Roberts, M.J., Ng, D., & Baruela, C. (2025). Using forced-journey choice methodology to investigate the usability of octolinear versus concentric circles transit maps. Schematic Mapping Workshop 2025, EIVP, Paris, April. http://www.tubemapcentral.com/writing/academicfiles/Roberts_etal_routechoice_SMW2025_2025.pdf

Using Forced-Journey Choice Methodology to Investigate the Usability of Octolinear Versus Concentric Circles Transit Maps

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***Abstract*—schematic maps based on concentric circles have generated interest amongst the general public and researchers but studies also suggest that such designs have usability issues. The current research implemented a forced-journey choice methodology to investigate the possibility that, for such maps, it is difficult to evaluate alternative journey options. Previous findings concerning adverse ratings by subjects were replicated but mean decision times for journey choices did not differ significantly compared with a conventional octolinear design. It is suggested that usability issues with concentric circles maps stem from difficulty in *generating* plausible journeys.**

Keywords—schematic maps, transit maps, usability testing, concentric circles maps

I. Introduction

Schematic maps based on concentric circles and spokes (also known as ortho-radial diagrams) have created a substantial niche for themselves in various domains. Many examples have generated high levels of internet interest amongst the general public (Fig. 1) and also media attention. Research has investigated usability [9], potential applications [3] and automated construction [1, 2, 11]. Actual application has been sporadic. The first known design was prototyped, by Erik Spiekermann in 1989, for Berlin, but not adopted. The author is aware of only two designs published for actual passenger use: Lisbon in 2001 and Köln in 2021 [6].

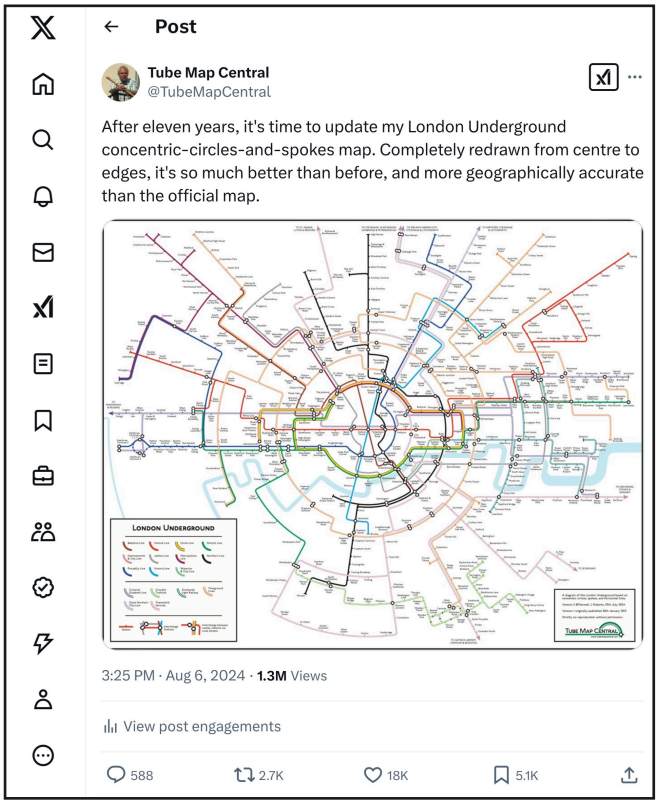


Fig. 1. A London Underground concentric circles map, designed by the author, secured over 18,000 'likes' on ***X*** in August 2024. Roberts [7] discusses the underlying objectives for creating this design.

