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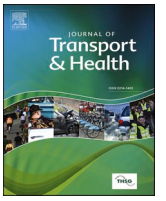

Eliciting citizens' priorities for active travel infrastructure investments: A qualitative analysis of best-worst scaling experiments

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ABSTRACT

Introduction: The built environment plays an important role in individuals' propensity to walk and cycle and local authorities increasingly invest financial resources towards its development. Organisations responsible for the built environment have developed auditing tools as guidelines to inspect routes and identify improvements to support active travel.
Methods: Using these auditing tools as a starting point, this study developed 21 walking and 25 cycling investment-relevant factors that were embedded into two choice-based survey instruments, respectively. The study used cognitive interview pre-testing to internally validate a preference-based elicitation approach known as Best-Worst Scaling (BWS), which aimed to capture pedestrian and cyclist preferences. We report findings from cognitive interviews (data analysed thematically) with 20 participants (10 pedestrians and 10 cyclists).
Results: In both sets of interviews, four themes emerged regarding how the participants approached the BWS task and five themes related to the understanding of the factors. The BWS choice tasks required refinement regarding the 'frame of reference', 'travel context', the 'decision-making strategy', and the 'concrete thinking' (finding some factors easier to interpret). Additionally, issues with understanding the factors, the wording, 'overlapping', negatively phrased factors, and technical jargon all pointed towards the need to refine auditing tools if these were to be introduced in a preference elicitation context.
Conclusions: This study helps to empirically uncover how citizens interpret infrastructure related aspects of walking and cycling by pointing to nuanced aspects that auditing tools may miss. The findings also helped develop an internally consistent preference elicitation survey-instrument that any local authority can implement to determine which walking and cycling infrastructure investments are a priority in their area.

1. Introduction

The importance of the physical environment in encouraging physical activity, and thus in improving public health, is widely recognised (Frank and Engelke 2001; Handy et al., 2002; Jackson 2003). Systematic reviews by Mayne et al. (2015) and Smith et al. (2017) found that infrastructure improvements, mainly those targeting active travel (e.g., walking and cycling), have positive impacts

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upon physical activity. Thus, public policy increasingly focuses on improving the built environment in ways that encourage people to walk and cycle for different purposes (DfT 2020).

Organisations, such as local authorities, responsible for designing, managing, and planning for the built environment employ auditing tools as guidelines to assess the quality of routes and identify infrastructure improvements to support active travel. Such walking and cycling auditing tools have been developed for assessing micro-level pedestrian and cyclist environments in the UK (Millington et al., 2009; Beynon et al., 2014), North America (Boarnet et al., 2006; Nabors et al. 2007, 2012; Cain et al., 2012) Australia (Pikora et al., 2002; Clifton et al., 2007; ARRB 2011; Taylor et al., 2017), Canada (MTO 2014) and China (Cerin et al., 2011; Sun et al., 2017).

When operating within a stringent financial environment, these auditing tools may be utilised as a means to identify citizens' priorities for physical interventions that impact upon cycling and walking uptake. However, auditing tools also tend to include many different factors relating to the built environment and infrastructure, normally more than 20 different factors, and identifying specific priorities using traditional ranking or rating exercises involve several inaccuracies and biases (Finn and Louviere 1992; Soutar et al., 2015). These inaccuracies and biases can arise from significant cognitive burden when multiple items are ranked or rated, as well as ranking/rating information being less accurate by omission of fine-grained item-importance information, as well as scale-region biases and granularity, leading to inconsistencies when factor ratings or rankings are compared (Adamsen et al., 2013; Campbell and Erdem 2015). While each item is of merit, such as when items are factors identified by experts and used in auditing tools, traditional ratings/rankings scales are also prone to boundary effects, such as "uniform positive response" (Marti 2012). Finally, developed by subject-experts for their own use, it is less clear whether terminology and phraseology from the field will be readily understood by the public, leaving potential for misinterpretation and misleading findings.

In this study, we report results from cognitive interviews to better enhance information from auditing tools and examine how citizens view different factors as potential areas for active travel investment and improvement. Thus, we employed a preference elicitation technique known as Best-Worst Scaling (BWS), to present participants with these different aspects of physically active transport infrastructure and so guide the discussion on how they view and prioritise these, and hence which factors may warrant investment. As part of BWS, participants make choices among sets of three or more options,[1] and choose the 'best' and the 'worst' options from each set (Soutar et al., 2015). Hence, BWS can ease cognitive burden arising from multiple item comparisons (Marti 2012) and multiple 'best-worst' selections circumvent some of the difficulties arising from simple ranks or ratings (Campbell and Erdem 2015) including over-use of a single response-option and scale boundary effects (Cohen and Markowitz 2002).

Studies employing BWS experiments remain sparse in the transport and mobilities literature; those that exist place emphasis on the quantitative analysis of the data and comparisons of modelling approaches rather than on qualitative testing and validation exercises of the BWS instruments (Schuster et al., 2024). For example, Echaniz et al. (2019) inspired by Beck and Rose (2016), compared conventional public-transport user satisfaction ratings with Best Worst Scaling data and found that BWS data offer improved, consistent evidence for decision making. Similarly, using a BWS Case 1 experiment, Tsafarakis et al. (2019) examined European citizens' priorities among 27 public transport innovations. Only Larranaga et al. (2019) who reported findings from a BWS experiment that aimed at capturing barriers to walkability, resembles the present study. In summary, most studies offer limited information on how their instruments were tested and internally validated, including validation of respondents' instrument understanding and interpretation.

The contributions of this study are twofold. Firstly, from a methodological perspective, we demonstrate how BWS can be employed to elicit citizens' priorities for walking and cycling infrastructure, offering significant advantages over ranking and rating tasks when embedded in survey questionnaires. Secondly, through an carefully designed internal validation exercise and subsequent analysis of a series of qualitative interviews, we empirically uncover how citizens interpret different aspects related to walking and cycling infrastructure investment (or improvements). This approach helps to explore more nuanced aspects of preference elicitation that are likely to be overlooked when directly implementing a survey embedded BWS experiment. Of equal importance, this exercise derives an internally valid survey-based preference elicitation survey instrument, for academics and local authorities to find out local priorities for walking and cycling, and then implement relevant interventions.

The remainder of this paper is organised as follows. Section 2 provides details on the methodology including the study design, interview data collection, and analysis. Section 3 presents the findings from the cognitive interviews in relation to both the preference elicitation instrument and how respondents interpreted the different factors related to active travel infrastructure investments. Section 4 discusses these findings and Section 5 summarises the conclusions and potential ways forward from this study.

2. Methods

As shown in Fig. 1, this study involved three key stages: (a) study design, including the generation of the BWS tasks and the associated interview questions; (b) the recruitment of participants and the implementation of the cognitive interviews, and (c) the interview transcription and thematic analysis of the interview data.

[1] As explained in Section 2.2, 'options' can be attributes (Case 1), attribute levels (Case 2) or alternatives (Case 3).

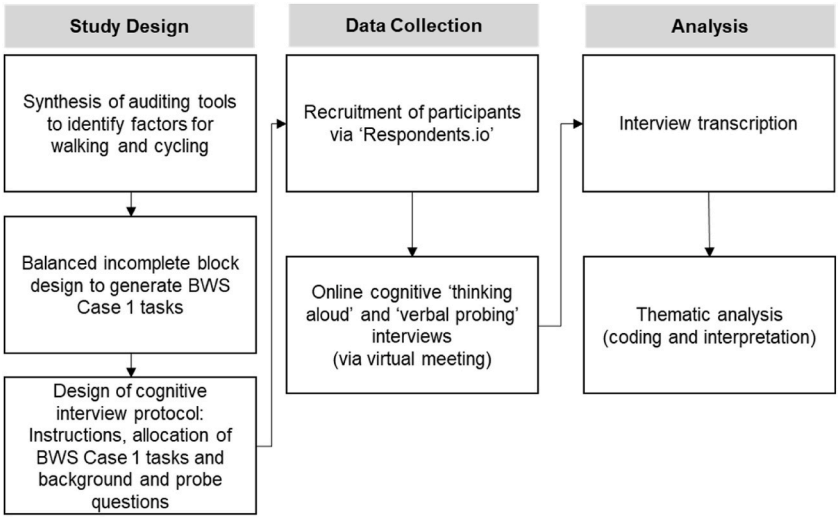

Fig. 1. Overview of the study design, data collection and analysis.

