = 502)	Urban	Commuting	Panel study *[Cross-lagged correlation]*	Car use vs. bus vs. car pool ratio (typical)	0.0
Van Acker et al. (2011)	Belgium (*N* = 1878; 58.7%;	Urban	active leisure activities	Cross-sectional *[SEM]*	Car use frequency (typical) [DV]	1.5

Author(s) (year)	Country (Sample Size; %female; mean age [SD], age range)[a]	Setting	Journey Purpose	Design *[Analysis]*	Dependent Variable (TMC Behaviour measure)	Quality Score
	30.6 years)		family visits fun shopping			
Van Vugt et al. (1995)	Netherlands (*N* = 56; 55.36%; 32 years)	Urban	Commuting	Experiment *[ANOVA]*	Car vs PT use preference (typical)	0.1
Van Vugt et al. (1996)	Netherlands (*N* = 192; 45.83%; 35.8 years)	Urban	Commuting	Experimental *[ANOVA]*	PT vs. car use preference (typical)	0.0
Verplanken et al. (1994)	Netherlands (*N* = 199; 53.77%; 39.9, 19-65 years)	Rural	Shopping trip outside village	Cross-sectional *[Path analysis]*	Car use frequency (typical)	0.3
Verplanken et al. (1998)	Netherlands (*N* = 200; 52%; 43.1, 20-70 years)	Rural	General trips outside village	Experimental *[Multiple regression analysis]*	Car use ratio (actual)	0.4
Verplanken et al. (2008)	UK (*N* = 433; 56%; 41.30 [11.29], 20-64 years)	Mixed	Commuting	Cross-sectional *[Multiple regression analyses]*	Car (incl. motorcycle & taxi) vs. alternative mode use ratio (typical)	1.0
Yang-Wallentin et al. (2004)	Germany (*N* = 912; 53%; 44.3 [15.7])	Urban	General purpose	Panel *[SEM]*	PT vs. car use ratio (actual)	1.0

SD = Standard Deviation, UK = United Kingdom, USA = United States of America, SEM = Structural Equation Modelling, PT = Public Transport, NR = Not reported, ANOVA = Analysis of Variance, DV = Dichotomous Variable, SOV = Single Occupancy Vehicle

[a] if SD not provided, Range is given [b] where information provided

3. Methodological Quality Assessment

Table S4 presents the criteria used to determine methodological quality assessing sample size, sample representativeness and validity and reliability of measures used.

Table S4. Indicators of study quality

		present (1)	absent (0)	Unclear or inadequately reported (0)
Criteria to be applied to each individual study	**1. Was the sample size large enough?**	Study performed a power analysis and met the required sample size.	Power analysis conducted and required sample size not achieved.	Study reports sample size included in the study but no power analysis was conducted or sample size included in the study is not reported.
	2. Was the sample size large enough when SEM was performed?	Where applicable, SEM/Path analysis is performed and N >200	Where applicable, SEM/Path analysis is performed and N <200	Sample size included in the study is not reported.
	3. Was the sample representative of the target population?	Study explicitly states that sample used for analysis is fully or to a large part representative of the target population.	Study explicitly states that sample did not match the target population.	Study does not give any information concerning representativeness
Criteria to be applied to each individual measure of a cognitive mechanism	**4. Did the study use a valid measure?**	Study reported use of a previously used or tested scale of this measure (content validity)	Study explicitly stated not to have used a previously used or tested measure	Study did not reference measure or gave information about measure validity
	5. Did the study use a reliable measure?	Where applicable, study reported at least acceptable internal reliability for multiple item scales (>2) (Cronbach's alpha >0.6) or reported Pearson's $r > .7$ for 2-item scales used to measure cognitive mechanisms	Where applicable, study reported inadequate internal reliability (Cronbach's alpha <0.6) or Pearson's $r > .7$	Where applicable, study did not report internal reliability data (Cronbach's alpha or Pearson's *r*)

High quality studies achieved an average score of 2.28, medium quality studies 1.16 and low quality studies 0.43. Three studies did not meet any of the quality criteria (Joireman, Van Lange, Kuhlman, Van Vugt, & Shelley, 1997; Tischer & Phillips, 1979; van Vugt, van Lange, & Meertens, 1996). Two studies met all quality assessment criteria and achieved a maximum score of 3 (Haustein & Hunecke, 2007; Murtagh, Gatersleben, & Uzzell, 2012). Studies with a prospective research design scored highest (M = 1.3), followed by cross-sectional studies (M = 1.2), longitudinal studies (M = 0.8). Experimental studies presented the lowest average quality rating (M = 0.5). Independent scores for each quality indicator can be found in Table S5.

14

Table S5. Detailed quality assessment scores

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
Abrahamse et al. (2009)	Intentions - Non-car use	n/a	1	0	n/a	0	**1.0**
	Attitudes - Car use	1	1				
	SN - Car use expectation	n/a	1				
	PBC - non-car use	1	1				
	PN - car and non-car use	1	1				
	Awareness of Consequences - Car use	1	1				
	Ascription of responsibilities - Car use	1	1				
Armitage et al. (2013)	PBC - reduce car use	1	0	0	n/a	1	**1.5**
	Attitudes - reduce car use	1	0				
	SN - reduce car use	1	0				
	Intention - reduce car use	1	0				
Baldassare (1991)	Attitudes about freeway satisfaction	n/a	0	0	n/a	1	**1.0**
	Attitudes about traffic problems	n/a	0				
Bamberg (2006)	Intention - PT vs Car	0	0	n/a	0	0	**0.1**
	Attitude - PT vs Car	0	0				
	PBC - PT vs Car	0	0				
	Change Intention - PT vs car	0	0				
	SN - PT vs car	0	0				
	Habit - Car vs PT	n/a	1				
Bamberg et al. (2003)	Intention - Car use	0	0	n/a	1	0	**1.0**
	Habit	0	0				
	Attitudes - Car use	0	0				
	SN - Car use	0	0				
	PBC - Car use	0	0				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
Bamberg & Schmidt (2003)	Role beliefs - Car use	0	0	n/a	1	0	**1.1**
	Intention - Car use	0	0				
	SN - Car use	0	0				
	Behavioural beliefs - Car use	0	1				
	Control beliefs - Car use	0	1				
	Normative beliefs - Car use	0	1				
	Ascription of responsibilities - Traffic	0	0				
	Habit - Car use (script-based)	0	0				
	Awareness of consequences - Traffic	0	0				
	PN - non-car use	0	0				
	PBC - Car use	0	0				
	Attitudes - Affective car use	0	0				
	Attitudes - Car use	0	0				
Bergstad et al. (2011)	Instrumental motives - visit family and friends	n/a	1	0	n/a	0	**1.0**
	Instrumental motives - can go out	n/a	1				
	Independent motives - free to stop everywhere	n/a	1				
	Independent motives - chose own route	n/a	1				
	Instrumental motives - makes life more easy	n/a	1				
	Independent motives - not dependent on others	n/a	1				
	Independent motives - brings wherever I want	n/a	1				
	Instrumental motives - comfortable	n/a	1				
	Independent motives - freedom	n/a	1				