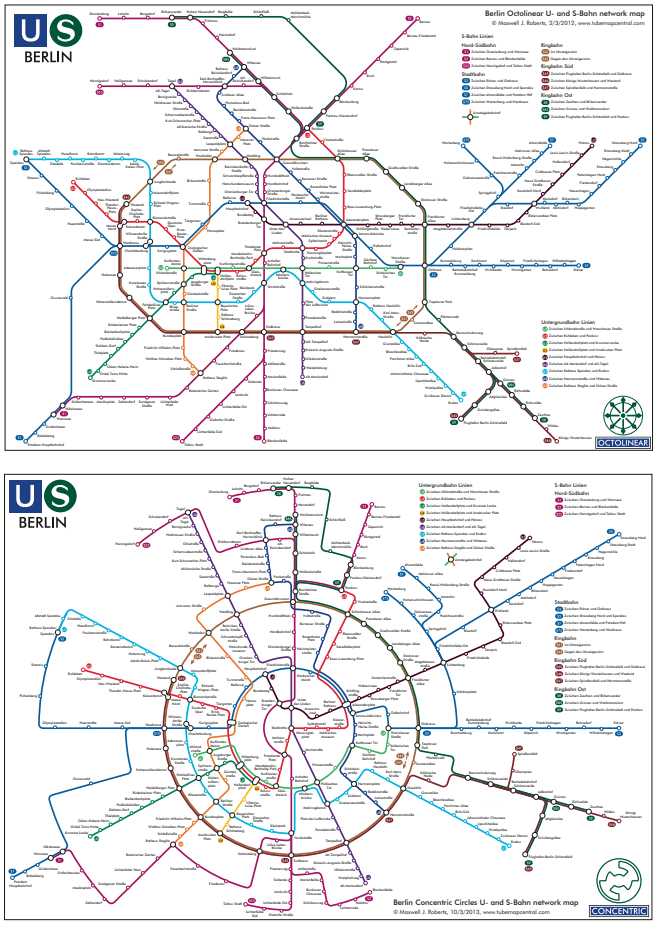
Maps based on concentric circles and spokes present a paradox. They undoubtedly have considerable and immediate visual impact but Roberts, Newton and Canals [9] identified a number of usability issues. They compared a concentric circles map of the Berlin U- and S-Bahn network with a conventional octolinear design (see Fig. 2). Octolinear maps implement the standard design rules of horizontal, vertical and 45º diagonal straight lines, as used by Henry Beck for the first London Underground diagram published in 1933 [5]. The concentric circles version received lower ratings from subjects *and* was slower for planning journeys between designated station pairs.

These findings can be interpreted using the concepts of *simplicity* and *coherence* from Roberts' *framework for effective design* [8, 9]. *Simplicity* refers to individual line trajectories which, ideally, should have minimal changes of direction. *Coherence* is a higher order criterion referring to the need for lines to relate to each other in order to give an orderly design with good shape. Compared with traditional octolinear designs, concentric circles maps tend to have complex line trajectories. Conversely, the more regimented construction techniques result in greater coherence. The adverse findings for the concentric circles map therefore suggest that a designer should prioritise simplicity rather than coherence when creating a schematic map.

Roberts, Newton and Canals [9] made an additional observation: Their subjects had been asked to identify likes and dislikes for each design, yielding a recurring complaint that the structure of the concentric circles map made every journey option look roundabout, hence it was difficult to identify efficient routes from competing alternatives. This led Roberts to propose a *forced-journey choice task* to evaluate this suggestion [4]: Subjects would be asked to evaluate pre-planned journeys rather than generate their own.

The study reported here further investigates the reasons for adverse ratings of concentric circles maps using the same two Berlin designs as previously (Fig. 2). Subjects were given computer-presented series of trials with each item comprising two highlighted plausible journeys linking origin and destination stations. The task was to estimate the faster journey for each trial, with decision times as the measure of performance. Assuming that, using a concentric circles map, it is difficult to identify optimum journeys from competing options, it is predicted that decision times should be greater than for an octolinear version. Subjects made journey-choice decisions for both maps and, after completing the trials, a questionnaire was administered, similar to ones used in previous research, to see whether previous adverse ratings for the concentric circles map could be replicated.

Fig. 2. Berlin maps used in the current experiment: a conventional octolinear design (upper) and a design based on concentric circles and spokes (lower). Both maps were designed by the author.