2.1. *Identifying walking and cycling infrastructure-related factors*

The first stage in this study was to synthesise evidence from studies published between 2010 and 2020 to establish documented factors that encourage (or discourage) walking and cycling. These factors were then matched to corresponding factors from the "Design guidance: Active travel" published by the Welsh Government (Beynon et al., 2014), which provides recommendations on creating, modifying, and managing the built environment to support infrastructure for active travel. This includes walking and cycling route auditing tools, comprising several factors under five categories: safety, directness, attractiveness, comfort, and cohesion.

Overall, 21 walking factors and 25 cycling factors were identified and then compared across other auditing tools from the UK and other countries.[2] Each factor was given a brief description inferred from the auditing tools for walking (Table 1) and cycling (Table 2), respectively.

2.2. *Design of the BWS profiles*

BWS is a preference elicitation method that is used to identify the relative importance of different items. For example, in the case of active travel infrastructure investment, it can answer the question on whether 'availability of lighting' is more important than 'the overall condition of the footway' and how many times the former is more (or less) important than the latter.

There are three types of BWS based on their format (Louviere et al., 2015). Case 1, the "Object" case, is suitable when the analyst is concerned with the relative values related to each item (object) of a list of items to be measured (Flynn and Marley 2014). For example, the items or objects in this study are those listed in Tables 1 and 2 and refer to stand-alone improvements of active travel infrastructure. These improvements do not have attribute or level structure (e.g., good, fair, poor) (Larranaga et al., 2019). Case 2, the "Profile or Attribute" case, refers to the situation where each item (object) has different attribute levels. In both Cases 1 and 2, subsets of the complete list of items (21 for walking and 25 for cycling) or attribute levels in Case 2, respectively, are shown, one at a time, and respondents indicate their 'best' and 'worst' choices within that subset, also known as 'profiles', without considering the value of the profile as a whole (Larranaga et al., 2019). Profiles describe specifications of products, services or policies using a combination of factors and their related levels (Louviere et al., 2015). Finally, Case 3, the "Multi-profile" case, is almost equivalent to Discrete Choice Experiments (DCEs) where respondents are asked to indicate their choices among entire profiles (Flynn 2010).

The information elicited using BWS is richer and cognitively easier than other rating or ranking scales (Marti 2012). BWS requires participants to choose only the 'extreme' items (i.e., 'Best' and 'Worst') on partial sets of the complete list; thus, making it much easier for respondents to provide their preference in an unbiased setting (Campbell and Erdem 2015). The BWS approach can overcome response biases by asking respondents to distinguish between the items as there is only one way to choose the most or least important item. Therefore, respondents cannot always choose the mid-points, end points or one end of a scale (Cohen and Markowitz 2002). An operational advantage of BWS over rating scales is its simplicity and ease; respondents are asked to choose just one item for 'best' (most important) and one item for 'worst' (least important), the task is undemanding and so less prone to bias arising from cognitive burden and this ultimately improves data quality (Soutar et al., 2015). Another advantage is that because BWS uses a common scale this scale

[2] As mentioned in Section 1, these are: in the UK (Millington et al., 2009; Beynon et al., 2014), North America (Boarnet et al., 2006; Nabors et al. 2007, 2012; Cain et al., 2012), Australia (Pikora et al., 2002; Clifton et al., 2007; ARRB 2011; Taylor et al., 2017), Canada (MTO 2014) and China (Cerin et al., 2011; Sun et al., 2017).

Table 1
Walking factors.

No	Factor	No	Factor
1	Feeling safe while walking along the footways	12	The total time given for pedestrians to cross
2	Availability of lighting along the footway	13	The overall condition of the footway, viability of footway for walking and pushing a pushchair
3	Clear lines of sight to all pathway users from all directions	14	The width of the footway and the ability for pedestrians to maintain a distance from traffic
4	Adequate separation between traffic and the footway	15	How steep or hilly is the pathway?
5	Traffic volume low, or you can keep distance from moderate traffic volumes	16	The materials used to create a pavement for pedestrians
6	Traffic speeds low, or you can keep distance from moderate traffic speeds	17	Having no obstructions that restrict clearance width of the footway
7	Provision of continuous footways for walking journeys	18	Availability of measures to slow down traffic and give priority for pedestrians
8	Presence of footways from the origin point to destination with limited/minimal number of crossing points	19	The level of noise and air pollution that pedestrians might be exposed to
9	Crossing points follow desire lines	20	Street furniture and amenities (e.g. Benches and/or ledges for sitting. Rubbish bins. Drinking fountains. Heat lamps. Public restrooms)
10	Possibility of crossing a route where no controlled crossings present	21	Availability of dropped kerbs and tactile paving on the footway
11	Total time spent on crossings and its effect on trip time		

Table 2
Cycling factors.

No	Factor	No	Factor
1	Pathway construction providing smooth and level surface	14	Cycling pathway clear of physical hazards such as evasion room, guardrail
2	Density of defects including raised/sunken covers, gullies, potholes	15	Routes should follow the shortest option available
3	Cycling comfortably without risk of conflict with other users (effective path width)	16	Cyclists have few stops or have priority over other vehicles
4	How steep or hilly is the pathway?	17	The length of delay caused by junctions
5	Feeling safe while riding a bicycle along the pathway	18	The length of delay caused by not being able to bypass slow moving traffic
6	Separation of cyclists from traffic	19	The ability for easily and safely join and navigate along the pathway and between different routes in the network
7	Availability of measures to reduce the risk of collisions at junctions	20	The continuity of cycling pathway
8	Non-complex and self-explanatory cycling network design	21	Availability of clear and direct signs towards destinations
9	Risk of collision resulted from conflict with kerbside activity	22	Availability of overlooked routes throughout its length
10	Reducing the speeds of motor vehicles on the shared route	23	Access to secure cycle parking
11	Risk of collision because of increasing traffic volume	24	The level of air pollution that cyclists might be exposed to on the pathway
12	Risk of collisions due to conflict with Heavy Good Vehicles (HGVs)	25	The level of noise that cyclists might be exposed to on the pathway
13	Availability of lighting along the pathway		

is independent of cultural context and thus an instrument can be applied across different countries (see, for instance, Auger et al. (2007)).

As shown in Fig. 1, this study employed a BWS Case 1 experiment as each item in Tables 1 and 2 were treated as stand-alone

Out of the five factors below, which are **The Most** and **The Least Important** factors that would **encourage you to walk more**

Most Important	Factors	Least Important
	Possibility of crossing a route where no controlled crossings present	
	Availability of dropped kerbs and tactile paving on the footway	
	Having no obstructions that restrict clearance width of the footway	
	Feeling safe while walking along the footways	
	Presence of footways from the origin point to destination with limited/minimal number of crossing points	

Fig. 2. An example BWS choice card (task).

'objects', corresponding to aspects of walking and cycling infrastructure, with no level structure. Following Louviere et al. (2013), the study generated balanced incomplete block design (BIBD) matrices for walking and cycling factors to construct the choice cards for the walking and cycling BWS experiments so that each choice card would include a smaller number of factors. The 'BWS' (Aizaki 2021) and 'crossdes' (Sailer 2013) packages in R software (R Core Team 2020) were used to design the combinations of different factors into profiles (choice cards). A BIBD design involves specifying a number of parameters as follows (White 2021):

1. The design matrix contains t number of items (objects) shown in b number of choice cards;
2. Each choice card contains k number of factors;
3. Each factor (t) appears r times and finally, each pair of items appears λ times.

The design is balanced when $\lambda = r\,(k-1)/(t-1)$ and both λ and r are integers.

In the walking experiment t corresponded to the factors, 21 in Table 1 and 25 in Table 2. k refers to the number of factors shown in each choice card. Orme (2005), via a simulation study, suggested specifying four or five factors for each choice card. This study included five factors per choice card hence k was equal to 5 with the prospect of checking whether this number of items would impact upon the respondents' cognitive burden (Chrzan and Patterson 2006). In the walking experiment, each factor was repeated five times ($r = 5$), and each pairwise comparison occurred once ($\lambda = 1$). In the cycling experiment, each factor was repeated six times ($r = 6$) and each pairwise comparison occurred once ($\lambda = 1$). An example choice card following the above process is shown in Fig. 2 (Fig. A1 in the Appendix offers the full specification). A BIBD does not exist for any number of factors t, hence the selection of the above parameters was also dependent on the availability of designs (see, Louviere et al. (2015)).

