East or West ? Map Design and Passenger Path Decisions on Mass Transit Networks

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***Abstract*— Network maps are one of the most important sources of information for novice travellers and are often used to infer temporal estimation for critical path decisions by aligning train and subway lines, relative location of stations, connections, etc. However, these maps are usually distorted for readability and design purposes: transport lines are almost always streamlined, stations are equalized, city-centres are larger than reality and peripheries are compressed. Previous research has shown how such distortions can influence travellers' choices and adopting itineraries that display travel time may influence behaviour and support or contrast the effects of different planning tools designed by transport authorities or transport companies. Working on the south part of the RER D line in Paris suburbs, our objective is to understand how network maps can benefit from incorporating travellers' mental mapping of space and time independently of objective measures of spatial and durational properties (i.e., contrasting psychological vs. objectively quantifiable aspects of travels). A better comprehension of the impact that map design have on passenger's route choices could have a strong impact on mass transit transport operations. A relatively simple modification of network maps could be used to impact passenger route choice and improve overall system quality at minimal cost, instead of a much more complex and onerous infrastructural or transport offer change.**

Keywords—network maps, route choices, congestion, Paris transport network, complexity

I. INTRODUCTION

A. Litterature review

Growing complexity of "megacities" transit networks increase year by year; that being followed by a nonlinear augmentation of inter-availability of transport modes and an equivalent increasing of path choices between starting and arrival positions. In this context, printed and non-interactive network maps, are conceived with the objective of representing the whole network possibilities to travellers. As such, they constitute at the same time a powerful tool to grasp on a high level the schematic structure of metropolitan complexity, thus structuring and helping citizen to build a functional diagram of their urban environment, and a painful multilayer of navigational choices between modes [1].

In its continuous research for operation optimization, a transport company should be so interested in recent research on how distortions and design practices and choices could impact and influence travellers' path decision choices. Between others, we can recall Avelar's work on schematic transport maps design [2] and on the use of spatial knowledge of users to personalize city maps [3]; Barkowsky et al. [4] on the simplification of geographic map shape by discrete curve evolution as well as the seminal Garland and Haynesm's work on transit maps colour coding and street detail effect on journey's planning performances [5]. In a more specific manner, a recent corpus of research has been developed in experimental psychology applied to transport network. Transport network maps are here to be intended as simplified spatiotemporal diagrams i.e. media representing schematic relations between modes, stations, and transport hubs. As summarised by Roberts et al. [6], maps have to be simple, coherent, balanced, and harmonic and with at least a certain respect of topographic relations to be accepted and used by travellers, but their inevitable distortions will influence traveller's choices who will adopt itineraries by interpreting represented travel time and distances. Some research have in particular stressed how these tools influence behaviour and support or contrast the effects of other planning tools designed by transport authorities or transport companies [7] [8] [9] [10] [11] [12]. We decided, in this study, to take advantage of a planned service modification in RER D line to tackle these opportunities and analyse how network maps are used and could be conceived in the objective of improving service as additional crowd management tools. However, we decided not to build, as recently done in literature, an online based tool and decided not to simplify the decision process (by means of showing a limited part of the map, by helping participants finding start and finish point, or by highlighting the line or the transfer station on which they could click on). We decided here to explore path choices in a more ecological perspective to see if the results showed in those previous experimental works, which could be accused of being oversimplified version of reality, could be equally found in more ecological trends choices.

B. The studied problem

The RER D line is a north/south services from Creil (just North of Île-de-France region), to several destinations in the south such as Corbeil-Essonnes, Melun or Malesherbes. Consequently, the representation of the south of the line is complex as it displays various branches and start/end of sub-lines. The area of concern we choose to study is in the south of the line between Juvisy and Corbeil-Essonnes.

Indeed, in December 2018 a new service affected the line and particularly this area. These changes have been made in order to improve train regularity, highly impacted all over the line by frequent delays due to infrastructural constraints in the southern part of it. From Paris, going south, the line used to present a fork after the station Viry-Châtillon giving two direct routes options to users, a Western and an Eastern one, to go to Corbeil-Essonnes (see map at the top of FIGURE I). Considering the new service, users will still be able to go to Corbeil-Essonnes directly from Paris on the Western route, but will have to change train at Juvisy or

Viry-Châtillon to take the Eastern route (see at the bottom of FIGURE I).