II. METHOD

A. Subjects

Sixty people took part in the experiment, either students of the University of Essex or acquaintances of the experimenters. They were recruited online, the majority via the departmental subject panel. All were unpaid volunteers. Forty five had never previously visited Berlin, ten rarely visited Berlin and only five were frequent visitors.

B. Materials

For the route choice task, twenty-four trials were devised, divided into Block 1 and Block 2 sets, and implemented for both maps. Each item comprised an origin and a destination station, sampled from across the region. Routes between station pairs were chosen to be plausible, but varied in the expected difficulty of choosing between them. For each trial, the alternatives had an identical number of interchanges. To avoid possible biases, all routes were devised using the octolinear map, without any reference to the concentric circles version. The full list of trials is given in Appendix A.

Trials were formatted showing the origin station double-circled and destination station single-circled. To display the routes, these were highlighted in green or yellow and designated A or B in large squares coloured to match the routes. Interchange stations were shown as grey boxes, coloured inside to identify the route(s) to which they applied. Examples are shown in Appendix B. Trials were presented with the map cropped to show the routes as large as possible on a computer screen, with decision buttons underneath.

The questionnaire comprised twenty-two statements, each to be rated on a five point scale: *strongly disagree/somewhat disagree/neither agree nor disagree/somewhat agree/strongly agree*. Statements were doubled, one designated for each map. Radio buttons were used to collect responses. Subjects were also invited to give four brief written statements to highlight what they liked and disliked about each map. They were additionally asked to rate their simple preference on a five point scale: *straight line map strongly preferred/straight line map preferred/neutral: neither map preferred/curved line map preferred/curved line map strongly preferred.* One final question asked how often subjects had visited Berlin.

The statement rating task questions were an embellished set taken from past research (e.g., [8, 9]) and the twenty that are directly relevant to usability issues are as follows:

1. I found journeys easy to plan using the map
2. Routes were difficult to discriminate (identify) using the map
3. The map appeared to be disorderly and badly organised
4. Station names were easy to identify using the map
5. On this map, it was difficult to identify whether a journey was likely to be direct or roundabout
6. If my intended journey could not be carried out because of disruption, I can imagine planning a new one quickly with this map
7. Station interchanges were difficult to negotiate using this map
8. The map had a pleasing shape and I liked looking at it
9. Line trajectories were easy to follow using this map
10. I found this map disorienting to use
11. I would be happy to use this map to plan real-life journeys around Berlin
12. The map looked like an amateur attempt rather than an official design
13. The map looked as though it was designed quickly
14. With this map, I would rather walk to take a taxi than use the Berlin Metro
15. The map looked as though a lot of thought went in to configuring it
16. I found the map visually disturbing
17. I found the map clean and uncluttered
18. The map appeared balanced and spread evenly across the page
19. I would look for another design of Berlin Metro to use at the earliest opportunity
20. It was easy to choose between options to find the best journey for me

C. Design

This was a single factor within-subjects design with two levels: Octolinear versus Concentric Circles. The dependent variables were (1) mean decision times for the route choice task, and (2) the quantitatively scored/aggregated answers for the questionnaire statement rating task. Subjects experienced both maps. They performed the route choice task either with Block 1 trials allocated to the concentric circles map and Block 2 trials for the octolinear version, or vice versa. Hence, journeys experienced for one map were different from those for the other. Block allocation to maps was counterbalanced, likewise order of map presentation. Order of trials within blocks was randomised.

D. Procedure

The tasks were implemented using Qualtrics. Thirty-six people were tested remotely and twenty-four with the experimenter present. The journey choice task was given first, with written instructions on-screen explaining the format and task. Subjects were informed: *for each trial, we would like you to decide which route, Option A or Option B, is likely to be the fastest. We would like you to use your intuition to try to make your decisions.* A practice trial was also given. Once this was complete, twelve trials for the first map followed, one per screen. Answers were input by clicking the appropriate button underneath the map, which cleared the screen and commenced the next trial. After these, the next screen explained that subsequent trials would use a new design of map, and another practice trial was given to illustrate this. Once the next block of trials was completed the questionnaire was presented, with all its items on one scrolling screen. Statement rating task items were chosen using radio buttons. There was no opportunity to view the maps while answering the questionnaire. Where the maps were referred to by instructions and on the questionnaire, the octolinear design was identified as the *straight line map* and the concentric circles version as the *curved line map*.