2.3. Cognitive interview protocol

Cognitive interviews can use different techniques, separately or in conjunction, including "thinking aloud" and "verbal probing" (Collins 2003). The "thinking aloud" technique (Willis 1999) is to ask respondents to verbalise their thoughts during the task (e.g., while completing a questionnaire or choice experiment) and thereby provides information concerning cognition, such as recollection of relevant information and the decision process when answering (Knafl et al., 2007). In the "verbal probing" technique, the interviewer uses verbal probes (often questions) to encourage participants to elaborate upon their thoughts and opinions about the task (Beatty and Willis 2007). Specifically, the interviewer probes to determine whether, and how, questionnaire items are understood, such as by asking participants to paraphrase items or define words or phrases from their perspective (Knafl et al., 2007). This study employed both techniques to assess the face and content validity of the factors drawn from auditing tools, namely whether factors were sufficient to satisfy their aims (Beatty and Willis 2007) and elicited an easy and unbiased response process (Drennan 2003) in the context of a BWS experiment.

The interview began with a brief introduction to the interview process and plain-language instructions for the thinking aloud and verbal probing portions. We then asked participants to complete three background questions sequentially (Table 3), both for basic information and for participants' familiarisation with the cognitive interviewing style (Willis 1999). Finally, participants completed the BWS tasks.

Before the BWS choice task (Fig. 2), the participants saw instructions (Fig. 3). These instructions helped to set the scene for the BWS tasks, and we also used cognitive interview techniques to evaluate the internal validity of the instructions (e.g., for clarity, misunderstandings, etc.). Once read, a participant's understanding and expectations for the task were probed using the questions in Part A of Table 4.

Following the instructions slide, the first choice card was presented (e.g. Fig. 2). Each choice card involved a prompt text (repeated in each choice card) and combinations of 5-of-21 factors (Table 1) and 5-of-25 (Table 2) factors in the walking and cycling experiments, respectively. Once participants completed a choice task, or when they engaged in dialogue with the interviewer, they were asked a subset of probe questions to elicit their thoughts and understand their comprehension of the task and the reasons for choices (see, Part B in Table 4).

2.4. Implementation, sampling and participants

The interviews took place between February and March 2021 and were conducted online using video conferencing software. During the interview, the BWS choice task materials were presented on MS PowerPoint slides using the 'share screen' function. The interviews were semi-structured, hence most questions were pre-written, but some were improvised to explore the information arising from the interview. Interviews were audio-recorded, and notes were also taken throughout. The duration of the interviews was between 32 and 40 minutes. Ethical approval was obtained for the study prior to commencement, and informed consent was obtained prior to the commencement of each interview.

The sample composition is shown in Table 5. Due to the Covid-19 pandemic restrictions, participants were recruited through the online platform 'Respondents.io'. Ten participants were sampled initially. However, over-sampling of female pedestrians and male cyclists necessitated sampling 10 further participants. We utilised the platform to target pedestrians and cyclists separately; cyclists were less likely to volunteer than pedestrians.

It is worth noting that sampling in qualitative research differs from sampling in quantitative research to the extent that participants are selected for their characteristics (here, being pedestrians or cyclists) rather than to create a sample representative of the population from which characteristics of the population may be inferred. In seeking volunteers from different demographics, our goal was not to

Table 3
Background questions.

Walking experiment		Cycling experiment	
No	Question	No	Question
Q1	Are you able to walk comfortably for more than 5 min at a time? • Yes •No	Q1	Do you ride a bicycle? •Yes – and I have regular access to a bicycle (including borrowed or public hire bikes) •Yes – but I don't have regular access to a bicycle •No
Q2	Do you walk independently (un-assisted)? •Yes •No, I need assistance from others (e.g. family, friends, carer) •No, I need assistance (e.g. wheelchair, mobility scooter, guide dog)	Q2	How often do you ride a bicycle? •Once a week •Between 2 and 3 times a week •More than 3 times a week •Once a fortnight •Less than once a fortnight
Q3	How often do you walk? •Once a week •Between 2 and 3 times a week •More than 3 times a week •Once a fortnight •Less than once a fortnight	Q3	How long have you been cycling? •Less than 6 months •6–12 months •1–3 years •3–5 years •More than 5 years

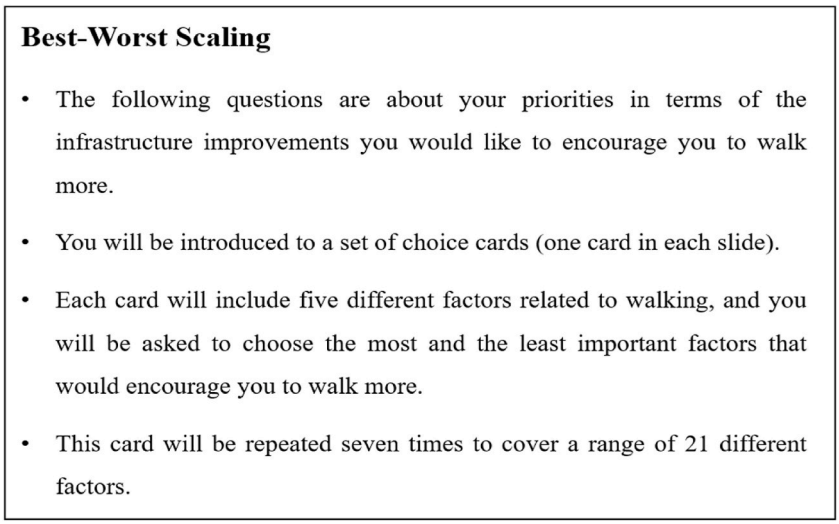

Fig. 3. Instructions to the BWS choice task.

Table 4
Cognitive probe questions.

Part	Questions
A	•How did you find that?[31] •Was there any part you had to go back and re-read •Was it easy or difficult to follow?
B	•How easy or difficult was this question to answer? Why? •So, which one would you choose as the most important for you? And which is the least? •I would like to ask you, in your own words, how would you describe the most important factor you chose? •Could you please put into words the least important factor that you chose? •Why did you choose the factors you did in this question? •What comes to mind for [word/phrase]? •Could you tell me a bit more about that? •You said 'xxx', perhaps you could elaborate on that for me? •Would you like to add any other factors you think are important?

Table 5
Characteristics of participants in cognitive interviews.

Walking				Cycling			
No	Gender	Age	Education	No	Gender	Age	Education
P1	Male	18–24	Some higher education, no degree	P11	Male	35–44	Postgraduate
P2	Female	35–44	Undergraduate	P12	Male	25–34	Postgraduate
P3	Female	35–44	Postgraduate	P13	Male	25–34	Postgraduate
P4	Female	45–54	Undergraduate	P14	Male	25–34	Undergraduate
P5	Male	25–34	Undergraduate	P15	Female	25–34	Undergraduate
P6	Male	25–34	Undergraduate	P16	Female	25–34	Undergraduate
P7	Female	25–34	Postgraduate	P17	Female	35–44	Postgraduate
P8	Male	25–34	Some higher education, no degree	P18	Female	35–44	Postgraduate
P9	Male	35–44	Undergraduate	P19	Male	25–34	Undergraduate
P10	Female	35–44	Some higher education, no degree	P20	Female	25–34	Some higher education, no degree

replicate their proportions within the population through sampling but to gather unique insights into walking and cycling that only they would have due to their age, gender, or educational background.

2.5. Thematic analysis

We used thematic analysis to analyse the interview data. This is a tool for in-depth analysis of qualitative (interview) data in "a precise, consistent, and exhaustive manner through recording, systematising and disclosing methods of analysis and the study findings with enough detail to enable the reader to determine the credibility and validity of the process" (Nikitas et al., 2018) and has been widely used in transport research (e.g., Alyavina et al., 2020; Liu et al., 2020; Nikitas et al., 2018).

Thematic analysis involves an iterative process of coding and interpretation that is useful when analysing data from cognitive interviews (Willis and Artino 2013). Firstly, recorded interview data was transcribed verbatim and the researcher notes from interviews added to comprise the dataset. All relevant features of the data were coded (labelled, categorised) and were used to infer themes (meaningful commonalities). Codes were entered into a table with participant-rows and theme-columns, collating all data pertinent to each theme (Fig. 4).