16

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	Total Score
	Independent motives - time saving	n/a	1				
	Instrumental motives - Protection against bad weather	n/a	1				
	Independent motives - car always available	n/a	1				
	Instrumental motives - good road holding	n/a	1				
	Instrumental motives - Safe in car	n/a	1				
	Instrumental motives - enables holiday trips	n/a	1				
Cao & Mokhtarian (2005)	Attitudes - Pro-environmental	0	0	0	n/a	1	**1.0**
	Personality - Calm	0	0				
	Personality - Loner	0	0				
	Attitude - Commute benefit	0	0				
	Attitude - Travel stress	0	0				
	Attitude - Pro-hi density	0	0				
	Personality - Adventure seeking	0	0				
	Lifestyle - Frustrated	0	0				
	Lifestyle - Family and community oriented	0	0				
	Lifestyle - Status seeker	0	0				
	Lifestyle - Workaholic	0	0				
Collins & Chambers (2005)	Social values - Environment	1	1	0	n/a	0	**0.9**
	Biospheric values - Environment	1	1				
	Egoistic values - Environment	1	1				
	Social beliefs - Environmental threat of cars	0	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Control beliefs (perceived) - environmental threat of cars	1	1				
	Egoistic beliefs - environmental threat of cars	1	1				
	Biospheric beliefs - environmental threat of cars	0	1				
	Consideration of future consequences - Environment	1	1				
Davidov (2007)	Habit - PT use	0	1	0	n/a	0	**0.5**
Friedrichsmeier et al. (2013)	Habit - Past behaviour	0	1	0	n/a	0	**0.3**
	Intention - Car use	0	0				
	Habit Strength	0	0				
	Habit - RFM	0	1				
	Habit - Context stability	0	1				
Gardner (2009)	Habit	1	1	1	n/a	0	**1.8**
	Intention - Car use	1	0				
Gardner & Abraham (2010)	Intention - Car use	1	1	1	n/a	0	**2.0**
	PBC - Environmental problem reduction	1	1				
	Environmental concern	1	1				
	Attitude - Non-car use	1	1				
	PBC - Car use	1	1				
	Attitude - Car use	1	1				
	SN - Non-car use	1	1				
	Descriptive norm - Car use	1	1				
	SN - Car use	1	1				
	PBC - Non-car use	1	1				
	PN - Non-car use	1	1				

18

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	Total Score
	Environmental problem awareness	1	1				
Gärling et al. (2001)	Attitude - Car use	1	0	n/a	0	0	**0.8**
	Habit - Script-based driving frequency	1	1				
Golob & Hensher (1998)	Attitudes - Traffic congestion is not so bad [ordinal]	n/a	0	n/a	1	0	**1.0**
	Attitudes - Car as status symbol [ordinal]	n/a	0				
	Attitudes - GGE abatement is possible [ordinal]	n/a	0				
	Attitudes - GGE is a serious threat [ordinal]	n/a	0				
Harland et al. (1999)	PN - Non-car use	1	1	0	n/a	0	**0.8**
	Intention - Non-car use	n/a	0				
	PBC - Non-car use	n/a	1				
	Attitude - Non-car use	n/a	1				
	Environmental Involvement (awareness of consequences)	1	0				
	SN - Non-car use	n/a	1				
Haustein & Hunecke (2007)	Intention1 - PT vs car	n/a	1	n/a	1	1	**3.0**
	Intention2 - PT vs car	n/a	1				
	PBC1 - PT vs car	n/a	1				
	PBC2 - PT vs car	n/a	1				
	SN1 - PT vs car	n/a	1				
	SN2 - PT vs car	n/a	1				
	Attitude - Car autonomy	n/a	1				
	Attitude - Car excitement	n/a	1				
	Attitude - Car competence 1	n/a	1				
	Attitude - Car competence 1	n/a	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Attitude - PT excitement 1	n/a	1				
	Attitude - PT excitement 2	n/a	1				
	Attitude - Bicycle excitement	n/a	1				
	Attitude - Bicycle autonomy	n/a	1				
	Perceived mobility necessity 1	n/a	1				
	Perceived mobility necessity 2	n/a	1				
Hunecke et al. (2001)	Perception of ecological problem - Car use	1	1	0	n/a	0	**0.9**
	PBC - Subway use	0	1				
	Personal ecological norm	1	1				
	SN - Subway vs car	1	1				
	Feelings of ecological guilt - car use	1	1				
	Awareness of consequences - car use	1	1				
Hunecke et al. (2007)	Values - Conservation	1	1	0	n/a	1	**2.0**
	Values - Self-transcendence	1	1				
	Values - Openness to change	1	1				
	Values - Self-enhancement	1	1				
Joireman et al. (1997)	Concern - Comfort	n/a	0	0	n/a	0	**0.0**
	Concern - Travel time	n/a	0				
	Concern - Flexibility	n/a	0				
	Concern - Environment	n/a	0				
	Concern - Public Health	n/a	0				
Kaiser & Gutscher (2003)	Intention - Non-car use	1	1	0	n/a	0	**1.0**
	PBC - Non-car use	1	1				
	Attitude - Non-car use	1	1				
	Descriptive norm - Car use	n/a	1				
	SN - Non-car use	n/a	1				

20

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
Kerr et al. (2010)	Intention - Car use	1	1	0	n/a	0	**1.0**
	Habit	n/a	1				
	SN - Car use	1	1				
	Attitude - Car use, convenience, reliability, comfort, security, pleasantness	1	1				
	PBC - Car use	1	1				
Klöckner & Blöbaum (2010)	Ecological Intention - PT vs car	1	1	n/a	1	0	**2.0**
	PBC	1	1				
	Habit - Car choice	1	1				
	Personal Ecological Norm	1	1				
	Social Ecological Norm	1	1				
	Awareness of need	1	1				
	Awareness of consequences	1	1				
Klöckner & Matthies (2004)	PN - non-Car use	1	0	0	n/a	0	**0.6**
	SN	1	0				
	Habit - Car choice	n/a	1				
Lois & Lopez-Saez (2009)	Symbolic motivations - Car use (Shopping)	1	1	n/a	1	0	**2.0**
	Instrumental motivations - Car use (Shopping)	1	1				
	Symbolic motivations - Car use (visiting friends/family)	1	1				
	Instrumental motivations - Car use (visiting friends/family)	1	1				
	Symbolic motivations - Car use (commuting)	1	1				
	Instrumental motivations - Car use	1	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	(commuting)						
	Symbolic motivations - Car use (leisure trips)	1	1				
	Instrumental motivations - Car use (leisure trips)	1	1				
Mann & Abraham (2012)	Intention - Car use	1	1	1	n/a	0	**2.0**
	Attitude - Car use	1	1				
	Moral Norm - Car use	1	1				
	PBC - Car use	1	1				
	PBC - Non-car use	1	1				
	Behavioural beliefs car use - Environment -bad	n/a	1				
	Behavioural beliefs car use - Cost-effective	n/a	1				
	Behavioural beliefs car use - Comfortable	n/a	1				
	Behavioural beliefs car use - Stress free	n/a	1				
	Behavioural beliefs car use - Reliable	n/a	1				
	Behavioural beliefs car use - Safe	n/a	1				
	SN	1	1				
	Behavioural beliefs car use - Healthy	n/a	1				
	Behavioural beliefs car use - Flexibility	n/a	1				
	Behavioural beliefs car use - time efficiency	n/a	1				
	Control beliefs car use - Congestion	n/a	1				
	Control beliefs car use - Journey chaining	n/a	1				
	Control beliefs car use - Parking difficulties	n/a	1				