III. RESULTS

For the journey choice task, latency data were analysed only for the twenty-four subjects who had been supervised. For each person, two mean decision times were calculated, one for the octolinear map trials and one for the concentric circles map (Table 1). These gave objective measures of performance for each design. Data for the different orders and item sets were not differentiated. Past research has shown that order effects – i.e. experience with one map influencing performance at a subsequent one – are unlikely to be substantial enough to qualify overall findings [8, 9].

For the questionnaires, responses to the twenty statement-rating items that were relevant to usability were converted to numerical values. These were encoded so that high scores indicated a positive disposition. Depending on the polarity of the question, the responses of *strongly agree* or *strongly disagree*, indicating a favourable evaluation, was scored as 5, and answers at the other extreme were awarded 1 point. For each subject, two *aggregate rating scores* were calculated by summing the numerical values awarded, one for each map. These gave quantitative measures of peoples subjective dispositions towards the designs (Table I).

Except where stated otherwise, single-factor within-subjects design Analysis of Variance (ANOVA) was used to test for significant differences between maps.

A. Comparing Octolinear and Concentric Circles Maps

For the decision times, there was no evidence to suggest that evaluating route options was harder overall for the concentric circles map than the octolinear version, with no significant difference between the means, $F(1, 23) = 0.06$, $MS_e = 17.2$, $p > .05$. Hence, from times taken to perform route choice, there is nothing intrinsically difficult about this task for the concentric circles map.

Despite the lack of difficulty in performing the journey choice task, the concentric circles map remained unpopular, as per previous research [9]. Looking at the questionnaire, for the question that directly solicited simple preference, the concentric circles design was almost as unpopular as previously, with just 13 out of 60 people (22%) explicitly preferring this to the octolinear version, compared with 15% for the earlier study. Only one person strongly preferred the concentric circles map. Thirty-six people expressed a simple preference for the octolinear map, fifteen strongly.

	Octolinear map	Concentric circles map
Objective measures: journey choice task decision times ($N = 24$)		
Overall		
Mean (*secs*)	9.7	9.4
SD	*8.6*	*5.8*
High consensus trials		
Mean (*secs*)	7.6	8.9
SD	*6.0*	*6.8*
Low consensus trials		
Mean (*secs*)	10.3	12.0
SD	*13.8*	*8.5*
Subjective measures: questionnaire rating scores ($N = 60$)		
Aggregate statement rating task score		
Mean (*range 20 to 100*)	74.8	68.2
SD	*12.8*	*13.1*
Directness questions (5 and 20)		
Mean (*range 2 to 10*)	7.1	5.7
SD	*1.7*	*1.9*

TABLE I. Means and standard deviations for the route choice task decision times, and questionnaire ratings, for the two map types.

Looking at questionnaire aggregate statement ratings for the two maps (Table I), there was a small but significant difference, with the octolinear version receiving the more favourable scores, $F(1, 59) = 6.80$, $MS_e = 192$, $p < .05$. Interestingly, for the two questions that directly referred to difficulty identifying direct versus indirect routes – numbers 5 and 20 – there was a strong significant difference in favour of the octolinear design, $F(1, 59) = 13.7$, $MS_e = 4.1$, $p < .01$. This confirms the observation made by Roberts, Newton and Canals from their qualitative data [9], that subjects were concerned that the concentric circles design often implied that all potential options would be indirect and, hence, self-generated alternatives were difficult to choose between.