The structure in Fig. 4 is analogous to a thematic diagram (Braun and Clarke 2006), and was checked for thematic consistency – that is each cell was checked to make sure that it illustrated the theme, and each theme was developed from the cells in its column. Consistent with thematic analysis as a qualitative approach, the importance of a theme was its substantive meaning and not the frequency of coded instances (Willis 1999) and, hence, valuable insights were sometimes derived from the data of a single individual, though more commonly we drew insights from recurring patterns across individuals (Nikitas et al., 2018; Alyavina et al., 2020). The themes that emerged were categorised under two main groups: how the participants approached the BWS task and understanding of the factors. These results (themes) are reported in the following section.

3. Findings

From both sets of interviews, we identified nine themes; four relating to how the participants approached the BWS task and five relating to understanding of the factors (Table 6).[5] All themes are presented in detail in the following sections with illustrative and evidential quotes from participants.

3.1. How the participants approached the best-worst Scaling task

As shown in Table 6, four themes were identified concerning 'how the participants approached the BWS task'.

- Missing a frame of reference,
- Travel context,
- Decision-making strategy, and
- Concrete thinking.

3.1.1. Theme 1: missing frame of reference

We used a repeated question on each choice card: "Out of the five factors below, which are The Most and The Least Important factors that would encourage you to (walk more/ride a bicycle)." This theme concerns this question, which some found to lack a frame of reference. Some participants were indecisive about making their choices and linked them to the purpose of travel. They often

[3] In the sense of 'how did you find that to be' or 'what was your experience'.
[5] This is equivalent to two themes and nine sub-themes; for brevity, we refer to the nine as 'themes'.

Participant	Ambiguity	Overlapped factors	Negatively phrased factors
3	The participant found the phrase 'feeling safe' in 'Feeling safe while walking along the footways' ambiguous about what it referred to being safe from,"feeling safe is still a little bit ambiguous of what that really means. Feeling safe from other people [...]	The participant found 'The width of the footway and the ability for pedestrians to maintain a distance from traffic' to overlap with 'Adequate separation between traffic and the footway' as both factors offer a distance from traffic: "I am not sure [...]	The participant pointed out that 'Possibility of crossing a route where no controlled crossings present' factor "does not feel like it is a choice for the pedestrian to make ... because almost objectively." And she went to describe it "I am imagining like a very busy road. [...]
2	"I think you feel safe if it is a public footpath that is used regularly and there is plenty of people around ... also, I suppose feeling [...]		
5	"I am thinking like the fear of effectively crime or in a flip side like natural danger", such as "walking along a river"		The participant seemed confused because of the double-negatives in 'Having no obstructions that restrict clearance width of the footway' factor, "I have [...]
8	"I guess from traffic. I would not want to walk along the motorway or dual carriageway"		

Fig. 4. An illustration of the collated data by theme (columns) from four interviewees (rows).[41]

Table 6
Summary of the themes identified from the thematic analysis.

Themes	
How participants approached the BWS task	Understanding of the cycling and walking factors
[1] Missing a frame of reference	[5] Factors with ambiguous words or phrases
[2] Travel context	[6] Overlapping of two or more factors
[3] Decision-making strategy	[7] Factors phrased negatively
[4] Concrete thinking	[8] Factors containing technical terms
	[9] Presupposition about some factors

indicated this by saying that 'it depends', for instance:

- "I suppose it depends on the purpose of encouraging me to ride a bicycle, if it was for commuting and transport rather than pleasure then I suppose length of delay would probably be the most important factor" (P11);
- "I suppose it depends on the type of walk, if it's walking to work, the street furniture and amenities is probably neither here nor there. If it's going on a long walk, well, perhaps that is slightly more relevant" (P4).

Missing a frame of reference made the question more difficult to answer, making some people more uncertain in their answers, and risking misinterpretation. Frames of reference cited as absent were often whether the journey purpose was work or recreational, but this entailed important differences in circumstances, such as the length of the walk mentioned by P4, or the degree of time pressure implied by P11.

3.1.2. Theme 2: travel context

This theme is also related broadly to the question: "Out of the five factors below, which are The Most and The Least Important factors that would encourage you to (walk more/ride a bicycle)." Some participants responded in terms of their current travel context and other contexts, conveying the importance of this to their choices. For example, for P17, the importance of lighting depended upon ambient light levels nearby: "If I was aware that a cycle pathway wasn't lit at all, I would probably avoid it. And so certainly sections of

the [cycle path through the park], I wouldn't cycle along there in the dark because they're not lit." For P18, some of the factors were only important outside of their local area: "In [the city] where I live, I don't think there was anything complicated about how, where to move and know where to cycle but maybe in [a city] like London or bigger cities, it's much more complex than where I am."

Importantly, these contextual differences made hypothetical choices more difficult within the BWS task and raises the issue of whether BWS answering would be affected by different contextual interpretations. P12, for instance, had a clear rural-context perspective in answering questions: they never abstracted, considered the factors to have an "urban bias", and articulated the importance of context in approaching the factors.

- "It's sort of semi-rural where I live, but if I lived in [a big city] probably navigating the city safely would probably ranking a bit higher for me. The signs and direction as to me doesn't have any impact, but I guess it depends on the end user. If I perhaps live in a city centre, I perhaps would use it more often." (P12)

While both frame-of-reference (theme 1) and context (theme 2) are about contingency, they differ in what is contingent, whether internal needs and requirements (of work or leisure travel) or external surroundings and what they afford. Crucially, both have the potential to affect the expression of best/worst preferences through drawing contrasts with existing infrastructure or commonly recurring purposes when travelling.

3.1.3. Theme 3: decision-making strategy

Theme three concerned how participants might (consciously or unconsciously) use different strategies in making their choices. This is informed by the *heuristics approach*, a framework for understanding how individuals can make satisfactory decisions with less effort (Shah and Oppenheimer 2008). Heuristic approaches were evident in some cases. We noticed, for instance, that P15 focussed attention on the shortest sentences on choice-cards and upon certain keywords, and that if sentences were of the same length, or P15 could not find any special keyword, they would tend to return to the start of the list. They were aware of this, saying: "Sorry, I'm aware that I'm sort of hopping from one to the other. I'm going to go back to the first question."

Compensatory decision-making was also clear as an alternative strategy used by some participants. Compensatory decisions are the sum of the weighted advantages (and disadvantages) of all the features considered, hence 'compensating' one against another; they can be more advantageous, but they are more cognitively difficult (Shiloh et al., 2001). We noticed that P18 adopted this strategy, moving from comparisons to a single decision:

> "[…] there's a few good ones here that the most important. I am kind of torn between third and fourth, but I think for me most often is the lighting as a female, especially in the evenings. I prefer to have very clear visibility not only from my bike, but from the streetlights. So, I can see far if there is anyone there."

This more *methodical approach* to decision-making was apparent with participant P3, as they wanted to understand and process each factor before deciding. On their first-choice card, P3 ranked the factors from the most to the least important. When we asked them to choose one as the most important and one as the least important, as this was the task, they said: "I feel like even if that is the goal, I feel like this still be my process. I would kind of rank them in my head and then determine which is the most and which is the least."

While qualitative analysis cannot quantify, or elaborate upon the underlying processes, of decision-making strategies, our data provided sufficient evidence that they were an important and meaningful aspect of this BWS task.

3.1.4. Theme 4: concrete thinking

Some participants seemed to be 'concrete' thinkers in interpreting factors. This led them to find some factors easier to evaluate than others. P3 provides a useful example. On their first choice-card, they found some of the factors before them to be abstract, and hence they were less certain in their choices. Then, they said of a subsequent choice card: "this makes much more sense than the previous one. It's got specific suggestions, suggestions for improvements, I think this is easier for me to engage with."[6] For some, such specific, instantiated, factors were easier to understand, as were those with examples:

> "If I took it away from that example, the bits of brackets, I would look at street furniture and amenities and go probably think of benches and other stuff … bins, and things like that. But it's nice to have it laid out in a way that confirms while thinking." (P5)

This theme is illustrated by the way in which P5, here, talks about the difficulty of abstractions, and begins to construct their own instantiations to understand the factor:

> "The way it's currently phrased … because there's no a specific object like an intangible kind of concept. I've got to mentally think about. So, in my head, I'm thinking about going down a public footway and then all of a sudden, there's a tree in the way

[4] For illustration purposes, the cell content has been abbreviated by […].

