To what extent do our walking and cycling behaviours relate to each other, and do we cycle as well as we think we do? Piloting the Walking and Cycling Behaviour Questionnaires in the UK

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Abstract

Greater uptake of active transport has been argued as necessary for the transport system to achieve relevant sustainability and public health goals; however, the research tools used to investigate behaviour when using these modes are far less well-developed than those used to investigate driving behaviour. This study takes two self-report behavioural measures, the Walking Behaviour Questionnaire (WBQ) and the Cycling Behaviour Questionnaire (WBQ), and pilots them in the UK. Exploratory and confirmatory factor analyses with data from 428 respondents revealed factor structures different to those described in the limited number of previous studies that used the CBQ and WBQ. Across both questionnaires, scales measuring intentional behaviour differed from original descriptions to a greater extent than did the scale concerning unintentional attention or memory errors. In addition to a validation exercise, this research explored the relationships between variables, finding a correlation between the reported performance of unintentional errors when walking and cycling. Looking in more detail at cycling behaviours, we found that those who rated themselves as more proficient cyclists also reported performing fewer unintentional cycling errors. Results also showed self-reported helmet use to bear little to no relationship with other self-reported cycling behaviours or self-rated cycling proficiency. Finally, using structural equation modelling, we demonstrated that responses to the CBQ add very little (over and above age, gender, and exposure to the road environment) to the explanation of self-reported past collision involvement. In total, only 7% of the variation in past collision involvement was explained by the included variables. We urge caution when using self-report behavioural measures that have not been validated in the context of intended use, and the importance of using such measures in combination with other approaches rather than in isolation when trying to develop an understanding of overall system performance.

Keywords: walking behaviour, cycling behaviour, self-report scales, road safety, pedestrians, cyclists

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Introduction

Road safety is a global issue of critical importance; around 1.35 million people die on the world's road every year and many more are seriously injured (WHO, 2018). Among the many perspectives of the issue, studies focussing on road user behaviour abound, and of the myriad methods available to study that behaviour, self-report questionnaires have proved highly popular. The most well-established is the Driver Behaviour Questionnaire (e.g., Reason et al., 1990). This has been systematically tested and validated across a large variety of settings (De Winter, Dodou & Stanton, 2015; af Wåhlberg, Barraclough & Freeman, 2015), and its factor structure (in terms of the constructs it intends to measure, i.e,., memory and attention lapses, dangerous errors, and intentional violations) has been found to be quite stable across both different questionnaire versions/adaptations and groups of drivers (Useche, Cendales, Lijarcio & Llamazares, 2021; Koppel et al., 2019). Although a focus on motorised vehicle drivers is perhaps understandable from a harm perspective, with a car having the potential to cause significantly more damage (to people or property) than a pedestrian or pedal cyclist, those two latter groups have attracted growing attention in the traffic psychology and safety literature over the past two decades. This is not only because responsibility is shared among all actors (hence all actors are of interest), but also that a driver focus excludes those parts of a population that do not regularly drive.

For the study of pedestrian behaviour, several related measures have been reported in the literature, with Díaz and colleagues' (Díaz et al. 1997; Díaz, 2002) providing the first (to our knowledge). Since that work, numerous researchers have used variations of the questionnaire across a variety of contexts, using names such as the Pedestrian Behaviour Scale (Granié et al. 2013), the Pedestrian Behaviour Questionnaire (Deb et al. 2017), or the Walking Behaviour Questionnaire (Useche, Alonso & Montoro, 2020) to refer to the measure. Broadly speaking, most versions are based on the DBQ (directly or indirectly) and measure three behavioural factors; intentional rule violations, aggressive behaviours, and unintentional errors (sometimes further subdivided into memory or inattention lapses and intentional actions resulting from a deficiency in knowledge of the rules). Although many examples of the questionnaire's use also include a 'positive behaviour' sub-scale (including items such as "I thank a driver who stops to let me cross") this is generally reported as unreliable (Granié et al. 2013; Deb et al 2017; McIlroy et al. 2019).

Questionnaire research on cyclist behaviour is less abundant. Perhaps the first to provide an example of such work was Feenstra et al. (2010), who adapted the DBQ to measure what they termed 'risky adolescent cycling behaviour' in a sample from the

Netherlands. The next available examples come from Hezaveh et al. (2018) and Useche et al. (2018; see also Useche et al. 2019). Both report studies with adult participants responding to questions again based on the DBQ, the former being conducted in Iran, the latter across 20 Spanish-speaking countries. Although the factors measured differed, intentional violations and unintentional errors were common to all three studies. These two factors were also found in O'Hern et al.'s (2020, 2021) use of the measure in Australia, in Wang et al.'s (2019) work in China using their own version (with the addition of two further error types relating to distractions and control errors), and in Kummeneje & Rundmo (2020) also in the use of their own version of the questionnaire in Norway.

One of the uses of the Driver Behaviour Questionnaire has been to predict collision involvement (or at least link questionnaire responses to self-reported collision involvement). Overall, results demonstrate that the link does indeed exist; those that report performing more risky or unsafe driving behaviours also report having been involved in more collisions as a driver (e.g., de Winter et al. 2015). This is particularly true for the violations and errors sub-scales (de Winter & Dodou, 2010). In the walking domain such links have also been explored, with mixed results. In McIlroy et al. (2019) only one factor of the pedestrian questionnaire used, and in only two of the six countries included in the investigation (i.e., the UK and Vietnam), was self-reported behaviour linked with self-reported collision involvement. In Useche et al. (2020), two of the three factors were linked with self-reported collision involvement, though one only indirectly through its effect on the other factor (i.e., the relationship between violations and collisions was mediated through errors). Granié et al. (2013) reported similar results, with 'lapses' (memory or attention errors) directly associated with self-reported collision involvement, a finding that has since been replicated by Esmaili et al. (2021).

The relationship has also been explored in the cycling behaviour questionnaire literature, with similar results to those found in driving and pedestrian studies. In Feenstra et al. (2010), self-reported collision involvement related to all three of their adolescent cycling behaviour questionnaire's factors. In Hezaveh et al. (2018) three of their five factors were associated with collisions (i.e., traffic violations and two types of error). In Useche et al. (2019), self-reported 'risky' cycling behaviours (a summation of errors and violations factors) were found to be linked with past collision involvement, while in Wang et al.'s (2019) study, three of their questionnaire's four factors (i.e., distraction and the two types of violations) were significantly related to self-reported collision involvement. Neither O'Hern et al. (2020) nor Kummeneje & Rundmo (2020) report exploring self-reported collisions.