The new service add complexity to the existing one as it creates two new independent RER D sub-lines, starting at Juvisy in direction of Malesherbes and Melun. Thus, the first aim of our study is to investigate how travellers understand the new services on the map depending on how it is designed.

Besides adding complexity to the area, the new service also breaks the equivalence of the two routes between Juvisy and Corbeil-Essonnes as the Eastern one involves one more transfer. One consequence that can be put forward is that most of users traveling between the two stations may prefer the direct Western route rather the Eastern one. This may create congestions in the Western route leading to potential traffic perturbations. Moreover, with the initial service we already observed that the Western route was more crowded than the Eastern one. Thus, a second objective of our study is to evaluate how the transportation map design can influence travellers' route choices.

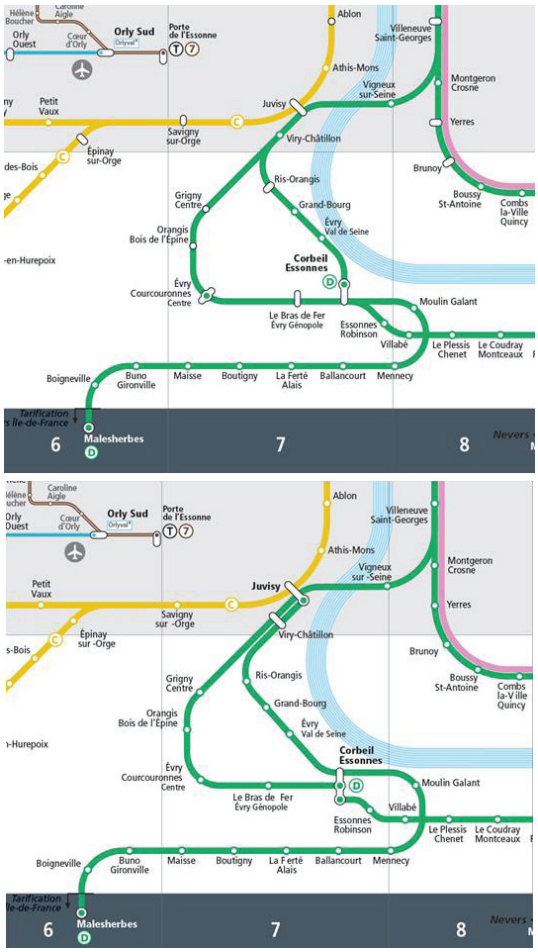

FIGURE I. AT THE TOP THE ORIGINAL MAP DESIGN AND AT THE BOTTOM THE PROPOSED NEW DESIGN

II. METHODOLOGY

A. *Participants*

256 participants took part in the study receiving a 15€ gift voucher for their participation. They were from 20 to 77 years old (M = 38.2; SD = 15.4), and regular users of the Île-de-France public transportation but not daily commuters of the SNCF South RER D line.

B. *Material*

Maps

We edited 8 variations of the current Île-de-France network map published by the Parisian transport authority, Île-de-France Mobilités, incorporating a possible version of the new service on RER D line.

All variations were simplified version of the actual network map presenting only high capacity transport modes (BRT were excluded) and were edited following the same design rules used in the current network map and according to previous results in the field. In their experiments, Guo et al. as well as Llyod et al. combined different modifications in one condition. Consequently, they were not able to identify what particular design modification affect the choice. Thus, we decided to create our design modifications by separating each source, and testing two combinations as follows (see also FIGURE II):

- Control: a standard adaptation of the map according to actual Île-de-France Mobilités network map design,
- Acute angle: the western option is designed with an acute angle (Guo et al. sharp turn effect),
- Vertical: the eastern option is vertically oriented (vertical-horizontal effect),
- Directness: the eastern option appear more direct (directness effect),
- 20 % ratio: augmenting of 20% the length ratio between the two routes (Guo et al. 20%),
- 40 % ratio: augmenting of 40% the different of length between the two routes (Guo et al. 40%),
- Directness + 20 % ratio: combination of directness and 20% ratio conditions,
- Directness + 20 % + more complex Juvisy station representation: as the precedent condition, and the transfer at Juvisy station seems more complex than usual.

All variations were printed in standard format (130cm x 100cm) as currently displayed in train and subway stations.

