Do you believe in transit schematic maps? Design influences on route choice.

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***Abstract*—This study completes previous research developed by Morgagni and Grison [5] on the impact of design modifications of the Greater Paris (France) transit map. Over 2000 non-residents of the region were asked to plan routes using several modified versions of the map to further explore the links between map design and interpretations made by travelers of the transit network's characteristics. This paper reports on how new design modifications linked to transfer stations influenced route choices. Results complete previous findings, confirming the specific impact of design modifications on non-residents' route choices for transport lines and transfer stations. This paper strengthens previous findings and provides perspectives for potential applications.**

Keywords—transport, transit maps, diagram, cognitive bias

I. Introduction

Recent research has demonstrated that when planning routes using a transit schematic map, travelers are strongly impacted by the implemented design characteristics [1, 2, 4, 6, 7]. Beyond the readability, complexity and perceptual biases that could be linked to this kind of operational maps, a hypothesis is that travelers interpret map design not only as a diagrammatic representation of the network travel alternatives and characteristics but as some kind of accurate geographical representation [12]. Indeed, Raveau et al. [11] found that topological factors presented on a distorted transit map are more important than actual topology to travelers' route choice decisions. Since then, a few studies have tried to better understand the effect of map design modification on route choice. Moreover, a better understanding of the relationship between transit map design and travelers' route choice might be of interest for transport operators. Indeed, it might help them to develop tools for passenger flow management to improve global comfort of passenger and transport reliability, especially in saturated megacities' transit networks.

II. Literature Review

To contribute mitigating possible bottleneck congestions in transport networks, Guo, et al. [3] recently proposed a route choice study in the Washington subway network, between Metro Center and Pentagon stations. Two routes are possible here, one without transfer, and a second one with a transfer. The authors proposed to online participants who did not know the city to choose a route between these two stations under various graphical design conditions. All designs were conceived to make the direct route less advantageous compared to the original version. Results show that increasing the length ratio of the direct route by 20% leads up to 6% more participants to choose the route with one transfer compared to the initial version. This can go up to 10% if the length ratio increased to 40%.

With these results in mind, Morgagni & Grison [5] recruited frequent travellers in Greater Paris to participate in a similar experiment using the region's transit map. Frequent travellers were asked to plan routes on a printed full-size transit map of the regional network. In the southern part of the RER D line, to cross over the area between Juvisy and Corbeil-Essonnes stations, two routes are available to travellers. The first one, the western one, has no transfer and has 4 stops, and the second one, the eastern one, has a transfer and 3 stops. To alleviate congestion on the direct western route, the authors applied the same kind of design modifications as Guo et al. [3] such as increasing the length ratio between the two routes by 20% or 40%, resulting in an elongation of the western route. Results highlight that a 20% increase in the length led travellers to choose more the eastern option than with the original design. On the contrary, the preference towards the eastern route is lower in the 40% condition than in the 20% one. What can explain this kind of difference between the two studies?

In a 2008 study, Vertesi [12] asked Londoners to draw a sketch map of Greater London. Her results suggested that participants structure their graphical productions by relying heavily on the city's transit map, i.e., on a diagrammatic representation of underground metro lines and stations. More recently, Prabhakar, Grison, Lhuillier & Morgagni [9] observed that sketch map drawings of Greater Paris, Greater London and Greater Berlin region inhabitants were more correlated to the regional transit schematic maps than the regional geographical maps while including specific schematic distortions for each city (compression, expansion, rotation, etc.). This effect was not observed for trained foreign participants. The contrast and the possible interactions between previous knowledge and perceptual visual biases could thus bring to question of the operational validity of the results observed by Guo et al. [3], especially regarding their potential use by transport operators to optimize passenger flow in transit networks which classically have high percentages of frequent travellers.