There are, of course, many factors that contribute to collision involvement, a point made by all the researchers cited here. It is also not fully clear what constitutes a 'risky' behaviour. For example, helmet use (or non-use) is a controversial topic in the academic (*e.g.*, Høye, Jensen & Sørensen, 2020; Ouellet, 2011) and popular (*e.g.*, The Guardian, 2017) literature, with unclear relationships with collision involvement (note that its protective benefit in the case of a crash is not in question) or with other 'risky' behaviours (Høye, Jensen & Sørensen, 2020; Webman et al., 2013). In a systematic review of the literature on the relationship between helmet use risky behaviour, Esmaeilikia et al. (2019) found mixed evidence. More work refuted a 'risk compensation' hypothesis (i.e., helmet use reduces an individual's perception of risk, so they engage in more risky behaviour to compensate) than supported it, while just under half of the studies reviewed (23 in total) found helmet use to be associated with safer cycling behaviour. The studies included in their review varied in methodology, but none used any form of the cycling behaviour questionnaire. How responses to this questionnaire relate to helmet use is therefore still in question.

Finally, the extent to which someone thinks they are good at something may or may not influence the behaviours they engage in. In the driving domain, it has been found that, among drivers over the age of 65, an increase in self-rated performance is associated with an increased risk of unsafe driving (Freund et al. 2005). In contrast, Amado et al (2014) found responses to the errors and violations factors of the DBQ were significantly related to an individual's self-rated performance; those that rated themselves as better drivers also reported performing fewer risky behaviours. This result was also found by Martinussen et al. (2014); drivers who reported higher levels of driving skill reported performing fewer risky driving behaviours. Xu et al. (2018) subsequently replicated the finding in China; higher self-rated driving performance is associated with safer driving behaviours as reflected in DBQ responses. It is perhaps unreasonable to directly translate this type of exploration to the walking domain (with our ability to walk not considered a skill in the same way driving is); however, it is possible to ask this question with regards to cycling behaviour. Specifically, to what extent does an individual's self-assessment of cycling proficiency relate to their responses to a cycling behaviour questionnaire? We know of no published work addressing this.

Aims and objectives

To our knowledge, no researcher has yet used a cycling behaviour questionnaire in a UK context. As such, the first aim of the current researcher was to validate the questionnaire (and its factors structure) in a UK sample. Research has demonstrated close links between pedestrian and driver behaviour, i.e., those that report performing riskier driving behaviours also tend to report performing riskier walking behaviours (e.g., Şimşekoğlu, 2015). The literature currently lacks an exploration of whether this is also true for walking and cycling behaviours; this is the second aim of the current article. The third aim of this research was to explore the extent to which self-reported cycling behaviours relate to self-reported helmet use. The fourth aim was to explore the extent to which a person's responses to a cycling behaviour questionnaire are related to their self-reported involvement in past collisions. Finally, the fifth aim of this work was to investigate the extent to which self-assessment of cycling proficiency is related to responses to a cycling behaviour questionnaire. As this research is largely exploratory, we made no formal hypotheses; however, based on the literature outlined above we might expect self-reported walking and cycling behaviours to be correlated, and for responses to the cycling behaviour questionnaire to be related both to previous collision involvement and to self-ratings of cycling proficiency.

Method

Survey instrument and dissemination

This article reports on parts of a larger survey. For the purposes of the current research, three sections are relevant: demographics and bicycle use, the walking behaviour questionnaire (WBQ) and the cycling behaviour questionnaire (CBQ). The demographics and bicycle use section included items regarding age, gender, cycling exposure (i.e., hours of bicycle use per week), previous cycling collision involvement (the number of collisions involved in over the past five years), self-rated performance riding a bicycle (on a rating from one to ten, 'very bad' to 'perfect'), and helmet use (on a five-point Likert scale from 'Never or almost never' to 'always or almost always').

The walking behaviour questionnaire (WBQ) was taken from Useche et al. (2020; see also Useche et al. 2021a) and contained 30 items found (in a Spanish sample) to measure three factors: violations (16 items), errors (10 items), and positive behaviours (four items). The cycling behaviour questionnaire (CBQ) was taken from Useche et al. (2018; see also Useche et al. 2021b) and contained 29 items found (in a mixed Latin and North American and Spanish sample) to measure three factors: traffic violations (eight items), errors (15 items), and positive behaviours (six items). The questionnaires are reported in full, below, in the factor analysis section. The original factor structures were not assumed to hold for the current study.

The questionnaire was disseminated online using Google Forms and advertised through a variety of social media pages, cycling and other transport fora, mailing lists, and through colleagues and associates of the researchers. Those that had completed the questionnaire were asked to pass on the link to friends and family, therefore representing both convenience and snowball sampling approaches. Ethical approval for the study was sought from, and granted by, the University of Southampton's (ID 63069) and the University of Valencia's Ethics Committees (IRB: HE0001290920).

Statistical analyses

For the WBQ and CBQ, the original factor structures were assessed using Confirmatory Factor Analysis (CFA). A variety of metrics are used to indicate the suitability of a factor structure to the data it aims at modelling. We considered Hooper et al.'s (2008) thresholds of $x^2/df<3$, RMSEA < .07, CFI > .95, TLI > .95, AGFI > .90, and SRMR < .08 and Hu and Bentler's (1999) two-index presentation strategy where a model is considered satisfactory if both RMSEA is under .06 and SRMR is under .09.

As stated above, we did not assume that the WBQ and CBQ factor structures would be suitable four our sample. Therefore, where appropriate the data were also subjected to Exploratory Factor Analysis using principal axis factoring. Factors were identified based on visual inspection of the anti-image matrix, scree plot, the rotated component matrix (using Varimax rotation), and informed by the conceptual links between items. Items that had a factor loading of less than .4 were removed (e.g., Stevens, 1992; Field, 2013). The reliability of the factors identified were again assessed using Cronbach's alpha, for which .7 is generally considered the cut-off value of what is acceptable (e.g., Nunally, 1978). Anything below that was considered not sufficiently reliable to be retained for further analyses.

To explore the relationship between self-reported walking and cycling behaviours, we performed correlational analyses using Spearman's and Pearson's coefficients. These statistics were also used to give an indication of the relationship between CBQ responses and self-reported helmet use. This was considered conceptually appropriate as neither is expected to 'predict' the other, rather for their relationship likely to be driven by a third variable (e.g., risk appetite) if such a relationship exists. Given the exploratory nature of this research, correlation analysis was also deemed sufficient to explore the relationship between self-rated cycling proficiency and responses to the CBQ.

Finally, to explore the extent to which CBQ responses were related to self-reported collision involvement, structural equation modelling (SEM) was used. One of the main aims of these types of questionnaires is to provide predictive value, hence the use of SEM to assess the extent to which CBQ responses could 'predict' collision involvement (acknowledging beforehand that this study had a cross-sectional design, not longitudinal). To control for the known effects of demographics on engagement in risky behaviour (across all domains, e.g., Byrnes et al. 1999) and for the influence of the amount of time spent on a bicycle on the likelihood of being involved in a collision, age, gender, and exposure were included as control variables in the model tested. More detail is provided in the relevant section, below. All analyses were carried out using SPSS (v.26) and Amos (v.27).