The difference in aggregate ratings between maps was smaller than previously [9] but, interestingly, the proportion of people whose aggregate scores were more favourable towards the octolinear design was similar. Previously, 68% of people gave a higher aggregate rating for the octolinear map versus the concentric circles design whereas, for the current study, 73% of people gave a higher rating. This indicated that, for the current study, those people who preferred the octolinear map – as identified from their questionnaire aggregate scores – were less likely to have a strong negative disposition towards the concentric circles design.

B. Decision Times as a Function of Route Consensus

It is possible that decision time effects might manifest themselves for certain trials only. Across subjects, for trials in which the data show the least clear preference for one route versus the other, it might be reasonable to expect that these would be the most difficult to judge. Hence, it can be predicted that these trials would have longer decision times than the rest. Taking a cut-off of 70% or fewer choices for the majority decision, twelve items were identified as *Low Consensus Trials*: Octolinear Block 1: Items 1, 4, 8, 11 and 12; Octolinear Block 2: Items 2 and 9; Concentric Circles Block 1: Items 8 and 10; Concentric Circles Block 2: Items 7, 9 and 11. Subject means were calculated for these and compared with means for the *High Consensus Trials* that they performed. These were trials with a cut-off of 90% or more choices for the majority decision. Seventeen items were identified as such: Octolinear Block 1: Items 5 and 7; Octolinear Block 2: Items 1, 3, 4, 8, 10 and 11; Concentric Circles Block 1: Items 2, 3, 5 and 7; Concentric Circles Block 2: Items 3, 4, 5, 6 and 8. Recalculated means are shown in Table I. It is important to note that, for the concentric circles map, with five items categorised as low consensus, and nine as high consensus (versus seven and eight respectively for the octolinear map), there is no indication that concentric circles trials are likely to yield more uncertainty amongst subjects than the octolinear equivalents.

A 2x2 (Consensus x Map Type) fully within-subjects ANOVA was used to compare trial categorisations. There was a significant main effect of Consensus (*Low*: mean = 11.2 secs, *SD 10.9*; *High*: mean = 8.3 secs, *SD 6.4*), $F(1, 23) = 4.51$, $MS_e = 44.9$, $p < .05$. Hence, trials in which there was not a clear consensus as to the fastest route were more difficult than trials with a clear consensus. There was also a small difference in favour of the octolinear map but this was not significant, $F(1, 23) = 1.31$, $MS_e = 38.9$, $p > .05$, nor was the interaction between the two factors, $F(1, 23) = 0.02$, $MS_e = 54.0$, $p > .05$.

Overall, comparing high versus low consensus trials, the validity of forced-journey choice methodology as a method of identifying usability issues has been supported by these findings. However, when using the concentric circles map, people's perceived and reported difficulties in performing this task have not been supported by the usability data.

C. Journey Preferences as a Function of Map Type

For most trials, there was agreement in preferred routes between maps but it is instructive to investigate items where there were strong disagreements to see whether these can be explained by the configurations of the maps. Several factors that influence route preference have been identified in past research, as reviewed by Wu *et al.* [10]. These include lengths of routes and simplicity and directness of line trajectories. For each trial, the chi-square statistic was used to identify the extent to which knowing the route preferences for one map predicted the other, yielding six items with a strong dissociation. These are shown in Appendix B. For each map, it was identified whether the preferred route had any advantage over the alternative for length, simplicity, directness, and number of stations along the way. Irrespective of map, preferred routes were related to the configurations of the designs. Only station counts were irrelevant, but for both maps. This suggests that the unconventional nature of the concentric circles map was not causing unconventional route identification strategies.

IV. Discussion

The findings in the current study replicated the low popularity of the concentric circles map previously identified by Roberts, Newton and Canals [9]. Hence, when subjects were asked to express a simple preference, a substantial majority selected the octolinear map and, when comparing aggregated statement rating scores, the mean score for the octolinear design was significantly greater. However, both these effects were smaller compared with previously and there are at least two possible explanations for this. First, the current study only asked people to *evaluate* pre-planned journeys. Previously, people were asked to *generate* preferred routes between designated station pairs. It is possible that aspects of the journey generation task itself compound people's discomfort when using the concentric circles design. Second, unlike previously, the two maps could not be viewed when performing the statement rating task, and this potentially diluted the strength of the effect.