Following the same line of questioning, Xu [10] realised a follow up study of Guo et al.'s work to explore the influence of the design modification following travellers' network knowledge. Participants were classified into three categories depending on their supposed familiarity with the transport network: Washington subway travellers (familiar), residents of the 8 counties covered by the Washington subway (a bit familiar), and residents of the 22 counties of the Washington DC area (unfamiliar). For the unfamiliar participants, the authors observed the same results as Guo et al. [3] for the conditions in which direct route sees its ratio increased by 20% or 40%. Indeed, in those condition participants tend to report they choice toward the undirect route. The same result is observed for the familiar participants when the direct route length is increased of 20% or when the undirect route is shortened. However, interestingly, for familiar participants, increasing of 40% the length of the direct route did not lead them to choose the undirect route. The 40% ratio condition appears as less effective than the 20% ratio conditions for the familiar participants.

While these studies seemed to confirm the influence of transit lines' form on route choice, they also reveal the importance of considering and assessing the effects of travellers' familiarity with the transport network.

III. RESEARCH QUESTION

Taking all together, these results suggest that design modifications of transit maps can have a real impact on how travellers interpret information about routes. Thus, if the route seems longer because the graphic line has been lengthened or complexified with turns, people will interpret this as a reality. This will consequently impact the choice of route. Nevertheless, it appears that effect of modification might not be the same depending on the traveller's familiarity with the network. One hypothesis to explain the differences is that familiar travellers will be sensitive to light and subtle change but not to major and more visible modification of the schema.

The research presented in this paper is conducted to validate this hypothesis, but also to validate the generalisation of those results.

Thus, a first objective of the present study is to confirm previous results showing that transit line form modifications impact differently the route choices of familiar (residents of the region) and unfamiliar (non-residents) participants. According to the literature, we hypothesize that non-residents will be more influenced than residents by more glaring modifications of transit maps, such as an increased 40% length ratio between routes.

A second objective is to test design modifications of another main element of transit maps, the transfer station symbol [2], on the decision to make transfers at a specific station. To do so, new designs were made to represent the previously preferred transfer station as increasingly more complex. We hypothesized that if participants interpret the graphical complexity of the transfer station as real, they will be more likely to make had a transfer in a visually simpler station.

The presented study draws on results observed in our previous one [5] on the southern part of the RER D in the Greater Paris transit map.

IV. METHODOLOGY

A. Participants

2482 participants took part in an online study (50,3% women; 49.7% men). They were aged from 18 to 65 years (M = 32.6, SD = 12). They did not reside in France and did not have any knowledge of the Greater Paris region transit network. They all were recruited using the online platform Prolific.

B. Material

Maps

As the experiment took place online on possibly small screens, maps presented to participants showed only parts of the Greater Paris transit map published by the Parisian transport authority, Île-de-France Mobilités. The maps focused on the specific tested line and could incorporate a possible new version of RER D line. They were simplified versions of the actual network map presenting only high-capacity transport modes (Bus Rapid Transport were excluded). Seven different parts of the network maps were selected for the test. Six of them were used as distractors and to prevent participants from guessing the purpose of the study.

Seven design variations of the southern RER D line map were produced to test our first hypothesis, following the same design rules used in our previous study [3, 4, 5, 8] as follows (see Figure 1):

- Control: a standard adaptation of the map according to actual Île-de-France Mobilités transit map design,
- Vertical: the eastern option is vertically oriented (vertical-horizontal effect),
- Directness: the eastern option appears more direct (directness effect),
- 20 % ratio: augmenting of 20% the length ratio between the two routes,
- 40 % ratio: augmenting of 40% the different of length between the two routes,
- Directness + 20 % ratio: combination of directness and 20% ratio conditions
- Acute angle + 20 % ratio: the western option is designed with an acute angle.