Results

Demographics

In total, 428 individuals responded to the questionnaire: three that did not identify as singularly male or female (aged 26 to 48, M = 40.3, SD = 12.4), 221 males (aged 19 to 77, M = 47.5, SD = 13.9), and 204 females, one of which did not give a response to the age question (aged 20 to 73, M (of 203) = 41.8, SD (of 203) = 11.7). For the 425 individuals that answered the question, the numbers of hours cycled each week ranged from below one (five participants) to 40 or more (one participant), with an average of 6.2 (SD = 4.3). Respondents reported having been involved in an average of 1.0 collisions over the past five years (SD = 1.2), with a range from zero to eight. Figure 1 displays this data across all 428 respondents. On average, participants rated their performance (out of ten) at an average of 7.7 (SD = 1.1); Figure 2 displays this information across the 428 respondents.

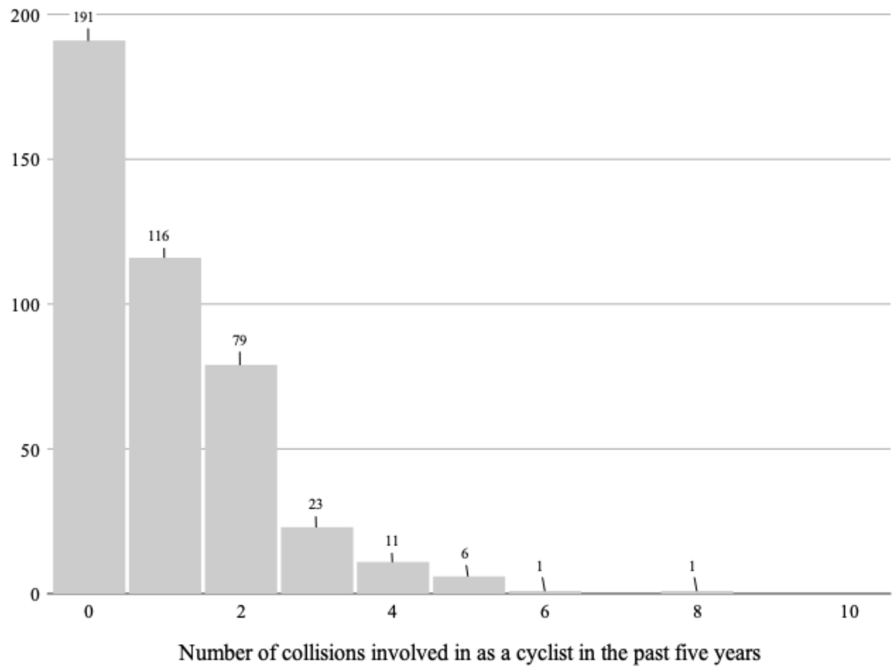

Figure 1. Responses to the item ‘During the past 5 years (and regardless of its severity), have you experienced any accident while riding a bike? How many?’, with options from ‘No: 0’ to ‘Yes: 10 or more’.

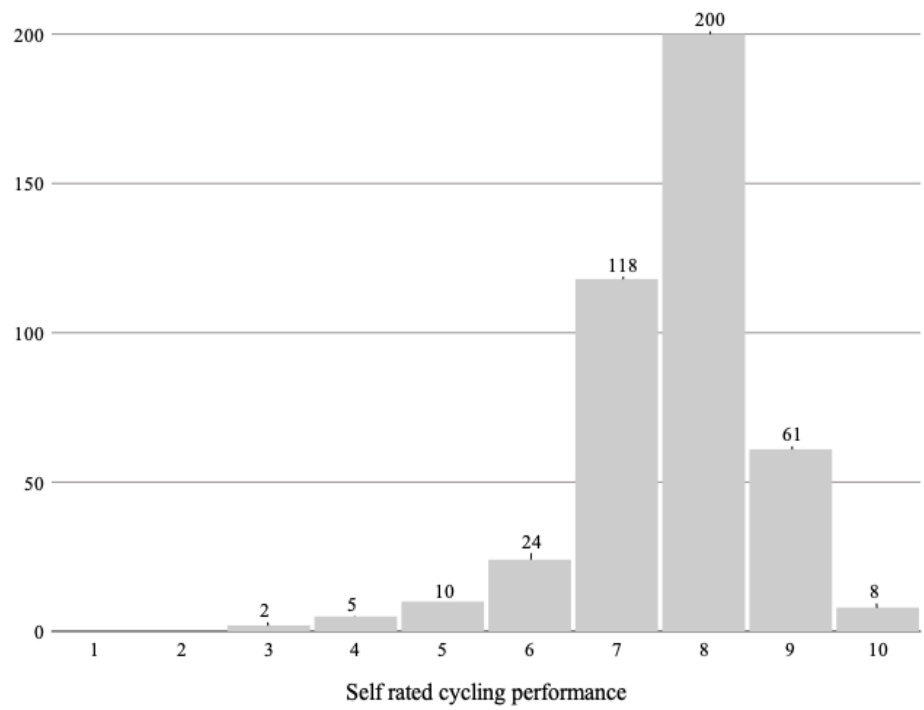

Figure 2. Responses to the item ‘In a range going from 1 (very bad) to 10 (perfect), how would you describe your performance when riding a bike?’

Factor analyses

<u>Walking Behaviour Questionnaire</u>

The Walking Behaviour Questionnaire questions are presented in full in Table 1, separated by the original factor structure (as described by Useche et al. 2020), with response means (and SDs) for each item (the responses ranging from zero to four). For Violations and Errors, higher numbers indicate a greater self-reported propensity to perform undesirable or risky behaviours. For positive behaviours, the opposite is true; higher scores indicate more positive behaviour. Cronbach's alpha for each original factor is also displayed. Although these figures suggest Violations and Errors to have internal reliability, the Positive Behaviour scale, having an alpha of .59, was considered insufficiently reliable.