22

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Control beliefs car use - Accident risk	n/a	1				
	Descriptive norm - Car use	n/a	0				
Matthies et al. (2006)	Perceived Behavioural Costs - PT vs Car	0	0	0	n/a	0	**0.3**
	PN - Car use reduction	1	0				
	Habit	n/a	1				
	SN - PT vs car	0	0				
Murtagh et al. (2012)	Social identity - Parent (Commuting)	n/a	1	1	n/a	1	**3.0**
	Transport identity - Motorist (Commuting)	n/a	1				
	Social identity - Worker (Commuting)	n/a	1				
	Transport identity - PT user (Commuting)	n/a	1				
	Transport identity - Pedestrian (Commuting)	n/a	1				
	Transport identity - Cyclist (Commuting)	n/a	1				
	Social identity - Member of local community (Commuting)	n/a	1				
	Social identity - Parent (General Purpose)	n/a	1				
	Transport identity - Motorist (General Purpose)	n/a	1				
	Social identity - Worker (General Purpose)	n/a	1				
	Transport identity - PT user (General Purpose)	n/a	1				
	Transport identity - Pedestrian (General Purpose)	n/a	1				
	Transport identity - Cyclist (General Purpose)	n/a	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Social identity - Member of local community (General Purpose)	n/a	1				
Nilsson & Küller (2000)	Attitudes - PT	0	1	0	n/a	0	**0.7**
	Attitudes - hazard/efficacy	1	1				
	Attitudes - Personal concern	0	1				
	Attitudes - Car affection	1	1				
	Attitudes - Environmental concern	0	1				
	Environmental Knowledge	0	1				
Panter et al. (2013)	Intention - Car use	0	1	0	n/a	0	**0.7**
	Attitude - Car use	0	1				
	PBC - Car use	0	1				
	Social Norm - Car use	0	1				
	Habits	0	1				
	Perceptions of route environment - pleasant to walk	n/a	1				
	Perceptions of route environment - dangerous to cycle	n/a	1				
	Perceptions of route environment - convenient to cycle	n/a	1				
	Perceptions of route environment - little traffic	n/a	1				
	Perceptions of route environment - convenient PT	n/a	1				
	Perceptions of route environment - no convenient routes for walking	n/a	1				
	Perceptions of route environment - safe to cross the road	n/a	1				

24

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	Total Score
Polk (2003)	Attitudes - Positive evaluation of automobility	n/a	1	0	n/a	0	**1.0**
	Attitudes - Automobility as a cause of environmental problems	1	1				
	Attitudes - Negative evaluation of automobility	n/a	1				
	Attitudes - Opinions of specific proposals to reduce car use	n/a	1				
	Attitudes - Environmental Concern	1	1				
Scheiner & Holz-Rau (2007)	Location attitudes - Subjective importance PT	n/a	0	n/a	1	0	**1.0**
	Location attitudes - Subjective importance shopping/services	n/a	0				
	Location attitudes - Subjective importance access to centre	n/a	0				
	Lifestyle - Out of home self-realisation	0	0				
	Location attitudes - Subjective importance PT	n/a	0				
	Location attitudes - Subjective importance shopping/services	n/a	0				
	Location attitudes - Subjective importance access to centre	n/a	0				
	Lifestyle - Out of home self-realisation	0	0				
Steg (2005)	Symbolic motives - Descriptive norm	1	1	0	n/a	1	**2.0**
	Symbolic motives - Social comparison and self-presentation	1	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Symbolic motives - SN (expectations family)	n/a	1				
	Instrumental motives - Attitudes car commute (8)	1	1				
Steg & Sievers (2000)	Environmental beliefs - Problem awareness	1	0	0	n/a	0	**0.5**
	Environmental beliefs - Efforts useful	1	0				
	Environmental beliefs - responsibility	1	0				
Tanner (1999)	Subjective constraints - Perceived behavioural barriers (car use reduction)	n/a	1	0	n/a	0	**1.0**
	Subjective constraints - Sense of responsibility (preservation of environment)	n/a	1				
	Biospheric values - General problem awareness	1	1				
	Egoistic values - Personal problem awareness (environment)	1	1				
	Perceived efficacy (change in environmental degradation)	1	1				
Tischer & Phillips (1979)	Beliefs - Car use attributes (18)	0	0	0	n/a	0	**0.0**
van Acker et al. (2011)	Travel attitudes - Pro-environment	0	1	n/a	1	0	**1.5**
	Lifestyle - Home-oriented traditional family	0	1				
	Lifestyle - Culture lover	0	1				
	Residential attitudes - Open space and quietness	0	1				

26

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Travel mode attitudes - bike/on foot = positive effects	0	1				
	Travel mode attitudes - bike/on foot = comfortable	0	1				
	Travel mode attitudes - Car = negative effects	0	1				
	Travel mode attitudes - Car = comfortable	0	1				
	Lifestyle - Home-oriented but active family	0	1				
	Residential attitude - Car alternatives	0	1				
	Lifestyle - Friends & trends	0	1				
	Residential attitude - Accessibility	0	1				
	Travel mode attitudes - PT = comfortable	0	1				
	Travel mode attitudes - PT = time-saving	0	1				
	Travel mode attitudes - PT = positive effects	0	1				
	Travel attitudes - Reduced driving social expectation	0	1				
	Travel attitudes - Frustrated traveller	0	1				
	Residential Attitudes - Social Context (ns)	0	1				
	Residential Attitudes - Safety & neatness (ns)	0	1				
	Lifestyle - Low-budget and active/creative	0	1				
	Lifestyle - low-budget and active/creative	0	1				
	Lifestyle - home-oriented traditional family	0	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Residential attitudes - Open space and quietness	0	1				
	Travel attitudes - Pro-environment	0	1				
	Lifestyle - Home-oriented but active family	0	1				
	Residential attitude - Car alternatives	0	1				
	Travel mode attitudes - Car = comfortable	0	1				
	Travel mode attitudes - bike/on foot = comfortable	0	1				
	Travel mode attitudes - Car = negative effects	0	1				
	Residential attitude - Accessibility	0	1				
	Travel attitudes - Reduced driving social expectation	0	1				
	Lifestyle - Friends & trends	0	1				
	Travel mode attitudes - PT = comfortable	0	1				
	Travel mode attitudes - PT = time-saving	0	1				
	Travel mode attitudes - PT = positive effects	0	1				
	Travel Attitudes - Frustrated traveller	0	1				
	Residential Attitudes - Social Context (ns)	0	1				
	Residential Attitudes - Safety & neatness (ns)	0	1				
	Travel mode attitudes - bike/on foot = positive effects	0	1				
	Lifestyle - Culture lover	0	1				