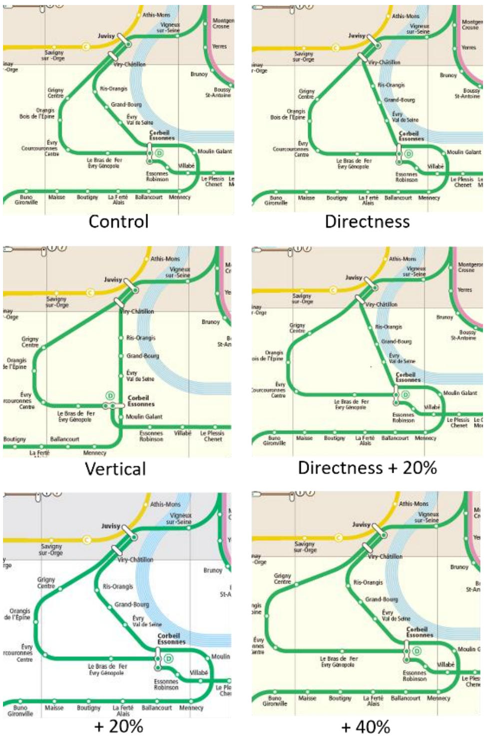

Fig. 1. The 6 modified versions of the map studied.

Two other variations were designed to test our second hypothesis and focus on the transfer node of Juvisy station, as follow (see Figure 2):

- Crossing: we inserted another line between the two RER D branches:
- Separation: we separated the two branches on the RER D line by adding a lateralized projection to the transfer point.

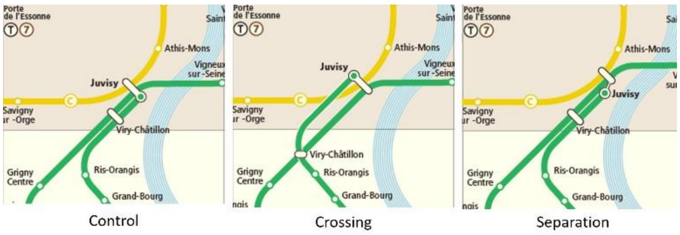

Fig. 2. The 3 versions of the transfer at Juvisy.

Routes

Six routes in the area of interest (south of RER D) and 11 control routes in the other areas of the map were identified. In the area between Juvisy and Corbeil-Essonnes, the eastern route is the shortest one (3 stations, 90 mm) and the western route is the longer one (4 stations, 145 mm). For 1 of the 6 routes of this area, the eastern route needed less transfers than the western. For 2 other routes, the western route needed less transfers than the eastern one. Finally, for 3 of the 6 routes, the number of transfers was equivalent. The following Table I summarizes all the 6 routes and their conditions.

TABLE I. ROUTES TESTED WITH THE INDICATION OF THE ONE WITH THE MINIUM NUMER OF TRANSFER.

Routes	**Less transfer**
Juvisy – Moulin Galant	EAST (0)
Corbeil-Essonnes – Créteil Pompadour	WEST (0)
Essonnes Robinson – Villeneuve Saint Georges	WEST (1)
Mennecy – Maison-Alfort Alfortville	EQUAL (1)
Le Vert de Maisons - Boigneville	EQUAL (1)
Vigneux-sur-Seine - Boutigny	EQUAL (1)

Post experiment questionnaire

To collect information about participants' socio-economical and transportation profiles, an online questionnaire composed of 8 items, about age, sex, profession, and general use of transportation was created.

C. Procedure

The experiment was hosted by the online platform Gorilla, and participants were recruited through the Prolific platform. When starting the experiment, participants were first provided with the general instructions.

Instructions explained that they will have to plan 19 routes (Origin – Destination pair, i.e., OD) using parts of Greater Paris (France) schematic public transit network map. For each trial (route to plan), the part of the map corresponding to the OD pair was displayed at the screen. At the bottom left of the screen, the OD pair was presented as follows: "you have to go from *origin* to *destination*". To select the route, the participant had to click on every station the route pass by (they will then be coloured with a yellow dot); and to indicate if necessary, using a drop-down menu (at the bottom right) the name of transfer station(s). When finished the participant was invited to click on the "next" button to proceed to the following trial (see Figure 3 for a completed trial where a yellow dot appeared each time a participant clicked on a station).

Trial order was randomized, and the OD pairs direction was counterbalanced across participants.

Once participants completed the 19 trials, they were invited to respond to the additional questionnaire. The experiment took on average 25 minutes.