Table 1. Walking Behaviour Questionnaire items separated by original factor structure, with means, standard deviations, and each factors' Cronbach's alpha (α)

No.	***Sub-scale* / Item**	**Mean (SD)**
Violations (α = .86)		
1	Crossing in the middle of the road, not on the designated crossing, in a city street	2.49 (1.01)
2	Crossing on a traffic light controlled crossing when the light is red for pedestrians	2.01 (1.11)
3	Walking on the road because the pavement is very narrow or there are many pedestrians already walking on it	2.22 (1.06
4	Crossing the road among cars despite being relatively close to a designated pedestrian crossing	1.54 (1.08)
5	Crossing at a run when the pedestrian traffic light is flashing, even if you make cars wait	1.48 (1.09)
6	Increasing your pace in order to overtake someone who is ahead of you, but is walking very slowly	2.93 (0.99)
7	Walking on the bike lane, even for a short time	1.28 (0.98)
8	Jumping a fence or obstacle in order to shorten the way	0.91 (1.01)
9	Running at the last moment, so you won't miss your bus or other public transportation	1.59 (1.14)
10	Walking while under the effects of alcohol or drugs	1.29 (1.09)
11	Walking while listening to music on your headphones	1.57 (1.41)
12	Walking while watching a video or checking your social media on your phone	0.97 (1.08)
13	Walking while you send a text message or talk in a chat	1.43 (1.10)
14	Walking while talking on the phone, with or without a 'hands-free' device	1.68 (1.16)
15	Walking so fast that people have to sidestep	0.68 (0.80)
16	Zig-zagging among people to reach your destination faster	1.71 (1.08)
Errors (α = .85)		
17	Walking while being distracted, so that a car has to stop or beep their horn at you	0.43 (0.64)
18	Bumping into someone because you were distracted	0.34 (0.58)
19	Bumping into an object because you were distracted	0.38 (0.62)
20	Forgetting, for a moment, the place you were going to	0.61 (0.83)
21	Stumbling upon an obstacle, a bump or a gap that you hadn't seen	0.82 (0.78)
22	Suddenly stopping or changing direction, almost making someone bump into you (for instance, looking into a shop window)	0.67 (0.73)
23	Realising that you have just crossed the road without looking in both directions	0.42 (0.64)
24	Realising that you have just crossed at a traffic light that was not green for pedestrians	0.72 (0.95)
25	Almost bumping into someone while turning a corner because you were not looking	0.65 (0.73)
26	Looking at some billboard instead of focusing on traffic	0.49 (0.74)
Positive behaviours (α = .59)		
27	Looking at both sides of the road before crossing, even if you take precedence	3.33 (0.94)
28	Waiting for the pedestrian traffic light to turn green before crossing, even when there are no vehicles approaching	1.87 (1.12)
29	Trying to walk on the left side, to avoid bumping into another pedestrian who may come from the opposite direction	2.26 (1.18)
30	Walking to the designated crossing area to cross the road, even if it requires some more time	2.01 (0.99)

A Confirmatory Factor Analysis for the 29-item, three-factor WBQ, on the full dataset of 428 responses, indicated unacceptable model fit: $x^2/df = 4.08$, RMSEA = .085, CFI = .71, TLI = .69, AGFI = .72, and SRMR = .087. Two items associated with the Positive Behaviour scale had factor loadings below .4 (items 27 and 29), and Cronbach's alpha for this factor was unacceptably low (at .59). As such, the original factor structure of the WBQ was not considered appropriate for our data.

Following poor model fit, the data were split randomly in half and one half subjected to Exploratory Factor Analysis (EFA; using 214 data points). Visual inspection of the scree plot indicated a four-factor solution to be suitable. The EFA resulted in removal of items 27 to 30 (i.e., the positive behaviour scale) due to low partial correlations, and items 6, 15, and 16 due to loadings lower than .4. Items 7 and 9 alone comprised the fourth factor; however, they were not considered conceptually related (i.e., concerning walking on bike lanes and running for public transport) hence were removed, leaving a three-factor solution. The resulting 21-item, three-factor scale was then subjected to CFA using the other half of the data set. This revealed items 8 and 10 to load poorly onto their respective factors, hence they were also removed. This resulted in the 19-item, three-factor scale is described in Table 2, and comprised the factors 'Violations', 'Device use', and 'Errors'. 'Violations' and 'Errors' contained items from their corresponding previous scales. The 'Device Use' scale was included based on its empirical justification. (i.e., the factor analysis results) and on the conceptual similarity of the items it contained (i.e., they all measured a similar underlying idea).

After inspection of modification indices, error covariances were added between three item pairs (1 and 2, 17 and 18, and 18 and 19), with the resulting model fit indices: $x^2/df =$ 1.61, RMSEA = .053, CFI = .94, TLI = .93, AGFI = .87, and SRMR = .069. Although CFI, TLI, and AGFI were lower than the thresholds described by Hooper et al. (2008), the differences were small, and the RMSEA and SRMR satisfied the criteria. Moreover, the two-index strategy describe by Hu and Bentler (1999; using RMSEA and SRMR) was satisfied. Model fit was therefore accepted and average scores for each participant calculated for the three sub-scales, namely Violations, Device use, and Errors, for use in subsequent analyses.

Table 2. Final Walking Behaviour Questionnaire items and structure, with factor loadings (from CFA) and Cronbach's alpha (α) (using the whole dataset).

No.	*Sub-scale* / Item	Loadings
Violations (α = .72)		
1	Crossing in the middle of the road, not on the designated crossing, in a city street	.65
2	Crossing on a traffic light controlled crossing when the light is red for pedestrians	.64
3	Walking on the road because the pavement is very narrow or there are many pedestrians already walking on it	.55
4	Crossing the road among cars despite being relatively close to a designated pedestrian crossing	.78
5	Crossing at a run when the pedestrian traffic light is flashing, even if you make cars wait	.70
Device use (α = .81)		
11	Walking while listening to music on your headphones	.52
12	Walking while watching a video or checking your social media on your phone	.82
13	Walking while you send a text message or talk in a chat	.93
14	Walking while talking on the phone, with or without a 'hands-free' device	.71
Errors (α = .86)		
17	Walking while being distracted, so that a car has to stop or beep their horn at you	.55
18	Bumping into someone because you were distracted	.54
19	Bumping into an object because you were distracted	.56
20	Forgetting, for a moment, the place you were going to	.54
21	Stumbling upon an obstacle, a bump or a gap that you hadn't seen	.51
22	Suddenly stopping or changing direction, almost making someone bump into you (for instance, looking into a shop window)	.76
23	Realising that you have just crossed the road without looking in both directions	.72
24	Realising that you have just crossed at a traffic light that was not green for pedestrians	.44
25	Almost bumping into someone while turning a corner because you were not looking	.64
26	Looking at some billboard instead of focusing on traffic	.49

Cycling Behaviour Questionnaire

The Cycling Behaviour Questionnaire (CBQ) questions are presented in full in Table 3 alongside response means (and SDs) for each item (responses again ranged from zero to four). The items are separated by the original factor structure of the 29-item measure (as described in Useche et al. 2021b). As with the WBQ, for the Violations and Errors sub-scales, higher numbers indicate a greater self-reported propensity to perform undesirable or risky behaviours, while higher scores in the Positive Behaviours sub-scale indicate a greater propensity to report performing positive behaviours. Cronbach's alpha for each factor is also displayed. For the Errors sub-scale this was acceptable, at .832; however, neither the Violations nor Positive Behaviours sub-scales achieved acceptable internal reliability (with alphas of .617 and .593, respectively). As with the WBQ, the CBQ was subjected to CFA (using the whole dataset of 428 responses), resulting in the following model fit indices: $x^2/df = 4.56$, RMSEA = .091, CFI = .50, TLI = .46, AGFI = .78, and SRMR = .183. These indicate a poor model fit, hence once again the data were split randomly in half and one of those halves subjected to an Exploratory Factor Analysis (EFA).