[6] These were walking factors. Amongst others, the first choice card showed factor #14 (the width of the footway and the ability for pedestrians to maintain a distance from traffic), factor 9 (crossing points follow desire lines) and factor 1 (feeling safe while walking along the footways). Amongst others, the second choice card showed factor 20 ('street furniture and amenities [e.g., benches and/or ledges for sitting, rubbish bins, drinking fountains, heat lamps, public restrooms]'), factor 19 ('the level of noise and air pollution that pedestrians might be exposed to') and factor 18 ('availability of measures to slow down traffic and give priority for pedestrians').

that's across the footway. I had to visually imagine it because there's no exact word for tree in the footway or any other object. Just being hung up on that one trying to make it more linguistic."

It is important to reflect that factors were drawn from auditing tools, which are enhanced by their abstraction to be applicable across varying circumstances, however, as this theme suggests, particular instances can be necessary for some when completing this BWS task, and this increases the difficulty of the task and risks imprecision due to uncertain interpretations.

3.2. Understanding of the factors

Five further themes were identified concerning the understanding of the factors in both experiments. These were: (theme 5) factors with ambiguous words or phrases; (theme 6) overlapping of two or more factors; (theme 7) factors phrased negatively; (theme 8) factors containing technical terms; and (theme 9) presupposition about some factors. The links between themes, factors and participants are shown in Table 7 (for walking) and Table 8 (for cycling).

3.2.1. Theme 5: factors with ambiguous words or phrases

Several participants (P2, P9, P14, P15, P19) reported varying comprehension difficulties in the instructions sheet prior to the BWS choice cards (e.g., Fig. 2), ranging from confusion or neglect of the title (P2, P19), finding bullet-points confusing (P4) or too dense (P9, P14), to difficulty absorbing (P15) and retaining (P19) the information. Moreover, the instructions sheet sometimes failed to prepare participants for the BWS task. For instance, P3 could not easily "visualise exactly what [was] going to happen" and was "unclear" whether elements in the task would be "things that do not already exist, or things that would be introduced."

Factor 1 (feeling safe walking the footways) was particularly ambiguous concerning the source of hazards, which was not limited to traffic-hazards. P3 identified ambiguity between other people and vehicles as hazards. P2 found safety in crowds: "you feel safe if it is a public footpath that is used regularly and there is plenty of people around" (P2). P5 identified hazards from crime and natural hazards: "fear of effectively crime or in a flip side like natural danger" such as "walking along a river". P8 interpreted "feeling safe while walking" as being safe "from traffic" that they "would not want to walk along the motorway or dual carriageway", and P6 also included cyclists on the footway as a safety hazard: "Traffic is definitely one part of it, but probably also from other people" and "bicycles." Hence, in a BWS task, differences in interpretation may lead to additional unexplained variance.

Two participants (P18 and P20) found the word 'measures' to be vague, in 'Availability of measures to reduce the risk of collisions at junctions': "what do you classify as the measures that reduce the risk?" (P18). 'Non-complex and self-explanatory cycling network design' was difficult to read for P18: "that is quite complicated question." Upon rereading, they went on to describe the item in some detail: "I mean in [this city] I do not think there is anything complicated about how, where to move and where to cycle but maybe in like London or bigger cities, is much more complex." Here, travel context (see Theme 2), being mostly lacking (their local cycling network is not complex), made the form of words more difficult to understand.

Sentence structures sometimes enhanced the confusion: P13 pointed out that 'The ability for easily and safely join and navigate along the pathway and between different route' was too long and "a lot of construction going on there." Ambiguity was also compounded for those for whom English was not their first language: P16, upon reading 'Risk of collision resulted from conflict with kerbside activity', asked "Oh, what is the kerbside?". Ambiguities could sometimes be unexpected and complex. For P11, 'The length of delay caused by not being able to bypass slow moving traffic' was ambiguous as to "whether that was on a bike or that would

Table 7
Themes highlighted by the participants about walking factors.

No	Description	Ambiguous words	Overlapped factors	Negatively phrased factors	Technical term	Presupposition about some factors
1	Feeling safe while walking along the footways	1	1 (4, 14)			
4	Adequate separation between traffic and the footway		2 (14)			
6	Traffic speeds low, or you can keep distance from moderate traffic speeds		2 (4)			
9	Crossing points follow desire lines				4	
10	Possibility of crossing a route where no controlled crossings present		1 (18)	2		
15	How steep or hilly is the pathway?	1				
17	Having no obstructions that restrict clearance width of the footway			3		
19	The level of noise and air pollution that pedestrians might be exposed to					2
20	Street furniture and amenities (e.g. Benches and/or ledges for sitting. Rubbish bins. Drinking fountains. Heat lamps. Public restrooms)			1		

Note: "No." are walking factors, numbered as they appear in Table 1. Cells in the columns "Ambiguous wording", "Negatively phrased factors", "Technical term", and "Presupposition about some factors", record the quantity of participants from whom these themes were identified for the factor in the corresponding row. For instance, from one participant the theme of 'Ambiguous wording' was identified as applying to Factor 1. Cells in the column "Overlapped factors" also include, in parenthesis, the number(s) corresponding to the factors identified as overlapping with the factor in the corresponding row. For instance, from participant number one, factor number one was identified as overlapping with factors four and fourteen.

Table 8
Themes highlighted by the participants about cycling factors.

No	Description	Ambiguous words	Overlapped factors	Negatively phrased factors	Technical term	Presupposition about some factors
1	Pathway construction providing smooth and level surface		2 (2)			
2	Density of defects including raised/sunken covers, gullies, potholes		1 (5)/1 (5, 12)			
4	How steep or hilly is the pathway?	1				
5	Feeling safe while riding a bicycle along the pathway		1 (10, 19)			
7	Availability of measures to reduce the risk of collisions at junctions	2				
8	Non complex and self-explanatory cycling network design	1				
9	Risk of collision resulted from conflict with kerbside activity	3		1		
11	Risk of collision because of increasing traffic volume			1		
12	Risk of collisions due to conflict with Heavy Good Vehicles (HGVs)			1		
14	Cycling pathway clear of physical hazards such as evasion room, guardrail	2				
17	The length of delay caused by junctions		1 (18)			
18	The length of delay caused by not being able to bypass slow moving traffic	1				
19	The ability for easily and safely join and navigate along the pathway and between different routes in the network	1				
20	The continuity of cycling pathway					1
22	Availability of overlooked routes throughout its length				2	

Note: "No." are cycling factors, numbered as they appear in Table 2. Cells in the columns "Ambiguous wording", "Negatively phrased factors", "Technical term", and "Presupposition about some factors", record the quantity of participants from whom these themes were identified for the factor in the corresponding row. Cells in the column "Overlapped factors" also include, in parenthesis, the number(s) corresponding to the factors identified as overlapping with the factor in the corresponding row.

encourage [him] to be on a bike as opposed to be in the car", hence ambiguous concerning the travel mode for which there is a delay, thus an ambiguity concerning the situation rather than only the meaning of a word or phrase alone.

The factor 'How steep or hilly is the pathway?' was often chosen as the most important. However, it actually split opinion. Some desired gradients. P7 walked through "a lot of hills" on her way to work and felt "like getting a proper workout from that." By contrast, P15 had "ridden up some really long hills and it [was] killer for [their] legs and would have preferred not to." Hence, whether this factor was important due to it being desirable or undesirable would not be manifest from quantitative data, and the assumption that gradients are invariably undesirable would lead to a mistaken inference by the researcher in a quantitative study using this item verbatim.

3.2.2. Theme 6: two or more overlapping factors

Participants sometimes identified conceptual overlap between specific factors, leading to confusion, because both factors afforded the participant the same facility. For instance, some equated walking factors 1, 4, and 14. Participant three (P3) was not "sure what in practice [,] the difference between" factors 14 and 4 was, namely 'The width of the footway and the ability for pedestrians to maintain a distance from traffic' (14) and 'Adequate separation between traffic and the footway' (4).