The lack of popularity of the concentric circles map in the laboratory is puzzling, given the enthusiasm such designs often receive online, albeit effectively from a self-selected sample. It is plausible that the map's high level of coherence results in a powerful initial visual impact but, when actually attempting to make use of such maps, usability issues then arise that result in more adverse evaluations. However, even though the concentric circles map was particularly poorly rated for questions directly relevant to the journey choice task, and even though this was in line with concerns volunteered by subjects in previous research, when comparing concentric circles and octolinear maps for route choice decision times, the expected significant difference was not present. This failure cannot be explained by lack of validity of the measure: Irrespective of map, decision times were significantly raised for items which did not have clear majority preferences, presumably because optimum routes were particularly difficult to identify for these. If there are actual difficulties in using concentric circles maps, measurable via task performance data, then these findings suggest that difficulties are likely to occur before people get to the point of deciding between alternatives Hence, this causes the difference in journey *planning times* identified by Roberts, Newton and Canals [9].

This leads to the question of whether journey *generation* for concentric circles maps is intrinsically difficult, so that perceptual/cognitive problems with interpreting maps that are structured in this way lengthens the assembly process, or else routes can be generated just as easily as for octolinear maps but, because such routes lack *plausibility*, this prolongs the search for adequate routes that might be more efficient to execute. Hence, the journey planning process is extended, not because it is difficult, but because it fails to result in satisfactory outcomes. This is illustrated in Appendix B, for example looking at Block 2/Trial 11. Here, neither of the concentric circles map options look appealing. Put simply, journey planning for an octolinear map could be described as searching for the *best route*, whereas journey planning for a concentric circles map could be described as an attempt to find the *least bad route*. Under such circumstances, adverse ratings would be expected after experience with using a map, even if it were not measurably difficult to use.

V. Conclusion

Concentric circles maps present interesting issues from a *User Experience* perspective. On brief, initial inspection, for many people these make a positive impact but, as a result of experience, this potentially swings to a negative disposition, owing to the difficulty in generating satisfactory journeys. Even if a design is impeccable from a usability perspective, if people reject it then it has failed. Nonetheless, a case can still be made for concentric circles maps in circumstances where the design rules are well-matched to the actual structure of a city. Where there is a mismatch, results can often be contrived, with complex line trajectories and topographical distortion. For concentrically-structured cities such as Amsterdam and Köln [3] such a design will highlight rather than distort the lines of communication, enhancing rather than conflicting with users' mental models of a city.

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APPENDIX A: FULL LIST OF TRIALS