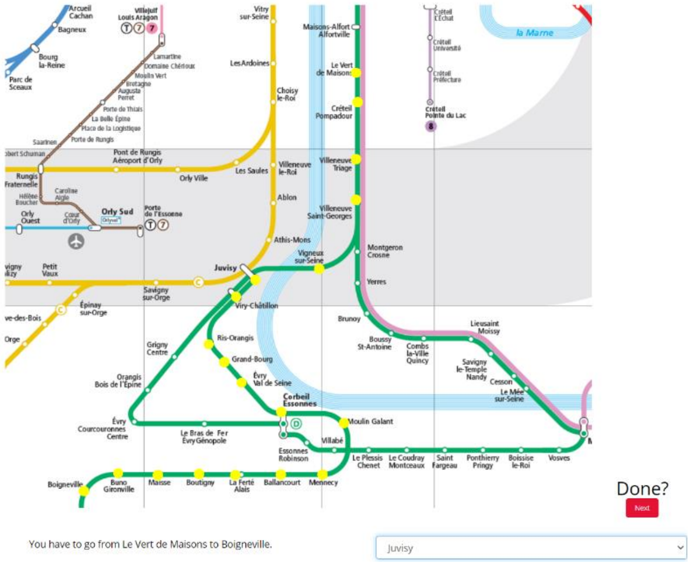

Fig. 3. Example of one completed trial.

D. Data analysis

Two hundred and one participants were excluded based on the poor quality of their responses (did not click on stations, for example). In this paper we overlook the distractive trials and focus on the analysis of the 7 trials in the RER D part that have been implemented to answer our hypotheses.

Coordinates of the dots placed on the schema by participants were collected to code which route option was selected by the participant, giving us a binary variable ("0" for the western option an "1" for the eastern one). The transfer station name was also recorded. We verified the veracity of the answer by combining the two variables, chosen path and corresponding transfer station, if the two did not correspond, the answer was classified as an error.

An average of 32.4% errors was recorded, which is high but can be explained by the difficulty to understand the transfers, and the way it was indicated on the map [4, 8]. Indeed, a considerable number of participants' responses indicated a plausible route but missed to indicate that there was a transfer. The percentage of errors was higher in the two conditions where the transfer station design was modified, with a mean 36.5% of errors.

For the following analysis, to focus on design effect on route choice, the choice was made to use percentage of route choice without considering the error rate [3, 11].

Pearson Chi2 tests were used to observe general and two-by-two variations between the control condition and modified alternatives in frequencies of route choice towards the eastern and western routes. The same analysis was used for transfer stations considering only the routes for which a transfer at Juvisy or Viry-Châtillon was needed.

V. RESULTS

A. Route choice depending on design rules

Table II presents the results in comparison with those obtained previously [5].

The general chi2 (route choice*map design) is significant ($X^2(6, 8354) = 34.4$; $p < .001$), indicating that the design influenced the proportion of route choice toward eastern or western option.

Looking into details with the two-by-two comparisons, we observe significant difference in distribution for all comparisons, except between the control and directness conditions. For all significant comparisons, design modifications led to a higher percentage of choice toward the eastern route, showing a positive effect of the design modification.

TABLE II. TWO-BY-TWO COMPARISON

Map	Eastern choice present study	Difference to control	Chi2	p value
Control	81.8%	NA	NA	NA
Vertical	85.4%	3.6%	4.5	< .05
Directness	85.1%	3.3%	3.6	= .06
20 % ratio	84.1%	2.3%	1.9	= .17
40 % ratio	87.5%	5.7%	11.7	< .001
Directness + 20%	89.5%	7.6%	22.3	< .001
Acute angle + 20%	88.0%	6.2%	13.8	< .001

B. Effect of design on transfer station choice

Table III presents the percentage of choice toward Juvisy or Viry-Châtillon stations.

The Chi2 test performed on the 3 maps showed a significant effect, $X^2(2, 1892) = 365.6$, $p < .001$. In the control condition, participants preferred to make their transfer at the Juvisy station.