Participant six (P6) elaborated on this conceptual overlap, also linking these factors with walking factor 1 ('Feeling safe while walking along the footways'), saying "that one, feeling safe while walking along the footways, kind of ties in a bit to the separation of traffic and the footway width." The implication is that whether separation from traffic is achieved through a wider footway or a greater gap between footway and traffic is a moot point, and that both are subsumed by the wider affordance of safety by the relationship between footway and trafficway. Similar conceptual overlaps were identified between walking factors 4 and 5, because (P4) "they are also offered me the chance for adequate separation" and between walking factors 10 and 18, because (P3) "giving priority to pedestrians is also enabling them to cross safely", each pair of factors, for some participants, fulfilling the same function, namely separation from traffic and enabling safe pedestrian road-crossing.

This was not limited to the walking factors, with participants P13, P15, and P19 finding different overlaps between cycling factors 1, 2, 5, 10, 15, and 19, significantly noting that some "encompass" others (P15 and P19) and that some are "redundant" when others would be sufficient to "make you feel safe". In interpreting this theme, it is important to consider that this may be the consequence of the way in which finer distinctions present in the auditing tool from which factors were drawn are failing to translate themselves into meaningful distinctions for non-experts, for whom the differential safety implications are not necessarily clear.

3.2.3. Theme 7: factors phrased negatively

Negative phrasing can be difficult to comprehend, particularly as sentence structures become more complex. Walking factor 10,

which was 'Possibility of crossing a route where no controlled crossings present', led P3 to state that they did "not feel like it is a choice for the pedestrian to make": that is, the verbal complexity alongside a negative phrase led to unintended interpretation. This complexity is revealed by P9, to relate to 'crossing' being interpretable as both a noun and a verb, or that it is "the same word [that has] different meanings in the same sentence." Likewise, walking factor 17 confused some participants (P4, P5 and P10) due to proximal use of two negatives: 'Having no obstructions that restrict clearance width of the footway.' P4 remarked: "it is a little bit of a 'no' and then a 'restrict'". Further, some participants remarked of the negative start to three factors, each beginning 'risk of collision' (factors 9, 11, and 12), that "it is obviously inferred, but you want to reduce that, not increase that" (P13). Negatively phrased factors could make the participants underestimate their value, neglect their importance, and most probably not choose them thus leading to dominance (Soekhai et al., 2021).

3.2.4. Theme 8: factors containing technical terms

Technical terms – i.e., those more frequently used by experts than the general public – were less frequent but did cause misunderstanding in each of two cases. These were 'desire lines' in 'crossing points follow desire lines' and 'overlooked routes' in 'availability of overlooked routes throughout its length'. Participants doubted that they understood these terms, for instance P1 said that they had "never heard [of desire lines] before" and that therefore they "cannot be sure what that is meant" (P1). It follows that such lack of knowledge precludes accurate answering. As P13 stated of 'overlooked routes': "I do not really know what you are saying there […] so, I cannot say how important it is." This illustrates the general importance of assessing adapted materials (such as auditing materials) for technical language before using it in a general-population sample.

3.2.5. Theme 9: presupposition about some factors

Respondents used their existing knowledge and experience when making decisions and framing answers (Tourangeau et al., 2000). Here, this was manifest in presuppositions about the feasibility of factors, presuppositions (which would be undetected in a purely quantitative study) that seemed to influence answering. Walking factor 19, 'the level of noise and air pollution that pedestrians might be exposed to', was presupposed by at least two participants to be beyond their control. For P10, this made it difficult to compare to other factors with respect to importance:

> "If I thought I was going to go for a walk around the city, then that's what I would be expecting there. I'd be expecting the noise. I'd be expecting the car pollution I would be expecting, you know, pedestrians, it'd be a busy environment. So, I suppose it depends on the area that you're walking in. It wouldn't put this off. It wouldn't be the most or the least important to us. It would just be a factor that's there" (P10)

By contrast, P16 was confident that "the level of noise [is] important, but don't know how they would reduce it." This interaction between feasibility (or efficacy) and importance was not limited to pollution. One participant (P17) chose 'the continuity of cycling pathway' as the least important factor because she thought of it as unrealistic:

> "We don't have many continuous cycling paths, a lot of it is roads or walking paths. So, it's not realistic, I don't think for it to be a continuous cycling pathway. So, it wouldn't be an important factor for me." (P17)

If a significant minority approached these factors in this way within a quantitative study, less feasible factors may be subject to some negative bias, that is found to be less important to respondents than they actually are.

4. Discussion

The aim of this study was to use cognitive interview pre-testing to enhance information from auditing tools to devise a content-valid instrument for eliciting investment-preferences for walking and cycling infrastructure using Best-Worst Scaling (BWS). This has been achieved through a carefully designed study framework, which is summarised in Fig. 1. After identifying relevant walking and cycling factors from several auditing tools and designing an initial experimental design, 20 cognitive interviews were conducted to assess and improve the internal validity of the BWS instrument. Qualitative (thematic) analysis of interview data led to nine themes summarised into two groups, which we discuss below, making reference to how we subsequently changed our instrument to address each issue identified.

4.1. How the participants approached the BWS task

The four themes related to how the participants completed the BWS task were addressed as follows. Theme 1 ('missing a frame of reference'), found in the repeated question on each choice card, was addressed by rephrasing this into: "Which of the following areas should be the highest priority and which of the areas should be of the lowest priority for your local council to pursue to encourage walking/cycling." We chose this wording because it establishes a clear frame of reference: local council action. Theme 2 ('travel context') is also addressed through this change, by emphasising a specific travel context (the local area) within a hypothetical scenario (future council policy).

Theme 3 ('decision-making strategy') presented some particular issues, but also offered insights into how the BWS task was approached. We found traces of different approaches to deciding between options that involved multiple items (Gunten and Scherer 2019) including heuristic dominance of some factors over others and more nuanced strategies when multiple factors were equally dominant (Einhor and Hogarth 1981; Payne 1982). Strategies depend upon both situations and personal characteristics (Zakay 1990;

Shiloh et al., 2001), so caution is warranted in inferring that a certain change will affect decision strategy. However, some participants were observed to use a simple heuristic approach where sentence-length affected attention, with shorter sentences being preferred. Therefore, we shortened factors with long sentences whilst retaining the meaning, limiting factors to a single line and thereby controlling for sentence-length. This also supports issues identified relating to factor phrasing and wording, where long and complex sentence-structures engendered some misunderstanding and cognitive difficulty.

Theme 4 ('concrete thinking') identified the need for many participants to instantiate entities from the abstract in order to understand and process them, hence often failing to appreciate the general implications of a factor (Gustafson and Waehler 1992). This can be addressed by using exemplars (Tsai and Thomas 2011), hence we added descriptive words to facilitate recollection of these. For instance, we changed "The overall condition of the footway, viability of footway for walking and pushing a pushchair" to "Well--maintained and level footpaths for walking and pushchairs", thus providing two concrete qualities (maintained, level) to guide recollection. Likewise, by changing "density of defects including raised/sunken covers, gullies, potholes" to "pathways free of defects such as gullies and potholes". We anticipate that it is easier to recollect instances of using paths without these than to consider their density. Not all terminology is easy to address in this way, so we also added a hover-over-text that elaborated upon terminology. For instance, 'short waiting times at controlled crossings' included the hover-over-text 'most crossings are single-phase pelican/puffin or zebra crossings', thus making it clear what is meant by 'crossings', and also addressing more particular language issues with this factor (see Section 3.2, *Theme 7: Factors phrased negatively*).