28

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Residential attitudes - Open space and quietness	0	1				
	Travel attitudes - Pro-environment	0	1				
	Residential attitude - Car alternatives	0	1				
	Lifestyle - Home-oriented but active family	0	1				
	Travel mode attitudes - bike/on foot = comfortable	0	1				
	Travel mode attitudes - Car = negative effects	0	1				
	Travel mode attitudes - Car = comfortable	0	1				
	Lifestyle - Culture lover	0	1				
	Residential attitude - Accessibility	0	1				
	Lifestyle - Home-oriented traditional family	0	1				
	Travel mode attitudes - PT = comfortable	0	1				
	Travel mode attitudes - PT = time-saving	0	1				
	Travel mode attitudes - PT = positive effects	0	1				
	Lifestyle - Low-budget and active/creative	0	1				
	Travel attitudes - Reduced driving social expectation	0	1				
	Travel Attitudes - Frustrated traveller	0	1				
	Residential Attitudes - Social Context (ns)	0	1				
	Residential Attitudes - Safety & neatness (ns)	0	1				

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	Lifestyle - Friends & trends	0	1				
	Travel mode attitudes - bike/on foot = positive effects	0	1				
van Vugt et al. (1995)	Prosocial Value Orientation	0	1	n/a	0	0	**0.1**
	Importance environment	n/a	0				
	Importance travel flexibility	n/a	0				
	Importance public health	n/a	0				
	Importance Cost	n/a	0				
	Importance Convenience	n/a	0				
	Importance Weather	n/a	0				
	Importance travel time	n/a	0				
van Vugt et al. (1996)	Collective motives (prosocial) - Concern for environmental pollution	n/a	0	0	n/a	0	**0.0**
	Individual motives (proself) - Travel flexibility	n/a	0				
	Individual motives (proself) - Protection against the weather	n/a	0				
	Individual motives (proself) - Travel convenience	n/a	0				
	Individual motives (proself) - Travel time	n/a	0				
Verplanken et al. (1994)	Attitudes - Car use	0	0	n/a	0	0	**0.3**
	Habit - RFM	n/a	1				
	Decisional involvement	1	0				
	Attitudes - Train use	0	0				
Verplanken et al. (1998)	Habit - RFM	n/a	1	0	n/a	0	**0.4**
	Habit - SPB	n/a	1				
	Intention - Car use	n/a	0				

30

Author(s) (year)	Cognitive Mechanism(s)	Indicators of Study Quality					
		reliable	valid	Large sample (Power Analysis)	Large Sample (SEM/Path = >200)	Representativeness	**Total Score**
	PBC - Car use	n/a	0				
	SN - Car use	n/a	0				
	Attitudes - Car use	1	0				
Verplanken et al. (2008)	Environmental concern	1	1	0	n/a	0	**1.0**
Yang-Wallentin et al. (2004)	Intention 1 - PT vs car	0	0	n/a	1	0	**1.0**
	Intention 2 - PT vs car	0	0				
	Intention 3 - PT vs car	0	0				
	PBC 1 - PT vs car	0	0				
	PBC 2 - PT vs car	0	0				

n/a = not applicable, PT = public transport, PBC = perceived behavioural control, RFM = Response Frequency Measure, SPB = Self-reported frequency of past behaviour, SN = social norms, PN = personal norms, GGE = greenhouse gas emission

4. Cognitive Mechanisms of Travel Mode Choice

The emerging groups were driven by the literature and often represent the structure of socio-psychological models, in particular the Theory of Planned Behaviour (TPB) (Ajzen, 1991). Sub-groups emerged where studies measured the same cognitive mechanism but with a conceptually distinctive content of that mechanism. Hence, cognitive mechanisms were often divided into car use and non-car-use. For example, studies measured the intention to use the car (car use Intentions) or the intention to use the car less (non-car-use Intentions). Other cognitive mechanisms, such as Identity, could not be considered conceptually distinct but correlations reported by three car-use studies (reporting 17 associations) could be considered congruent with car use (pro-car Identity) and incongruent with car use (anti-car Identity). Added specificity to modifiable determinants of socio-psychological models has been shown to add to their predictive validity (Kaiser & Gutscher, 2003; Sheppard, Jon, & Warshaw, 1988) and is now frequently adapted in transport research (e.g. Gardner & Abraham, 2008, 2010; Mann & Abraham, 2012).

Overall, 333 associations were identified in the literature. Figure S2 presents the number of cognitive mechanisms studies over time. Attitudes were the most widely researched cognitive mechanism. A plethora of associations characterised by inconsistent conceptualisations and operationalisations suggested a more fragmented approach to the synthesis of attitudinal variables. What studies denoted as "attitudes" varied from (1) general evaluations or beliefs about specific car use/ non-car-use attributes to, (2) concerns about or subjective importance of factors not related to car use/ non-car-use. Hence, we classified these into five different categories: (1) car use attitudes, (2) non-car-use attitudes, (3) attitudes towards travel in general, (4) attitudes towards the environment and health, and (5) attitudes towards transport environment.

Table S6 shows an overview of the emerged categories of cognitive mechanisms and the corresponding definition can be viewed in Table S7. For illustrative purposes, Table S6 includes the numbers for a meta-analysis where $k \geq 2$.