TABLE III. PERCENTAGE OF CHOICE TOWARD JUVISY OR VIRY TRANSFER STATION DEPENDING ON THE MAP.

Map	Juvisy transfer	Viry transfer
Control	78.9%	21.1%
Crossing	36.4%	63.6%
Separation	83.2%	16.8%

According to our hypothesis, the modification applied to the map in the crossing condition led participants to change their transfer station toward Viry-Châtillon ($X^2(1, 1291) = 240.2$, $p < .001$. On the contrary, the modification applied to the separation map did not produce the expected effect. Indeed, significantly more participants chose the Juvisy station with the separation map than with the control map ($X^2(1,1306) = 3.9$, $p = .047$).

VI. DISCUSSION

The study presented in this paper reinforces previous results observed in literature on the impact of transit map design on route choice.

First, we observe the impacts of transit map modifications on route choice, for non-residents of the region. Non-residents seem more impacted by significative and important changes in the map than previously tested residents and travellers (see Table IV for comparisons), having previous knowledge of the transit network characteristics [5, 10]. Indeed, contrary to what has been observed in our first study on residents [5], a change of 40% of length on one route showed a significant effect on route choice (+0,6% for residents vs. +5,7% for non-residents of eastern choice). This result is consistent with Xu et al. [10] findings on the Washington network on non-residents' choices. Combinations of changing form (directness, verticality) and length are effective for non-residents too. Moreover, while the modification resulting of the combination of directness and lengthening of 20% did not produce any effect on residents (-0,7% for eastern route) [5] we do observe a change of route choice of +7.6% for the eastern route for non-residents. All these results confirm the hypothesis that choices of people that do not know well the network are more impacted by the design changes.

TABLE IV. COMPARISON OF RESULTS OF THE STUDIES CONDUCTED IN PARIS AND DC ON BITH RESIDENTS AND NON RESIDENTS

Map/ Difference to control	Paris non residents	Paris residents [5]	DC non-residents [3]	DC periphery residents [10]	DC center residents [10]	DC metro frequent user [10]
Control	(81.8%)	(83.8%)	(72.1%)	(71.6%)	(71.6%)	(72.4%)
Vertical	+ 3.6%	+ 1 %				
Directness	+ 3.3%	+ 2.1 %				
20 % ratio	+ 2.3%	+ 3.4 %	+ 3.1 %	+ 6.7 %	+ 2.4 %	+ 6 %
40 % ratio	+ 5.7%	- 1.4 %	+ 9.5 %	+ 12.1 %	+ 8.8 %	+ 3.9 %
Directness + 20%	+ 7.6%	- 0.7 %				
Acute angle + 20%	+ 6.2%	- 2.3 %	+ 5.7%	+ 6 %	+ 5.7%	+ 7.1 %

We also introduced new types of design modifications for transfer stations, with the goal estimate to what extent it will be possible to make a transfer in bigger already overcrowded stations less attractive. As for the previous modifications, the more subtle condition (separation of the big station into two parts, one per line) didn't have a significant effect. However, the more visible Crossing condition (pulling away the two lines and putting one across another line) had the overwhelming effect of reversing the preference for the bigger station, from almost 80% to 36.4% choice. Note that we do observe a high percentage of error in both conditions of transfer node modification. This might be explained by the participant's difficulty to understand complex transfer nodes as we observed that most errors made are due to a misinterpretation of them. In this context the proposed design change may have increased their misunderstanding. Additional work is thus needed to improve the understanding of transfer node and then validate the effect of their design on route planning.

To sum up, we reproduced previous results on transit map design effects, introduced new effective modifications, and confirmed the difference effect of design on resident and non-residents. Improving the understanding of the effect of these modifications should help transport operators use them more adequately and effectively to improve passenger flow and comfort.. Note that an additional step might be needed to fill the gap between this research on static transit maps and their dynamic application, which will be to study this question on new planning aid tools such as smartphone apps.

VII. ACKNOWLEDGEMENT

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