Table 3. Cycling Behaviour Questionnaire items separated by original factor structure, with means, standard deviations, and each factors' Cronbach's alpha (α) value.

No.	***Sub-scale* / Item**	**Mean (SD)**
Violations (α = .62)		
1	Cycling under the influence of alcohol and / or other drugs or hallucinogens	0.45 (0.67)
2	Riding against the traffic flow (wrong way)	0.24 (0.52)
3	Zigzagging between (weaving in and out of) vehicles when using a mixed lane	0.72 (0.93)
4	Handling potentially obstructive objects while riding a bicycle (food, packs, cigarettes ...)	0.38 (0.70)
5	Feeling that sometimes I'm going at a higher speed than I should be going at	0.77 (0.83)
6	Crossing what appears to be a clear crossing, even if the traffic light is red	0.67 (0.92|
7	Carrying a passenger on my bicycle without it being adapted for such a purpose	0.06 (0.26)
8	Having a dispute in speed or 'race' with another cyclist or driver	0.27 (0.60)
Errors (α = .83)		
9	Unintentionally crossing the street without looking properly, thus making another vehicle brake to avoid a crash	0.21 (0.50)
10	Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly	0.19 (0.43)
11	Braking suddenly and being close to causing an accident	0.33 (0.57)
12	Failing to notice the presence of pedestrians crossing when turning	0.29 (0.51)
13	Not braking on a 'Stop' sign and being close to colliding with another vehicle or pedestrian	0.12 (0.34)
14	Braking very abruptly on a slippery surface	0.57 (0.69)
15	While I am distracted, I do not realise that a pedestrian intends to cross a pedestrian crossing, and do therefore I do not stop to let him or her do so	0.33 (0.57)
16	Not realising that a parked vehicle intends to leave and consequently having to brake abruptly to avoid a collision	0.72 (0.77)
17	When riding on the left side, not realising that a passenger is getting out of a vehicle or bus, and thus being close to hitting them	0.34 (0.61)
18	Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, consequently having to brake	0.20 (0.52)
19	Misjudging a turn and hitting something on the road, or being close to losing balance (or falling)	0.44 (0.62)
20	Unintentionally hitting a parked vehicle	0.06 (0.26)
21	Failing to be aware of the road conditions and falling over a bump, hole or obstacle	0.57 (0.71)
22	Confusing one traffic signal with another, manoeuvring according to the latter	0.19 (0.45)
23	Trying to brake but not being able to use the brakes properly due to a poor hand positioning	0.23 (0.54)
Positive behaviours (α = .59)		
24	I stop and look at both sides before crossing a corner or intersection	3.52 (0.80)
25	I try to move at a prudent speed to avoid sudden mishaps or braking	3.41 (0.75)
26	I usually keep a safe distance from other cyclists or vehicles	3.40 (0.69)
27	When I use the bike path (or bike-lane), I always use the indicated lane	3.30 (0.75)
28	I avoid going out on my bike in adverse weather conditions	1.99 (1.20)
29	I avoid going out on my bike if I feel very tired or sick	2.79 (1.09)

After visual inspection of the scree plot, a three-factor solution was considered appropriate. Several items were removed: items 28 and 29 were removed due to low partial corelation, items 1, 4, 5, 7, 8, 9, 20, 22, 23, and 27 were removed due to factor loadings below .4, and items 11 and 12 were removed due to loading similarly onto two factors. Items 13 and 15 were also removed as although they came from the original 'Errors' sub-scale, they loaded onto the same factor as three 'Violations' items with which they did not conceptually relate. The resulting 13-item, three-factor scale was then assessed using Confirmatory Factor Analysis (CFA) using the second half of the dataset (of 214 responses). Exploration of the modification indices following CFA resulted in error covariances added between two item pairs (10 and 18 and 16 and 17), resulting in the following model fit indices: $x^2/df = 2.09$, RMSEA = .051, CFI = .93, TLI = .90, AGFI = .93, and SRMR = .048. As above (in the WBQ analysis), although

CFI and TLI values were lower than the thresholds suggested by Hooper et al. (2008), the differences were again small (at .02 and .05) and the remaining indices were satisfied, as was Hu and Bentler's (1999) two index strategy. As such, the model was accepted. The retained questions, their factor structure, their factor loadings (as calculated in the CFA), and the factor's Cronbach alpha (based on the whole sample) are presented in Table 4. Although the alpha statistic indicated sufficient internal reliability for the Errors sub-scale, the Violations sub-scale cannot be considered as having internal reliability (at alpha = .51). Although the Positive behaviour sub-scale also showed internal reliability lower than would normally be accepted, at .67 it was considered close enough to include in subsequent analyses, although results should be taken with more caution (see the discussion section for more on this).

Table 4. Final Cycling Behaviour Questionnaire items and structure, with factor loadings (from CFA) and Cronbach's alpha (α) values (using the whole data set)

No.	***Sub-scale* / Item**	**Loadings**
Violations (α = .51)		
2	Riding against the traffic flow (wrong way)	.64
3	Zigzagging between (weaving in and out of) vehicles when using a mixed lane	.46
6	Crossing what appears to be a clear crossing, even if the traffic light is red	.55
Errors (α = .71)		
10	Colliding (or being close to it) with a pedestrian or another cyclist while cycling distractedly	.51
14	Braking very abruptly on a slippery surface	.56
16	Not realising that a parked vehicle intends to leave and consequently having to brake abruptly to avoid a collision	.44
17	When riding on the left side, not realising that a passenger is getting out of a vehicle or bus, and thus being close to hitting them	.52
18	Trying to overtake a vehicle that had previously used its indicators to signal that it was going to turn, consequently having to brake	.46
19	Misjudging a turn and hitting something on the road, or being close to losing balance (or falling)	.57
21	Failing to be aware of the road conditions and falling over a bump, hole or obstacle	.46
Positive behaviours (α = .67)		
24	I stop and look at both sides before crossing a corner or intersection	.51
25	I try to move at a prudent speed to avoid sudden mishaps or braking	.77
26	I usually keep a safe distance from other cyclists or vehicles	.65

Correlation analysis

As previously mentioned, to assess the extent to which CBQ and WBQ response were related, and the extent to which self-reported helmet use and self-rated cycling proficiency related to CBQ responses, correlation analyses were performed. Table 5 displays correlations between CBQ and WBQ items, Table 6 shows relationships between CBQ items and self-reported helmet use and self-rated cycling proficiency. For completeness, Table 5 also displays internal correlations within the WBQ measure (i.e., correlations between sub-scales) and Table 6 displays the relationship between self-reported helmet use and self-rated cycling proficiency.