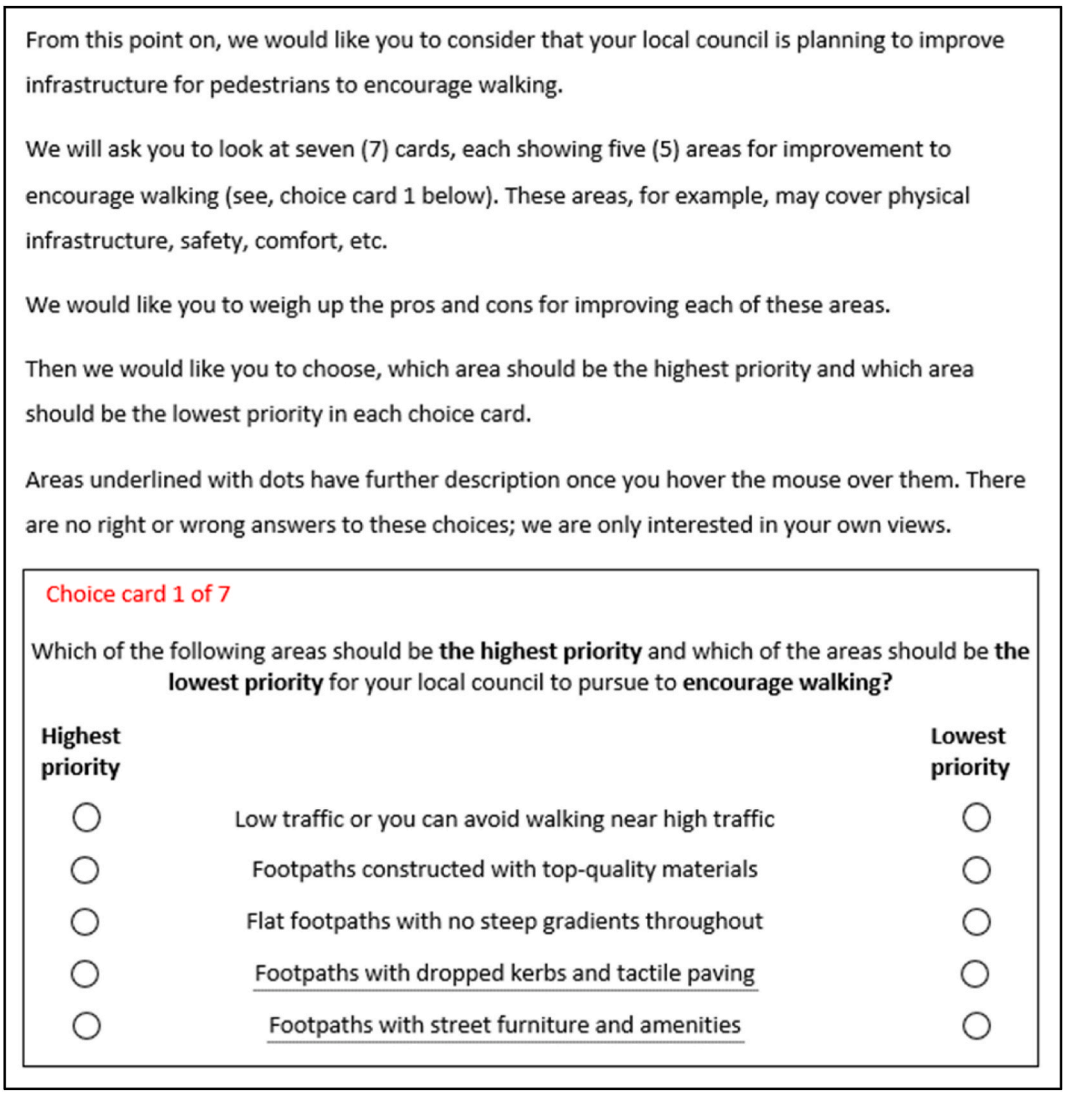

Fig. 5. The revised BWS choice task.[71].

4.2. Understanding of the factors

The psychology of survey response (Tourangeau et al., 2000) emphasises the importance of precise wording; the complexity of question wording is frequently related to the vagueness and complicated semantic and grammatical structure (Menold 2020). This includes ambiguous and inaccurate words and phrases (Lenzner et al., 2010), and complexities arising from sentence length challenging the memory capacity of the individual trying to understand it (Yan and Tourangeau 2008). We addressed ambiguities first by deleting the choice-card title so as not to disturb the participants through their different assumptions about it. Then, we re-wrote the instructional bullet-points more precisely. Examples of these materials are shown in Fig. 2 (before changes) and Fig. 5 (after changes).

This study also showed the phrase 'feeling safe' to be ambiguous as to the source of hazard and that safety factors often overlapped one another, leading to redundancies. Therefore, the 'feeling safe' factor was rephrased more precisely with reference to safety from crime, since other factors already addressed traffic safety aspects adequately. Concern about safety from crime, including violence and vandalism, and its relationship to walking and cycling is evident from many previous studies. For example, Foster et al. (2014) found a reduction of recreational and transport walks within the local neighbourhood to be associated with an increased fear of crime. In neighbourhoods with a record of violence, women and the elderly were disproportionately affected (Roman and Chalfin 2008). Cycling is also affected: accident risks discourage cycling (Rietveld and Daniel 2004; Southworth 2005) and Mosquera et al. (2012) found that women were more often the victims of personal assault, mugging and injuries while cycling than men.

Similarly, the way the gradient factor ('how steep or hilly is the pathway?') was phrased confounded aspects together in a single question (Bradburn et al., 2004), which can increase the cognitive burden on the respondents (Menold 2020), but, more importantly, obscures accurate inference from data. Therefore, we reworded this as 'flat (footpaths/pathways) with no steep gradients throughout' to make it read as a statement, definitive and cohesive with the other factors, and, if chosen as most important, allowing a clear inference to preference for level footpaths and pathways.

The overlap between some of the factors was cleared by rephrasing each factor to address different specific issues. For example, 'feeling safe while walking along the footways' became 'footpaths are clear of any signs of crime or vandalism', and the footpath width factor was rephrased specifically as 'adequate footpath width to accommodate both walking directions' with a hover-over-text 'for example, you do not need to 'give and take' with other walkers or walk on roads' to highlight only the width issue.

Other overlapping factors were also addressed through rephrasing. The traffic speed factor was reworded into 'low traffic speeds or you can walk away from high-speed areas' so as to remove overlap with 'adequate separation between the road and footpaths'. The surface material factor was rephrased into 'pathways are smooth and with level surface' with hover-over-text 'machine laid a smooth and non-slip surface' to distinguish it from the surface maintenance factor which was reworded to 'pathways free of defects such as gullies and potholes'. Schriesheim (1995) found that positive wording accounted for a greater proportion of personality trait variance than negative wording, implying that positive phrasings are more reliable as indices of true attitudes than are negative phrasings. The negative wording found in some factors was changed into positive wording consistent with the required meaning of the factors as encouraging walking and cycling (Soekhai et al., 2021). For example, 'having no obstructions that restrict clearance width of the footway' was changed into 'footpaths free of obstructions such as poles and signs', and 'risk of collision because of increasing traffic volume' was changed into 'low traffic volumes to reduce risk of collision'.

The technical language used in some factors was simplified and explained using hover-over-text. 'crossing points follow desire lines' was rephrased as 'crossing points are along the footpath of destination', with the hover-over-text 'Crossings do not divert you away from your destination'. 'Availability of overlooked routes throughout its length' was replaced by 'pathways are near city amenities throughout their length', and the text 'cycling pathways are close to shops, cafes, services/enhance the feeling of social safety' was added as a hover-over-text.

Finally, the question can express a limited set of options, each of which has no known location as the correct answer and thus pushed the respondents to faulty presuppositions (Tourangeau et al., 2000). As presuppositions reflected a lack of feasibility or efficacy concerning factors, we addressed this by rewording those factors to positive and encouraging statements. For example, 'The level of noise and air pollution that pedestrians might be exposed to' was divided into two different factors, each emphasising low levels in a specific location: 'Low levels of noise along the footpaths' and 'Low levels of air pollution along the footpaths', thus allowing efficacy (one can choose a different path) and feasibility (reasonably, a council can more easily address localised pollution). Similarly, 'The continuity of cycling pathway' was replaced by 'Provision of continuous pathways for cycling', 'provision' emphasising feasibility. The amended wording of the walking and cycling factors are summarised in Tables 9 and 10, respectively.

5. Conclusion

Through a comprehensive study framework (Fig. 1), this paper demonstrated how cognitive interview pre-testing was employed to enhance the development of a universal survey-based BWS instrument to identify and rank funding priorities for walking and cycling infrastructure to elicit citizens' choices. We found cognitive interviewing to be invaluable in identifying potential sources of inaccuracy and bias in the instrument, as well as in enhancing our understanding of how participants engaged with the task and the issues it raised. We argue for the use of BWS experiments (instead of ranking or rating tasks) as they offer a cognitively easier and methodologically robust way to elicit preferences. Despite their advantages, the implementation of BWS experiments remains limited in the field of

[7] Note: Underlying text indicates the presence of hyperlink offering additional details about those factors.