32

Table S6. Overview of cognitive mechanisms studied and number of associations tested

Cognitive mechanism	*N* of unique studies	*N* of unique associations	N unique studies in MA car use behaviour	N unique studies in MA non-car-use behaviour	Component of which model
Attitude	**32**	**125**	**20**	**4**	
Car use	18	40	13	0	
Non-car-use	10	25	3	4	TPB
Travel in general	5	17	3	0	
Environment & health	11	14	7	0	
Travel in general	5	17	3	0	
Subjective norm (SN)	19	23	8	5	
Car use SN	8	8	6	0	TPB
Non-car-use SN	12	15	3	5	
Descriptive norm	4	4	3	0	TPB
Control Beliefs	**20**	**31**	**12**	**5**	
Perceived Behavioural Control (PBC)	17	26	11	5	
Car use PBC	8	13	6	0	TPB
Non-car-use PBC	11	13	5	5	
PBC - Environment	5	5	4	0	
Intention	17	21	10	5	
Car use Intention	9	9	7	0	TPB
Non-car-use Intention	8	12	3	5	
Personal Norm	9	9	5	2	NAM
Ascription of Responsibility	**5**	**5**	**3**	**0**	NAM
Awareness of Consequences	**8**	**11**	**5**	**0**	NAM
Altruistic Value Orientation	**5**	**11**	**2**	**0**	VBN
Identity, Role Beliefs & Personality	**5**	**38**	**3**	**0**	
Anti-car identity	3	11	2	0	TIB
Pro-car identity	3	12	3	0	
Social Comparison	**3**	**6**	**2**	**n/a**	n/a
Habit	**14**	**18**	**9**	**2**	
RFM	11	11	6	2	TIB
Other measures	5	7	5	0	

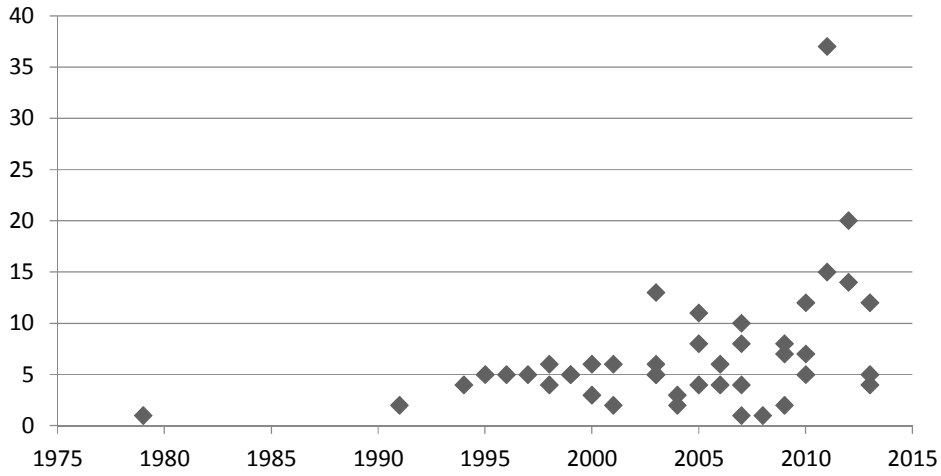
TPB = Theory of Planned Behaviour, NAM = Norm Activation Model, VBN = Value-Belief-Norm model, TIB = Theory of Interpersonal Behaviour

Table S7. Definition of emerged categories of cognitive mechanisms

Cognitive Mechanism Category	Definition	Example Question
Car use Attitude	Relates to general evaluation of car use as being good or bad, positive or negative, favourable or unfavourable. Also contains car-use-relevant beliefs (affective and behavioural)	"Making most of my journeys next week by car would be" good/bad "The most cost-effective way of getting to campus is by driving there every day" agree/disagree
Non-car-use Attitude	Relates to general evaluation of not using the car or using any other transport mode but the car as being good or bad, positive or negative, favourable or unfavourable. Also contains non-car-use-relevant beliefs (affective and behavioural)	"Making most of my journeys next week without my car would be" good/bad
Attitude - Travel in General	Evaluations, concerns or subjective importance of travel characteristics not specific to a particular mode.	"To which extent are you concerned with flexibility while traveling" very much/not at all
Attitude - Environment & Health	Comprises of general or specific evaluations, subjective importance, worry, opinions or concerns, about environment and public health	"I am worried about environmental problems such as air pollution, noise, and energy use" agree/disagree
Attitude - Transport Environment	Combines evaluations, concerns or subjective importance of spatial characteristics, elements of urban design or aspects of built-environment	"How important are the following features of the neighbourhood for your personal decision in favour of a certain place of residence?" agree/disagree
Car use Subjective Norm	Are injunctive norms or normative beliefs that refer to the individuals perception of important others' beliefs about personal car use	"If I use a car for most of my journeys in the next week, most people who are important to me would approve." agree/disagree
Non-car-use Subjective Norm	Are injunctive norms or normative beliefs that refer to the individuals perception of important others' beliefs about the individual's non-car travel	"People who are important to me expect that I will use environmentally friendly means of transportation." agree/disagree
Descriptive Norm	Is the individual perception of other people's car-use-relevant behaviour	"Most people who are important to me use a car for most of their journeys within the city" agree/disagree
Car use Intention	Refers to the intention to choose the car for journeys (over a certain period of time or at a specific time point)	"I intend to use the car for most of my journeys during the next week" agree/disagree
Non-car-use Intention	Is the intention to reduce car use or to use any other form of transport than/instead of the car	"I intend to use PT instead of the car for daily trips from my residence" agree/disagree

Cognitive Mechanism Category	Definition	Example Question
Car use PBC	Refers to beliefs about the capability of using the car	"Circumstances force me to use the car on my frequent trips" agree/disagree
Non-car-use PBC	Are beliefs about the capability of using any other mode of transport than/instead of the car	"For me to use PT instead of the car for daily trips from my residence would be" easy/difficult
PBC - Environment	Relate to beliefs about the capability of reducing environmental problems by decisions regarding transport. Can also relate to personal belief/opinion about activities that are essential in ameliorating the environmental state.	"Through my transport decisions, I can make a difference to the environment" agree/disagree
Non-car-use Personal Norm	Relates to the moral obligation or the individual's values to use non-car travel modes	"Due to values important to me, I feel obliged to use the car as little as possible." agree/disagree
Awareness of Consequences	Describes certain degree of awareness/ concern with consequences that individual's own actions or other people's actions with regards to car use are harmful/have bad consequences for the environment and society	"Car use causes serious air pollution in the world" agree/disagree
Ascription of Responsibilities	Refers to the extent to which the individual feels responsible that his/her own car-use-related actions or other people's car-use-related actions can influence these consequences/(environment and societal) problems	"I feel personally obliged to reduce smog" agree/disagree
Altruistic Value Orientation	Items were categorised when studies explicitly referred to the construct as being a value orientation	"How important is [value] to you as a guiding principle of life?" very important/not at all
Identity, Role Beliefs & Personality	Refers to several measures/ways in measuring of an individual's set of characteristics/lifestyle desires/personality or general efforts to establish a person's individuality	"How important to you is [identity] in defining who you are?" very important/not at all
Social Comparison	Refers to items asking in how far people compare their own actions with others' and also in how far they try to exceed others	"I can distinguish myself from others" agree/disagree
Car use Habit - RFM	Car use habit measured using the Response Frequency Measure (RFM) by Verplanken et al. (1994)	n/a
Car use Habit - Other Measures	Car use habit measured not using the RFM	n/a

Figure S1. Number of cognitive mechanisms measured over time



5. Further Details on Meta-analysis

Correlation coefficients could be extracted from 26 retrieved papers. In addition, 19 authors were asked to provide missing data and nine were willing/able to do so. We excluded Nilsson and Küller's (2000) study because it was not possible to determine if the dependent variable measured car use or non-car-use and because four out of six scales measure cognitive mechanisms showed low internal reliability e.g., Attitude – public transport (α = .48), Attitude - personal concern (α = .35), Attitude - environmental concern (α = .50), Environmental Knowledge (α = .44). One study reported cognitive mechanisms for both, car use and non-car-use (Scheiner & Holz-Rau, 2007) and was therefore included in both meta-analyses. The following chapters complement the results section and further describes salient observations made during the synthesised literature as well as more detailed results tables.