Table 5. Pearson's correlation coefficients for the relationships between CBQ and WBQ factors.

	CBQ Error	CBQ Positive Behaviour	WBQ Violation	WBQ Device use
CBQ Positive Behaviour	-.25***			
WBQ Violation	.18***	-.18***		
WBQ Device use	.19***	-.05	.32***	
WBQ Error	.41***	-.20***	.24***	.27***

*** p<.001

Table 6. Pearson's correlation coefficients for the relationships between self-reported helmet use, self-rated cycling proficiency, and CBQ factors.

	CBQ Error	CBQ Positive Behaviour	Self-reported helmet use
Self-reported helmet use	.02	.14*	
Self-rated cycling proficiency	-.23***	.13*	.01

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

As can be seen from Table 5, all factors of the CBQ correlate significantly (at <.001) with all WBQ factors, except for the Device Use factor of the WBQ and the Positive Behaviour factor of the CBQ; these do not correlate. Although correlation coefficients generally indicate weak relationships, the two Error factors show a medium relationship. Those that report performing more errors when cycling also report performing more errors when walking. The analysis suggests self-reported helmet use does not correlate with a tendency to report performing errors when cycling but does weakly relate to the Positive behaviours factor. Although self-rated cycling proficiency significantly but weakly correlated with Error scores, it's relationship with Positive Behaviour was even weaker, and it was not related to self-reported helmet use.

'Predictive' analysis

As aforementioned, to assess the extent to which the CBQ is a useful tool for understanding who might get into a collision as a cyclist, a Structural Equation Modelling approach was taken. In addition to the Errors and Positive Behaviour factors of the CBQ, we included age, gender, and exposure (the number of hours spent cycling each week) in the model. Self-reported collision involvement in the past five years was taken as the outcome variable. Only data from respondents that answered all age, gender, exposure, and collision involvement questions were included, and only males and females (i.e., no participants that did not identify solely as male or female, of which there were three).

Figure 3 shows the path model tested with regression coefficients displayed, the correlation coefficient for the relationships between Errors and Positive Behaviour, and the squared multiple correlation (i.e., R^2) for self-reported collision involvement.

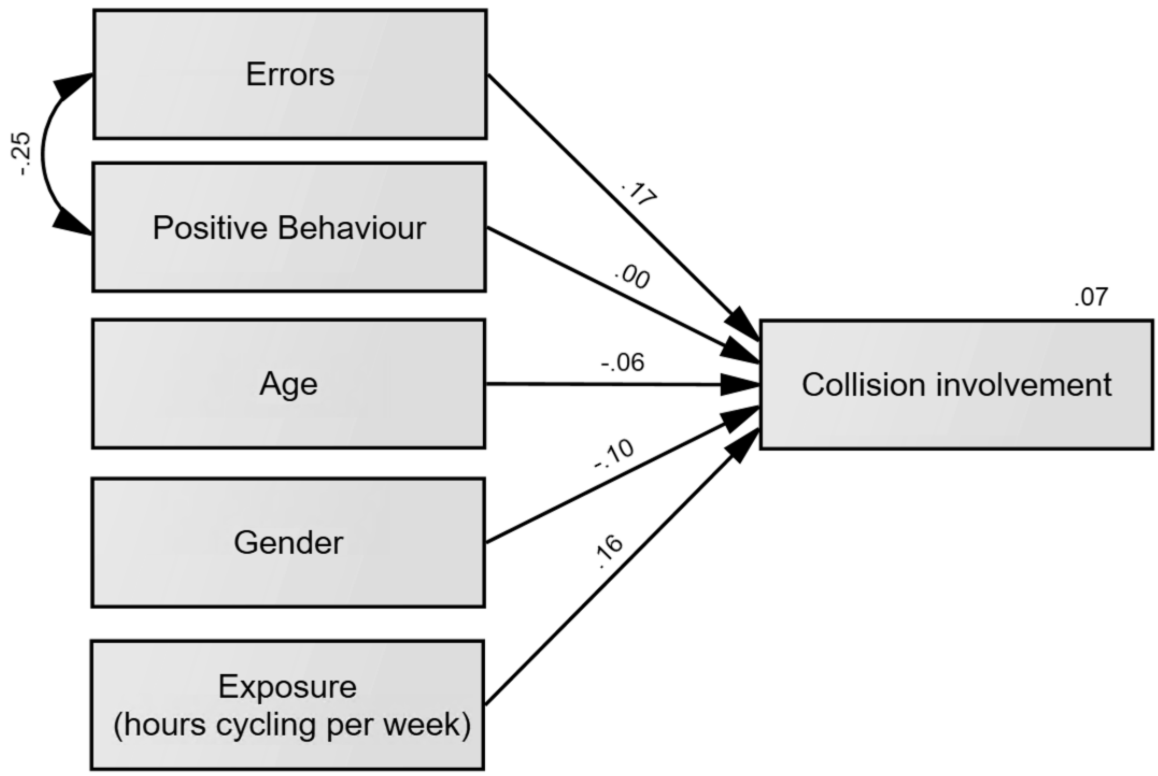

Figure 3. Path model tested using SEM with correlation and standardised regression coefficients, and squared multiple correlation (R^2 for collision involvement) displayed. Note that covariances were also included for all control variables, but are not displayed here for clarity.

The relationships between Errors and collision involvement, and between exposure and collision involvement, were both significant at the $p < .001$ level, and the relationship between gender and collision involvement significant at the $p = .03$ level. Those that report performing more errors, that cycle for more time each week, and males (compared to females) also report having been involved in more collisions in the past. No other relationships (other than the correlation between the two CBQ factors, discussed above) were statistically significant. Note that the regression weights were found to be quite low, and that the total amount of variance explained in self-reported collision involvement was only 7%.

Discussion

This research had five main aims: first, to apply the Walking and Cycling Behaviour Questionnaires (WBQ and CBQ) in the UK to assess their validity in a context in which they had not previously been applied; second, to assess the extent to which responses to the measures correlate; third, to assess the extent to which self-reported helmet use relate to CBQ responses; fourth, to explore the extent to which CBQ responses relate to self-reported collision involvement, accounting for demographic and exposure factors; and finally, to assess the extent to which self-rated cycling proficiency relates to CBQ responses.