Table 9
Amended wording of walking factors.

	Factor	Hover-over text
1	Footpaths are clear of any signs of crime or vandalism	
2	Availability of lighting along the footpath	
3	Clear lines of sight to all footpath users from all directions	
4	Adequate separation between the road and footpaths	
5	Low traffic or you can avoid walking near high traffic	
6	Low traffic speeds or you can walk away from high-speed areas	
7	Provision of continuous footpaths for walking	Walking not interrupted by road traffic
8	Low levels of noise along the footpaths	
9	Crossing points are along the footpath of destination	Crossings do not divert you away from your destination
10	Only possible to cross the road from controlled crossings	
11	Short waiting times at controlled crossings	Most crossings are single-phase pelican/puffin or zebra crossings
12	Pedestrians have enough time to cross the road	
13	Well-maintained and level footpaths for walking and pushchairs	
14	Adequate footpath width to accommodate both walking directions	For example, you do not need to 'give and take' with other walkers or walk on roads
15	Flat footpaths with no steep gradients throughout	
16	Footpaths constructed with top-quality materials	
17	Footpaths free of obstructions such as poles and signs	
18	Measures to stop traffic and give priority for pedestrians	Measures to stop traffic such as zebra crossing, pedestrian signals with pushbuttons, school crossing
19	Low levels of air pollution along the footpaths	
20	Footpaths with street furniture and amenities	Street furniture and amenities including sitting areas, drinking fountains, litter bins and public toilets
21	Footpaths with dropped kerbs and tactile paving	Dropped kerbs are where the footpath gently slopes to the same level as the road. Tactile paving is a system of textured strips on footpaths to assist visually impaired people

Table 10
Amended wording of cycling factors.

	Factor	Hover-over text
1	Pathways are smooth and with level surface	Machine laid a smooth and non-slip surface
2	Pathways free of defects such as gullies and potholes	
3	Adequate path width to prevent conflict with other users	
4	Flat pathways, with no steep gradients throughout	
5	Pathways free of any signs of crime or vandalism	High-quality street scenery and pleasant interaction
6	Adequate separation between the road and pathways	
7	Measures to reduce risk of collision at junctions	Measures such as closing side roads or treating them to blend in with footpaths
8	Clear, understandable pathway markings and layout	
9	Pathways clear from conflict with kerbside activities	No interaction with vehicles parking or loading, bus stops
10	Low speeds of motor vehicles on shared routes	
11	Low traffic volumes to reduce risk of collision	
12	Measures to avoid conflict with Heavy Goods Vehicles	Measures such as banning of HGVs along cycling paths
13	Availability of lighting along the pathway	
14	Pathways clear from physical hazards such as guardrails	
15	Pathways follow the shortest option available	
16	Few crossing-stops or priority over other vehicles along the route	
17	Short waiting times at junctions along the route	
18	Being able to bypass slow moving traffic to reduce delay	You can always choose an appropriate speed and pass other vehicles
19	Safely join/leave and navigate along pathways	
20	Provision of continuous pathways for cycling	
21	Clear and direct signs towards all destinations	
22	Pathways are near city amenities throughout their length	Cycling pathways are close to shops, cafes, services/enhance the feeling of social safety
23	Access to secure cycle parking along the route	
24	Low levels of air pollution along the pathways	
25	Low levels of noise along the pathways	

transportation research (Gong et al., 2021; Song et al., 2021; Schuster et al., 2024).

While BWS experiments evidently present advantages in reducing respondents' cognitive burden, it is also worth recognising several challenges. Firstly, while ranking or rating (compared to BWS) offers the prospect of avoiding some of the issues identified around complexity – such as heuristic answering and contextual framing – these preference elicitation approaches are not necessarily free of these and related issues or interpretation and understanding, and so validity is enhanced through cognitive pre-testing whichever approach to preference elicitation is favoured. However, secondly, the construction of BWS does require greater expertise, resources, and effort on the part of the researcher than does developing or adapting ranking or rating questions, and so the latter are likely suitable for simpler and quicker research goals. Finally, cognitive interviewing could be done in waves, so that the degree of improvements obtained from amendments can be better understood (Beatty and Willis 2007). This was a step we were unable to implement in this study due to time and resource constraints but which can enhance validity further. Nevertheless, this study has, through qualitative investigation, shown the potential value of using BWS tasks as a 'vehicle' to better understand nuanced aspects of citizens' choices and interpretations of active travel infrastructure investment. Most importantly, through this process, we derived a general instrument, which can be used in different contexts for the collection of comparable data (Mueller Loose and Lockshin 2013).

This study also highlights the importance of the qualitative process (via cognitive interviews) prior to a large-scale survey. Cognitive interviews and thus pretesting of a BWS experiment can help enhance data accuracy through the early detection of cognitive challenges. Most importantly, refining materials through cognitive pretesting can improve the internal validity of the instrument – i.e., bridge the gap between the researcher's intended and participants' interpretation of questions. This study has shown that cognitive interviewing is an effective tool in ensuring the validity and usability of the instrument prior to a large-scale fieldwork, especially in the case of BWS experiments. The findings of this study present a case for ways to revise and use infrastructure-related factors for eliciting investment priorities for walking and cycling. Future studies involving BWS experiments should incorporate a detailed qualitative framework for cognitively testing BWS experiments as part of the survey development process, especially if the survey context is new and items are objective as was the case with auditing tools in this study.

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CRediT authorship contribution statement

Fahad Albahlal: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Paul Haggar:** Methodology, Validation, Data curation, Writing – original draft, Writing – review & editing. **Dimitris Potoglou:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Fig. A1 shows the BIBDs for both experiments, in which rows refer to the number of the choice card, the five columns represent the five items in each choice card, and the numbers in each column are the factors numbered as in Tables 1 and 2.

BIBD for walking experiment

```
> set.seed(123)
> find.BIB(t=21, k=5, b=21)
      [,1] [,2] [,3] [,4] [,5]
 [1,]    1    6   12   16   19
 [2,]    5   15   16   20   21
 [3,]    3    5    6    7   18
 [4,]    4    7   10   11   16
 [5,]    1    2    3   10   20
 [6,]    3    4   13   19   21
 [7,]    4    6    8   17   20
 [8,]    2    7    8   15   19
 [9,]    2    6   11   14   21
[10,]    2   13   16   17   18
[11,]    5   10   14   17   19
[12,]    8   10   12   18   21
[13,]    3   11   12   15   17
[14,]    2    4    5    9   12
[15,]    1    5    8   11   13
[16,]    1    7    9   17   21
[17,]    6    9   10   13   15
[18,]    7   12   13   14   20
[19,]    9   11   18   19   20
[20,]    3    8    9   14   16
[21,]    1    4   14   15   18
> isGYD(bibd)

[1] The design is a balanced incomplete block
 design w.r.t. rows.
```

BIBD for cycling experiment

```
> set.seed(4763)
> find.BIB(t=25, k=5, b=30)
      [,1] [,2] [,3] [,4] [,5]
 [1,]    2   10   21   24   25
 [2,]    2    7    9   13   19
 [3,]    9   13   20   23   24
 [4,]    6   13   15   16   21
 [5,]    3    9   14   16   22
 [6,]    2   11   12   15   17
 [7,]   11   14   19   23   25
 [8,]    1   10   12   14   20
 [9,]    8   13   14   17   21
[10,]    1    2   16   18   23
[11,]    7    9   10   17   18
[12,]    1    3    5   17   24
[13,]    1    7   15   22   25
[14,]   16   17   19   20   25
[15,]    3    6    7   11   20
[16,]    4    7   12   14   16
[17,]    3    8   10   15   23
[18,]    1    6    8   10   19
[19,]    1    4    9   11   21
[20,]    4    6   17   22   23
[21,]    5   10   11   13   22
[22,]    2    3    5    6   12
[23,]    5    7   18   21   23
[24,]   12   19   21   22   24
[25,]    5    8    9   12   25
[26,]    3    4   13   18   25
[27,]    4    8   11   16   24
[28,]    6   14   15   18   24
[29,]    2    8   18   20   22
[30,]    4    5   15   19   20
> isGYD(bibd)

[1] The design is a balanced incomplete block
 design w.r.t. rows.
```

Fig. A1. BIBDs for walking and cycling experiments.

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