5.1 Car Use Intentions towards Car Use

The high heterogeneity index could be due to considerably different individual effect sizes. Two of the non-urban studies (Panter, Desousa, & Ogilvie, 2013; Verplanken, Aarts, van Knippenberg, & Moonen, 1998) reported effect sizes of r = .11 and r = .20, respectively, whereas Mann and Abraham (2006) reported a very large relationship between intentions and car use (r = .88). This can be explained by the study being conducted at a location (Falmer Campus, Sussex University) that is very accessible via multiple modes of transport and is being served by regular public transport. Therefore, although being in a rural location, the geographical conditions are not representative for rural locations, traditionally considered remote.

5.2 Awareness of Consequences towards Car Use

Studies used different measures to assess the awareness of consequences. Some items referred to impacts on the environment or society due to actions of the individual (Steg & Sievers, 2000) and some to the behaviour in general (Tanner, 1999). This might be due different conceptualisations of this cognitive mechanism that exist in the literature. Steg (2005), for instance, explains that a "person needs to be aware of consequences of their own behaviour for others or the environment" (Awareness of Consequences) and that he "needs to feel personally responsible for these problems" (Ascription of Responsibilities). Stern et al. (1999) define Awareness of Consequences as "awareness of threats to nonhuman species and the biosphere" and Ascription of Responsibilities as "the belief that action can alleviate

consequences". Lastly, Schwartz adopted the general approach and conceptualised Awareness of Consequences as "the extent to which someone is aware of adverse consequences of not acting prosocial for others or for other things one values" and Ascription of Responsibilities as a construct that "reflects feelings of responsibility for negative consequences of not acting prosocial"

5.3 Car Use Habit – Other Measure towards Car Use

Friedrichsmeier, Matthies, and Klöckner (2013) included four different operationalisations of habit and tested associations of script-based, past behaviour, self-report habit index and context stability separately. Therefore, this study was included in the category of RFM of car use habit and also in the category for other habit measures. Likewise, Verplanken et al. (1998) applied two different measures for habit (RFM and past behaviour) and provided two separate correlation coefficients for the two measures hence are included in both groups. Klöckner and Blöbaum (2010) used two different measures of habit (RFM and self-report habit index) but combined the two scales into one variable on the grounds of acceptable inter-correlation (α =.73). This study was therefore included in the category "other habit measures".

5.4 Longitudinal Studies

We identified four longitudinal studies in the review of which three were eligible to be entered into meta-analyses (Armitage et al., 2013; Friedrichsmeier et al., 2013; Tischer & Phillips, 1979). Across three studies, ten associations with car use were tested, all corresponding to a different cognitive mechanism category (see table below). In all cases, individual effect sizes were the expected direction and in many cases the magnitude was consistent with the pooled effect size for the cognitive mechanism. Unfortunately, we were unable to conduct a separate meta-analysis for those studies as insufficient number of studies reported correlation coefficients for the same cognitive mechanism.

Table S8: Effect sizes of longitudinal studies

Study	Cognitive Mechanism Category	study effect size *r*	*r*+
Tischer & Phillips (1979)	Car Use Attitudes	0.29	0.36
Friedrichsmeier et al. (2013)	Car Use Habit - RFM	0.44	0.47
	Car Use Intentions	0.51	0.5
Armitage et al. (2013)	Non-car-use PBC	-0.261	-0.47
	Non-car-use Attitudes	-0.098	-0.23
	Non-car-use Subjective Norms	-0.072	-0.15
	Non-car-use Intentions	-0.127	0.38

38

Table S9. Detailed results of the meta-analysis of car use

Cognitive mechanism (sub-groups)	*n*	*k*	*K*	*r*+	95% CI	I^2 (%)	X^2	*Egger's test*
Car Use Attitudes	**4647**	**38**	**12**	**0.22*****	**0.13, 0.30**	**91.6**	**115.52*****	**6.8 (*p* = 0.01)**
non-urban	3186	29	6	0.14***	0.06, 0.23	87.2	28.54***	8.8 (*p* = 0.07)
urban	1461	9	6	0.31***	0.21, 0.41	83.2	28.66***	3.6 (*p* = 0.17)
non-commuting journeys	3019	24	6	0.15**	0.05, 0.25	92.4	52.85***	9.4 (*p* = 0.12)
commuting journeys	1628	14	6	0.34***	0.26, 0.42	78	21.33***	4.2 (*p* = 0.11)
non-European	927	3	3	0.37***	0.26, 0.48	83.9	11.55**	7.8 (*p* = 0.10)
European	3720	35	9	0.18***	0.09, 0.27	90.8	73.57***	6.3 (*p* = 0.04)
typical car use	4218	28	10	0.21***	0.12, 0.30	92.3	101.16***	6.5 (*p* = 0.01)
actual car use	429	10	2	0.28*	0.06, 0.50	92	12.47***	-
TPB measures	1290	6	6	0.33***	0.20, 0.46	89.3	42.97***	2.8 (*p* = 0.62)
Beliefs	3586	32	7	0.19***	0.09, 0.29	92.2	69.25***	9.2 (*p* = 0.01)
Non-car-use Attitudes	**812**	**3**	**3**	**-0.23****	**-0.40, -0.06**	**90.7**	**20.14*****	**-**
Attitudes - Travel in General	**1486**	**10**	**3**	**0.05**	**-0.05, 0.15**	**84.6**	**11.92****	**-**
Attitudes - Environment & Health	**4097**	**9**	**7**	**-0.10****	**-0.17, -0.03**	**86.2**	**40.68*****	**-**
non-urban	2804	3	3	-0.09	-0.18, 0.00	89	18.31***	-
urban	1293	6	4	-0.13*	-0.25, 0.00	87.4	21.31***	-
Attitudes - Transport Environment	**4811**	**12**	**4**	**-0.28*****	**-0.41, -0.15**	**97.5**	**104.16*****	**-**
non-urban	1759	8	2	-0.17***	-0.23, -0.11	70.5	3.34	-
urban	3052	4	2	-0.35***	-0.52, -0.17	98.6	64.26***	-
Car Use Subjective Norms	**1455**	**6**	**6**	**0.20****	**0.05, 0.35**	**91.3**	**53.18*****	**12.2 (*p* = 0.20)**
Non-car-use Subjective Norms	**944**	**3**	**3**	**-0.15*****	**-0.20, -0.11**	**0**	**1.31**	**-**
Car Use Descriptive Norms	**532**	**3**	**3**	**-0.07**	**-0.35, 0.21**	**94.2**	**32.44*****	**-**
Car Use PBC	**1605**	**9**	**5**	**0.39*****	**0.18, 0.6**	**97.1**	**110.83*****	**-6.3 (*p* = 0.75)**
Non-car-use PBC	**1200**	**5**	**5**	**-0.42*****	**-0.57, -0.28**	**93**	**49.24*****	**-**
PBC - Environment	**324**	**4**	**4**	**-0.08****	**-0.17, -0.05**	**52.8**	**6.3**	**-**