Results indicated neither the WBQ nor CBQ factor structures as originally described to be suitable for use in our UK sample. Following exploratory (EFA) and confirmatory (CFA) factor analyses, the factors that were found to be suitable from each measure did indeed correlate with each other, particularly in the case of Errors (i.e., unintentional memory or attention errors); those that report performing more errors when walking also report performing more errors when cycling.

Cycling errors were also significantly related to self-rated cycling proficiency, with those rating themselves as more proficient also reporting performing errors to a lesser extent. The relationship was, however, fairly weak, and although the relationship between self-rated proficiency and the performance of positive (or self-protective; see below for more discussion) behaviours was also statistically significant, it was even weaker. Self-reported helmet use weakly correlated with Positive or self-protective cycling behaviours (that are also conceived as intentional and proactive) but not with Errors, whose nature is assumed as non-deliberate (Reason et al., 1990). Finally, a structural equation model revealed Errors to be significantly related to self-reported past collision involvement, though only weakly. Positive behaviours were not related to past collision involvement.

Assessing the WBQ's and CBQ's validity in a UK sample

Neither of the two measures used in this study had previously been applied in a UK context. Given evidence that the same road user behaviour measure may have different factor structures in different contexts (e.g., Deb et al. 2017; Granié et al. 2013; McIlroy et al. 2019), it was therefore deemed important to assess their validity. To this end, Confirmatory Factor Analysis revealed neither measure (as originally described) to be suitable for our sample.

The subsequent exploratory and confirmatory factor analyses presented above resulted in removal of 11 items from the 30-item Walking Behaviour Questionnaire (WBQ) described by Useche et al. (2020), with the Positive behaviour factor (and all its questions) removed entirely, and a new factor (Device use) included. Our Violations scale included five items, all of which came from Useche et al.'s Violations scale, with all but one specifically asking about road crossing behaviours (the other referring to walking on the road due to a narrow or busy pavement). Our Device use factor included items that were all included in Useche et al.'s Violations factor. All referred to the use of a mobile phone or listening to music (with device use implicit in this) while walking, hence were conceptually related to each other. On first inspection they appear less related to the road crossing items; this distinction was reflected in our data. Our Errors factor was identical to that reported in the original description of the WBQ, suggesting memory and attention errors to be a more stable construct (across questionnaire application contexts) than traffic violations committed by pedestrians.

This suggests that people in Spain (where the WBQ was developed) and the UK conceptualise unintentional walking behaviours in a similar way, but that there are quite significant differences when intention is involved. This could also explain the complete removal of the Positive behaviour factor, the items in which all deal with intentional behaviours. That positive behaviour is not a stable factor has been shown elsewhere in the pedestrian behaviour literature (McIlroy et al. 2019; Deb et al. 2017; Granié et al. 2013), though it is interesting to note that in other pedestrian behaviour questionnaires this factor often also includes (or indeed only includes) items that can be thought of as relating to polite or pro-social behaviours, such as waving to thank someone for letting a person cross the road. What is considered 'polite' is quite different across and even within cultures (e.g., Hall, 1955). That said, only one of the items in the Positive behaviour factor of the WBQ presented above could be considered related to being pro-social (i.e., walking in a particular area to give more space to others), with the other behaviours related more to self-protection (i.e., looking both ways, waiting for a green pedestrian light, and crossing at a designated area). In this way the items could be considered more related to the violations factor, with the difference being that they are reverse coded compared to the other items in that sub-scale. That said, they did not load onto that factor either.

It is worth pointing out that the WBQ used here differs to many other self-report pedestrian behaviour measures in its lack of an aggressive behaviour sub-scale. The three-factor structure of intentional violations, unintentional errors, and aggressive behaviours commonly reported in the literature (e.g., Deb et al. 2017; McIlroy et al. 2019; Nordfjærn and Şimşekoğlu, 2013; Nordfjærn and Zavareh, 2016; Qu et al. 2016; Yıldırım, 2007) therefore cannot be replicated using the WBQ used here. Instead, we found a separation of the violations sub-scale into two parts, one related to crossing or walking on the road, the other to using a device. Whether this distinction holds in other contexts of use, or is unique to our UK sample, remains to be seen.

To achieve good fit to our data, the WBQ had to shortened quite significantly, with many items not found to reliably measure the same underlying construct. This finding was even more pronounced for the CBQ. Although the factors were the same (i.e., no additional ones were created), the Errors factor was reduced from eight to three items, Violations from 15 to seven, and the Positive behaviours from six to three. As with the WBQ, the Positive behaviour factor of the CBQ contained items that can be best thought of as relating to self-protection rather than referring to pro-social behaviours. Two of the three questions that were removed were conceptually quite different and concerned bicycle avoidance (in poor weather or when feeling tired or ill). It is unsurprising that these questions did not load well onto the same factor given how distinct they are. Also worth noting is the marginally low reliability score we found for the final positive behaviour scale (at $\alpha = .67$). It may be useful to include additional, more loosely related items in future applications of the measure in order to increase that reliability.

The unsuitability of the third removed item, concerned with use of indicated lanes in bicycle paths, is likely due to the general lack of 'indicated lanes' on bicycle paths in the UK, a country argued to have substantial shortcomings in this regard compared to other European countries with greater cycling traditions (Wardlaw, 2014). Where bike lanes are present, they are typically provided as a single lane on the road itself, hence there is usually no option to travail in an unindicated lane. The significant variation in cycling infrastructure provision around the world (or indeed within a given country, or even city) renders such questions of limited use in a context where the measurement of risky behaviour is the goal. Although non-use of bike lanes might be related to a general propensity to perform risky behaviours in one setting, in another setting the reasons for non-use could be quite different. This also applies to the pedestrian domain; for example, footpath and footbridge non-use in Bangladesh has little to do with a person's appetite for risk and more to do with the state of the infrastructure and its use by other actors (e.g., street vendors; Debnath et al. 2021).

Assessing behavioural constructs' relationships

As might be expected given literature suggesting self-reported road user behaviour is similar regardless of the road user role taken (Şimşekoğlu, 2015), we found self-reported walking and cycling behaviours to be significantly related to one another. The only exception to this was the lack of relationships between CBQ Positive behaviour scores and WBQ Device use scores. Whether someone reports using devices while walking or not appears to bear no relationship to their tendency to report performing self-protective behaviours when cycling. Most relationships were quite weak, with a correlation of around .20; however, the two Errors factors correlated at .41, i.e., moderately. Those that report performing more memory or attention errors when walking also do so when cycling.