Block 1	Origin/Destination Station pairs	Route A	Route B	Octolinear % Route A	Concentric % Route A
Trial 1	Landsberger Allee/Brandenburger Tor	S42 ➔ Gesundbrunnen ➔ S1/2/25	S9/85/41 ➔ Frankfurther Allee ➔ U5	69	21
Trial 2	Rathaus Steglitz/Grunewald	U9 ➔ Zoologischer Garten ➔ S7	S1 ➔ Nickolassee ➔ S7	13	0
Trial 3	Treptower Park/Zitadelle	S42 ➔ Jungfernheide ➔ U7	S41 ➔ Neukölln ➔ U7	78	96
Trial 4	Hermanstraße/Friedrichstraße	U8 ➔ Jannowitzbrücke ➔ S5/7/75	S41/45/46 ➔ Tempelhof ➔ U6	47	71
Trial 5	Alt Reinickendorf/Wedding	S25 ➔ Gesundbrunnen ➔ S42	S25 ➔ Tegel ➔ U6	91	93
Trial 6	Ullsteinstraße/Schönhauser Allee	U6 ➔ Tempelhof ➔ S41/45/46	U6 ➔ Stadtmitte ➔ U2	25	89
Trial 7	Charlottenburg/Schönhauser Allee	U7 ➔ Jungfernheide ➔ S41	S5/7/75 ➔ Zoologischer Garten ➔ U2	94	100
Trial 8	Schönleinstraße/Thielplatz	U8 ➔ Kottbusser Tor ➔ U1 ➔ Nollendorfplatz ➔ U3	U8 ➔ Hermannplatz ➔ U7 ➔ Fehrbelliner Platz ➔ U3	50	39
Trial 9	Birkenstraße/Strausberger Platz	U9 ➔ Westhafen ➔ S41 ➔ Frankfurther Allee ➔ U5	U9 ➔ Zoologischer Garten ➔ U2 ➔ Alexanderplatz ➔ U5	81	89
Trial 10	Westphalweg/Parcelsus-Bad	U6 ➔ Friedrichstraße ➔ S25 ➔ Karl-Bonhoeffer Nervenklinik ➔ U8	U6 ➔ Leopoldplatz ➔ U9 ➔ Osloer Straße ➔ U8	22	64
Trial 11	Wuhletal/Alexanderplatz	U5	S5	69	29
Trial 12	Tegel/Friedrichstraße	U6	S25	63	71
Block 2					
Trial 1	Savignyplatz/Eberswalder Straße	S5/7/75 ➔ Alexanderplatz ➔ U2	S5/7/75 ➔ Zoologischer Garten ➔ U2	93	88
Trial 2	Fehrberlinnerplatz/Westhafen	U7 ➔ Jungfernheide ➔ S41	U7 ➔ Berliner Straße ➔ U9	36	88
Trial 3	Gesundbrunnen/Schönfliess	S2 ➔ Blanckenburg ➔ S9	S1 ➔ Hohen Neuendorf ➔ S9	93	91
Trial 4	Magdalenenstraße/Schönhauser Allee	U5 ➔ Alexanderplatz ➔ U2	U5 ➔ Frankfurther Allee ➔ S9/85/41	7	0
Trial 5	Porchimer Allee/Beusselstraße	U7 ➔ Neukölln ➔ S42	U7 ➔ Neukölln ➔ S41	75	97
Trial 6	Frankfurter Allee/Hoppengarten	U5 ➔ Lichtenberg ➔ S5	U5 ➔ Wuhletal ➔ S5	82	91
Trial 7	Guntzelstraße/Warschauer Straße	U9 ➔ Zoologischer Garten ➔ S5/7/75	U9 ➔ Kurfürstendamm ➔ U1	25	35
Trial 8	Otisstraße/Heidelburgerplatz	U6 ➔ Friedrichstraße ➔ S1 ➔ Schöneberg ➔ S41/46	U6 ➔ Leopoldplatz ➔ U9 ➔ Spichernstraße ➔ U3	0	0
Trial 9	Nauenerplatz/Südstern	U9 ➔ Osloer Straße ➔ U8 ➔ Alexanderplatz ➔ U7	U9 ➔ Leopoldplatz ➔ U6 ➔ Mehringdamm ➔ U7	36	34
Trial 10	Britz-Süd/Hackescher Markt	U7 ➔ Mehringdamm ➔ U6 ➔ Friedrichstraße ➔ S5/7/75	U7 ➔ Hermannplatz ➔ U8 ➔ Jannowitzbrücke ➔ S5/7/75	7	25
Trial 11	Pankow/Potsdamerplatz	S1/2/25	U2	100	69
Trial 12	Hermanstraße/Gesundbrunnen	U8	S42	71	25

TABLE II. The set of trials used in this study, showing the origin/destination stations pairs for each trial and the two routes that subjects were asked to evaluate. Also shown is the percentage of trials in which Route A was chosen for the two map types.