Car Use Intentions	**2375**	**7**	**7**	**0.50*** **	**0.31, 0.68**	**98.3**	**262.35*** **	**8.3 (*p* = 0.33)**
non-urban	844	3	3	0.34	-0.04, 0.71	99.2	118.42***	-
urban	1531	4	4	0.59***	0.47, 0.70	95.6	49.6***	9.1 (*p* = 0.01)
non-commuting journeys	1438	3	3	0.50***	0.33, 0.67	96.7	54.89***	-
commuting journeys	937	4	4	0.50**	0.15, 0.85	98.9	207.12***	26.4 (*p* = 0.24)
typical car use	1839	4	4	0.47***	0.26, 0.67	97.9	135.45***	6.2 (*p* = 0.62)
actual car use	536	3	3	0.62***	0.25, 0.98	98.7	143.41***	-
Non-car-use Intentions	**943**	**3**	**3**	**-0.38***	**-0.68, -0.09**	**98.1**	**87.86*** **	**-**
Non-car-use Personal Norms	**793**	**5**	**5**	**-0.35*** **	**-0.42, -0.28**	**69.3**	**12.32***	**-**
Ascription of Responsibilities	**642**	**3**	**3**	**-0.14**	**-0.31, 0.03**	**87.7**	**14.69*** **	**-**
Awareness of Consequences	**2139**	**6**	**5**	**-0.22*** **	**-0.29, -0.16**	**69.1**	**12.72***	**-**
Altruistic Value Orientation	**184**	**3**	**2**	**-0.32*** **	**-0.34, -0.29**	**0**	**0.07**	**-**
Identity Anti-Car	**1609**	**11**	**2**	**-0.08****	**-0.11, -0.02**	**39.1**	**1.64**	**-**
Identity Pro-Car	**4229**	**11**	**3**	**0.05*** **	**0.04, 0.07**	**0**	**0.88**	**-**
Social Comparison	**1247**	**6**	**2**	**0.16****	**0.06, 0.26**	**84.5**	**6.61***	**-**
Car Use Habit - RFM	**2058**	**6**	**6**	**0.47*** **	**0.39, 0.56**	**89**	**37.70*** **	**2.7 (*p* = 0.42)**
typical car use	445	3	3	0.53***	0.39, 0.66	87.9	11.55**	-
actual car use	1613	3	3	0.46***	0.35, 0.57	92.1	24.19***	-
Car Use Habit - Other Measures	**2160**	**7**	**5**	**0.38*** **	**0.20, 0.56**	**97.8**	**128.33*** **	**7 (*p* = 0.48)**
past behaviour	1248	2	2	0.58***	0.37, 0.78	97.7	60.06***	-
SRHI	523	2	2	0.28	-0.08, 0.64	98.6	40.97***	-
latent variable	1437	2	2	0.49***	0.29, 0.69	98.6	52.62***	-

*p<.05, **p<.01, ***p<.001

[a] K refers to the unique number of studies included in the analysis.

40

Table S10. Detailed results of the meta-analysis of non-car-use

Cognitive mechanism (sub-groups)	*n*	*k*	*K*	*r+*	95% CI	I^2 (%)	X^2	*Egger's test*
Non-car-use Attitudes	**2597**	**7**	**4**	**0.36*****	**0.21, 0.51**	**97.1**	**79.26*****	**11.3 (*p* = 0.19)**
Non-car-use Subjective Norms	**2745**	**6**	**5**	**0.28*****	**0.14, 0.41**	**95.6**	**78.47*****	**5.1 (*p* = 0.41)**
Non-car-use PBC	**3500**	**9**	**5**	**0.49*****	**0.41, 0.57**	**93.9**	**55.08*****	**8.3 (*p* = 0.14)**
typical non-car-use	2347	4	3	0.49***	0.39, 0.59	93.3	26.02***	-
actual non-car-use	1153	3	2	0.50***	0.34, 0.66	97.2	29.11***	-
Non-car-use Intentions	**3493**	**8**	**5**	**0.48*****	**0.35, 0.61**	**97.3**	**131.63*****	**11.8 (*p* = 0.18)**
* $p < .05$, ** $p < .01$, ***$p < .001$								

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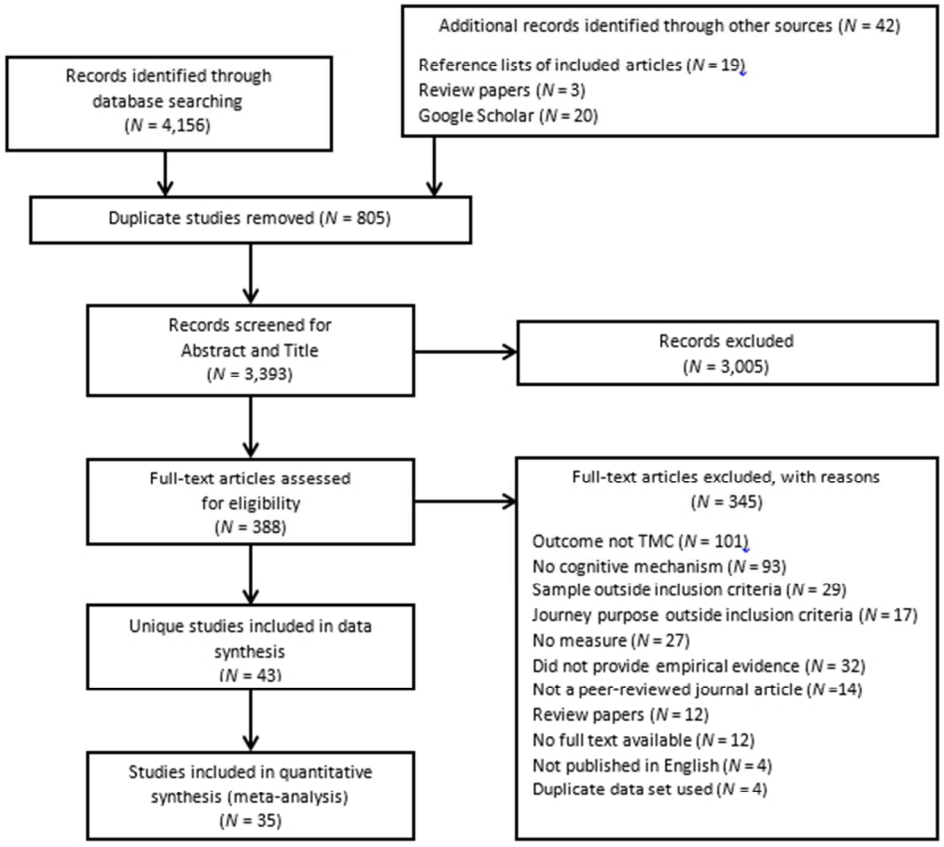