The other relationships explored related to self-rated cycling proficiency and helmet use. The strongest relationship in this regard (at $r = .23$) was between CBQ Error scores and cycling proficiency; those that rated themselves as more proficient also reported performing fewer memory or attention errors when cycling. Responses to the Positive behaviour sub-scale were also significantly correlated with self-rated cycling proficiency, though to a weaker extent (at $r = .14$). This contrasts with driving research in those over 65 that suggested increased unsafe driving in those rating themselves as more proficient (Freund et al. 2005). That said, it is entirely in agreement with the work using the Driver Behaviour Questionnaire (Amado et al. 2014; Martinussen et al. 2014) that those rating themselves as more proficient in driving also reported performing fewer errors and violations. We replicate this finding (for Errors and, to a lesser extent, Positive behaviour) in cycling.

In terms of self-reported helmet use, this did not correlate with Errors at all. It was also only weakly correlated with Positive behaviours (at $r = .14$), but the relationship was still significant (at $p < .05$). As described above, the questions in the Positive behaviour factor measure the tendency to perform self-protective behaviours when cycling (i.e., stopping and looking both ways at intersections, maintaining a prudent speed for safety, and keeping a safe distance from others) hence could be considered conceptually similar to the use of a helmet. In this way, our results are congruent with those reported by Esmaeilikia et al. (2019) in their review of helmet use and cycling safety; we found no strong evidence to support that non-use of a helmet is linked to performance of other risky behaviours, but that there is some evidence for a weak link with performance of other ‘safer’ behaviours (Esmaeilikia et al. 2019).

To assess the CBQ’s ability to ‘predict’ (in the statistical sense) collision involvement, a structural equation modelling approach was taken such that the effects of demographics and exposure (i.e., the numbers of hours cycled weekly) could be simultaneously considered. Although the results found the reporting of Errors to significantly relate to collision involvement, the relationship was relatively weak, with a standardised regression coefficient of .17. This was similar for exposure, or the number of hours spent cycling each weak. This suggests that the potential to get involved in a collision as a cyclist is similarly influenced by the amount a person cycles and their tendency to perform memory and attention errors when cycling. That said, even when including gender (which was also significantly related to collision involvement), our data could only explain 7% of the variation in the collision involvement responses. With 93% of the variance not explained by the factors in our model, clearly there is a lot more to collision involvement than self-reported behaviour and demographics.

Limitations and future work

First, we must accept the limitations of self-report scales. People may not behave as they say they do, and their self-reported collision-involvement may not truly reflect reality, especially if potentially sensitive topics such as risky behaviour or “accidents” are addressed in the questionnaire (af Wåhlberg, 2010). These are issues with all self-report scales of the types described above; hence, our research is by no means unique in this regard. This does not, however, remove the utility of this type of research, it is simply something that must be considered, with focus on observations of exhibited behaviours and collection of recorded collision involvement data being the logical next steps in any follow-up research. If such research could be conducted longitudinally, the limitation in performing ‘predictive’ analyses could also be overcome. Although the analysis presented above talks of one factor predicting another, this is (as previously described) in the statistical sense. A prospective cohort study would be required to assess the measures’ real-world predictive ability (though we should point out that this is an elusive quality even for well-established measures such as the Driver Behaviour Questionnaire; e.g., af Wåhlberg et al. 2015).

Second, we cannot guarantee that our sampling method returned a sample that is truly representative of the wider bicycle using population in the UK. For example, being an online-only questionnaire, certain groups would have been less likely to complete it than others (for example, those who interact less with information technologies). Notwithstanding, and given the positioning of this study as a pilot of the two questionnaires and an early exploration of relationships, we do not consider these issues overly problematic. Although our sample size was not especially large (at 428 respondents), it is in line with other similar examples of questionnaire exploration published in the literature (e.g., Hezaveh et al. 2018; Useche 2021b; Wang et al. 2019; Xu et al. 2018) and our gender and age distributions were not weighted towards any particular group. That said, a larger, stratified, random sample would allow for greater confidence when generalising results.

In terms of future work, the main message of this research is to exercise caution when adopting scales that have been developed and validated in contexts distinct from that in which dissemination is intended. Indeed, we would argue caution even when disseminating a questionnaire in the same context as that in which it was developed. This is especially important for new measures, of which both the WBQ and CBQ are examples. Neither has yet attracted significant attention in the literature, and, unlike the better-established Pedestrian Behaviour Questionnaire (or Scale, depending on the reporting author: Granié et al. 2013, Deb et al. 2017, McIlroy et al. 2019) or well-established Driver Behaviour Questionnaire (Reason et al. 1990), neither has been disseminated across a wide variety of culturally distinct contexts. This would be the obvious next step for these measures; to be disseminated in multiple countries and the validity (and country differences therein) explored.

We think this particularly important for the Cycling Behaviour Questionnaire (CBQ). First, this is still a largely under-used mode of transport in high-income settings where there are goals to increase cycling rates (for example, see the UK's Department for Transport's (2021) cycling strategy). If the CBQ is to achieve the kind of utility that the DBQ has done (e.g., in terms of using it to understand some of the determinants of behaviour, such as attitudes) the research community needs to be confident that it measures that which it sets out to measure. Second, the image or perception of cycling is one that varies significantly around the world (e.g., Oke et al. 2015; Oldenziel & de la Bruhèze, 2012) and indeed even within a single country (Aldred & Jungnickel, 2014). This variety is reflected in (or reflects) the extent to which cycling is supported by (for example) transport and planning authorities or private enterprise in different countries (e.g., Teixeira et al. 2020; Todd et al. 2021). Although there is of course variety in walking and driving infrastructure and policy globally, it does not exist to the same extent as it does with cycling. Especially careful attention therefore needs to be paid to tools intended to be used for research into cycling, particularly where even the definition of a 'risky' behaviour can still be disputed, as is the case with helmet use (e.g., Goldacre & Spiegelhalter, 2013) or setting off in advance of a red light turning green (e.g., Shaw et al. 2015).

Conclusions

This research has highlighted the importance of checking a self-report, behavioural measure's suitability before any large-scale dissemination effort is made. The Walking Behaviour Questionnaire (WBQ) and Cycling Behaviour Questionnaire (CBQ) piloted here did not measure all the same constructs when applied to our UK sample's data as they did in the small number of previous studies that have used them. We therefore urge caution, especially when the measure in question measures behaviour that involves intention (as opposed to unintentional mistakes). We think this is especially important for tools aimed at measuring cycling behaviour given the variety with which use of the mode is perceived and facilitated nationally and internationally, and its position as a mode whose uptake is encouraged from transport sustainability and public health perspectives. Furthermore, our analysis showed that only 7% of the variance in self-reported past collision involvement could be explained by demographic, exposure, and self-reported cycling behaviour factors. This low figure points to the importance of the myriad other factors that contribute to road safety outcomes. Road safety efforts should consider as many of these as possible (ideally through taking a whole-system perspective), considering not only *what* behaviours manifest, but *why* they manifest. Self-report questionnaires used in isolation are unlikely to provide this insight; however, used in concert with other measures they can still inform the design of road safety strategies aimed at influencing that behaviour.

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