APPENDIX B: TRIALS WITH STRONGEST DISAGREEMENT BETWEEN MAPS

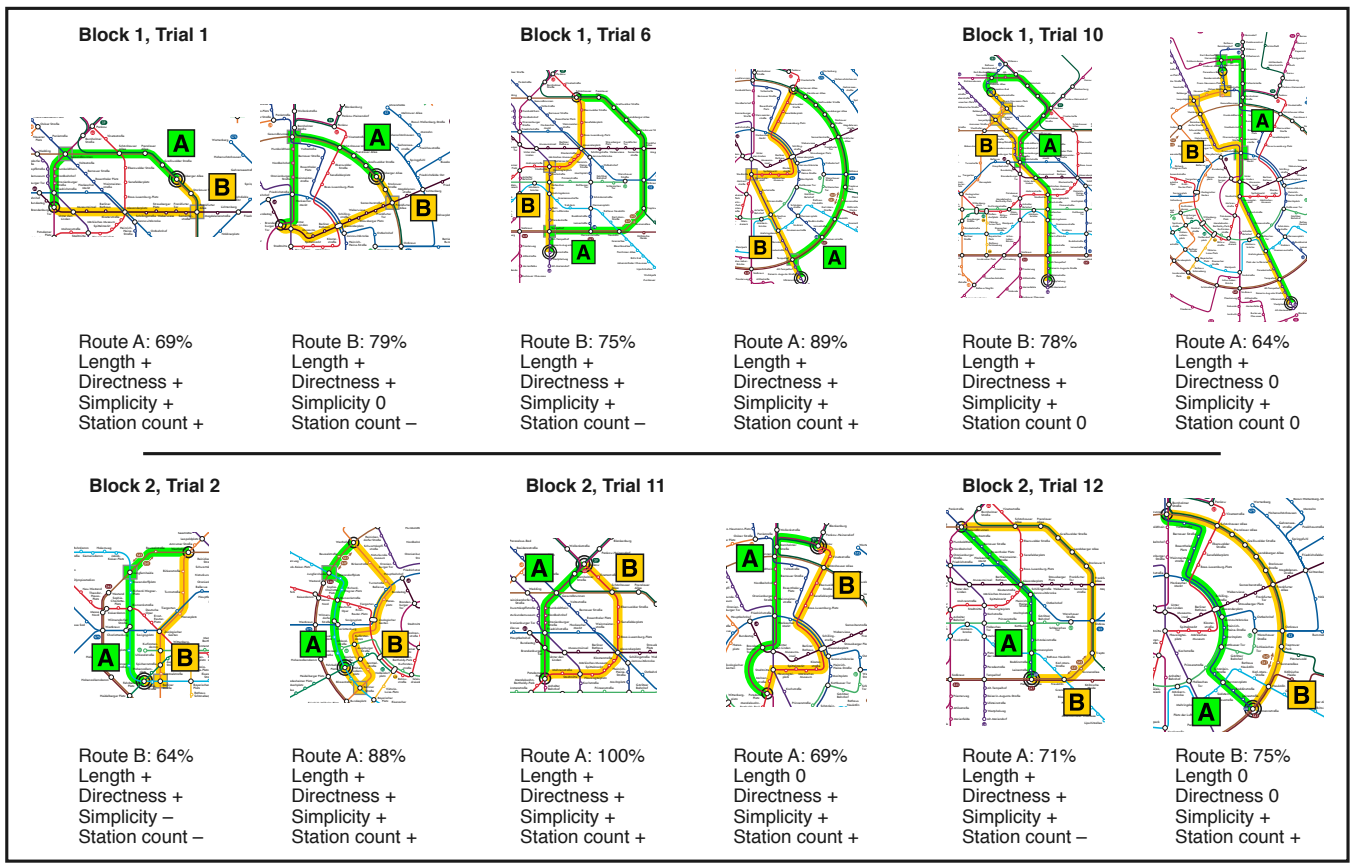

Fig. 3. The six trials showing the greatest disagreement in preferred routes between maps. For each trial, for each map, it has been identified whether the preferred route was the shorter length, the more direct, had the simpler trajectory, or the smaller number of intermediate stations. '+' indicates that the preferred route had the advantage for a criterion, '–' that it had a disadvantage, and '0' that the two route options were indistinguishable.