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) flowchart
Figure 1 near here

Cognitive mechanism (sub-groups)	*n*	*k*	*r*+	95% CI	I^2 (%)	*Egger's test*
Car Use Attitudes	**4647**	**38**	**0.22*** **	**0.13, 0.30**	**91.6**	**6.8 (*p* = 0.01)**
non-urban	3186	29	0.14***	0.06, 0.23	87.2	8.8 (*p* = 0.07)
urban	1461	9	0.31***	0.21, 0.41	83.2	3.6 (*p* = 0.17)
non-commuting journeys	3019	24	0.15**	0.05, 0.25	92.4	9.4 (*p* = 0.12)
commuting journeys	1628	14	0.34***	0.26, 0.42	78	4.2 (*p* = 0.11)
non-European	927	3	0.37***	0.26, 0.48	83.9	7.8 (*p* = 0.10)
European	3720	35	0.18***	0.09, 0.27	90.8	6.3 (*p* = 0.04)
typical car use	4218	28	0.21***	0.12, 0.30	92.3	6.5 (*p* = 0.01)
actual car use	429	10	0.28*	0.06, 0.50	92	-
TPB measures	1290	6	0.33***	0.20, 0.46	89.3	2.8 (*p* = 0.62)
Beliefs	3586	32	0.19***	0.09, 0.29	92.2	9.2 (*p* = 0.01)
Non-car-use Attitudes	**812**	**3**	**-0.23****	**-0.40, -0.06**	**90.7**	**-**
Attitudes - Travel in General	**1486**	**10**	**0.05**	**-0.05, 0.15**	**84.6**	**-**
Attitudes - Environment & Health	**4097**	**9**	**-0.10****	**-0.17, -0.03**	**86.2**	**-**
non-urban	2804	3	-0.09	-0.18, 0.00	89	-
urban	1293	6	-0.13*	-0.25, 0.00	87.4	-
Attitudes - Transport Environment	**4811**	**12**	**-0.28*****	**-0.41, -0.15**	**97.5**	**-**
non-urban	1759	8	-0.17***	-0.23, -0.11	70.5	-
urban	3052	4	-0.35***	-0.52, -0.17	98.6	-
Car Use Subjective Norms	**1455**	**6**	**0.20****	**0.05, 0.35**	**91.3**	**12.2 (*p* = 0.20)**
Non-car-use Subjective Norms	**944**	**3**	**-0.15*****	**-0.20, -0.11**	**0**	**-**
Car Use Descriptive Norms	**532**	**3**	**-0.07**	**-0.35, 0.21**	**94.2**	**-**
Car Use PBC	**1605**	**9**	**0.39*****	**0.18, 0.60**	**97.1**	**-6.3 (*p* = 0.75)**
Non-car-use PBC	**1200**	**5**	**-0.42*****	**-0.57, -0.28**	**93**	**-**
PBC - Environment	**324**	**4**	**-0.08****	**-0.17, -0.05**	**52.8**	**-**
Car Use Intentions	**2375**	**7**	**0.50*****	**0.31, 0.68**	**98.3**	**8.3 (*p* = 0.33)**
non-urban	844	3	0.34	-0.04, 0.71	99.2	-
urban	1531	4	0.59***	0.47, 0.70	95.6	9.1 (*p* = 0.01)
non-commuting journeys	1438	3	0.50***	0.33, 0.67	96.7	-
commuting journeys	937	4	0.50**	0.15, 0.85	98.9	26.4 (*p* = 0.24)
typical car use	1839	4	0.47***	0.26, 0.67	97.9	6.2 (*p* = 0.62)
actual car use	536	3	0.62***	0.25, 0.98	98.7	-
Non-car-use Intentions	**943**	**3**	**-0.38***	**-0.68, -0.09**	**98.1**	**-**
Non-car-use Personal Norms	**793**	**5**	**-0.35*****	**-0.42, -0.28**	**69.3**	**-**
Ascription of Responsibilities	**642**	**3**	**-0.14**	**-0.31, 0.03**	**87.7**	**-**
Awareness of Consequences	**2139**	**6**	**-0.22*****	**-0.29, -0.16**	**69.1**	**-**
Altruistic Value Orientation	**184**	**3**	**-0.32*****	**-0.34, -0.29**	**0**	**-**
Identity Anti-Car	**1609**	**11**	**-0.08****	**-0.11, -0.02**	**39.1**	**-**
Identity Pro-Car	**4229**	**11**	**0.05*****	**0.04, 0.07**	**0**	**-**
Social Comparison	**1247**	**6**	**0.16****	**0.06, 0.26**	**84.5**	**-**
Car Use Habit - RFM	**2058**	**6**	**0.47*****	**0.39, 0.56**	**89**	**2.7 (*p* = 0.42)**
typical car use	445	3	0.53***	0.39, 0.66	87.9	-
actual car use	1613	3	0.46***	0.35, 0.57	92.1	-
Car Use Habit - Other Measures	**2160**	**7**	**0.38*****	**0.20, 0.56**	**97.8**	**7 (*p* = 0.48)**

past behaviour	1248	2	0.58***	0.37, 0.78	97.7	-
SRHI	523	2	0.28	-0.08, 0.64	98.6	-
latent variable	1437	2	0.49***	0.29, 0.69	98.6	-
*p<.05, **p<.01, ***p<.001						

Table 1. Results of the meta-analysis of car use

Cognitive mechanism (sub-groups)	*n*	*k*	*r*+	95% CI	I^2 (%)	*Egger's test*
Non-car-use Attitudes	**2597**	**7**	**0.36*** **	**0.21, 0.51**	**97.1**	**11.3 (*p* = 0.19)**
Non-car-use Subjective Norms	**2745**	**6**	**0.28*** **	**0.14, 0.41**	**95.6**	**5.1 (*p* = 0.41)**
Non-car-use PBC	**3500**	**9**	**0.49*** **	**0.41, 0.57**	**93.9**	**8.3 (*p* = 0.14)**
typical non-car-use	2347	4	0.49***	0.39, 0.59	93.3	-
actual non-car-use	1153	3	0.50***	0.34, 0.66	97.2	-
Non-car-use Intentions	**3493**	**8**	**0.48*** **	**0.35, 0.61**	**97.3**	**11.8 (*p* = 0.18)**
* $p < .05$, ** $p < .01$, *** $p < .001$						

Table 1. Results of the meta-analysis of non-car-use