Routes

We identified 7 routes in our area of interest (south of RER D) and 7 control ones in other areas of the map. In our 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 2 of the 7 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 7 routes, the two routes were equivalent in their number of transfers. The following TABLE I summarizes all the routes and their correspondent condition.

Post experiment questionnaire

In order to collect information about participants' socio-economical, as well as transportation use profile, we created an on-line questionnaire composed of 8 questions, about age, sex, profession, and general use of transportation (which lines and frequency).

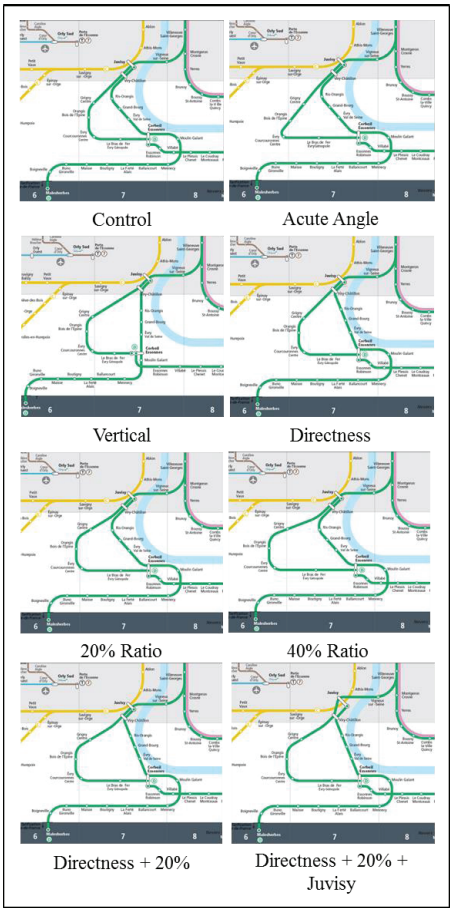

FIGURE II. THE EIGHT MAP DESIGNS TESTED

TABLE I. SUMMARY OF ROUTES, THE ASSOCIATED AREA AND CONDITION

Routes	**Area**	**Less transfers**
Juvisy - Corbeil-Essonnes	RER D	East
Juvisy - Moulin Galant	RER D	East
Gare de Lyon - Corbeil-Essonnes	RER D	West
Villeneuve Saint-Georges - Essonnes Robinsson	RER D	West
Maisons-Alfort Alfortville - Mennecy	RER D	Equal
Châtelet Les Halles - Boigneville	RER D	Equal
Vigneux-sur-Seine - Boutigny	RER D	Equal
Saint Denis - Creil	RER D, Line H	Control
Chaponval - Epinay Villetaneuse	Line H	Control
Bécon les Bruyères - Nanterre Préfecture	Line L, RER A	Control
Asnières-sur-Seine - Achères ville	Line L	Control
Argenteil - Saint-Ouen l'Aumône	Line J, Line H	Control
Enghein-les-Bains - L'Isle-Adam Parmain	Line H	Control
Ermont Eaubonne - Persan Beaumont	Line H	Control

C. Procedure

In order to achieve a better ecological dimension in network maps practices we decided to test participants individually facing in a quiet room a vertical and real size version of the map displayed at the same height as in stations. They were first asked to read and sign a letter of information about the experiment and the consent form. Then, we invited them to stand up in front of the printed transportation map and they were presented the instructions.

We explained that they will have to plan routes using the transportation map between designated origin and destination stations. For each route, they will have first to search on the map origin as well as destination stations locations, and encircle them directly on the map with a felt pen (the map was protected by a Plexiglas). Then, participants had to search and draw on the map the route they will have choose to use if they had to do this travel. If the route they choose required a transfer or more, they had to indicate the transfer station with a cross on the station. In order to recreate the limited information they could have in real contexts of use (without taking transit application in consideration), participants were informed that all trains were omnibus (stop at all stations), and have equivalent frequency. Once participants considered they completed the task, they told the experimenter who took a photograph of the drawn route, then erased it from the map. Once this procedure was completed for one route and clearly understood, the experimenter gave the participant the next route to plan.

Each participant completed 10 routes, 3 routes in the area of interest (south of RER D) and 7 control ones. The choice of the 3 test routes amongst the seven was randomized, and the origin-destination order counterbalanced. The order of presentation of the 10 routes was also randomized.

Once participants had completed all 10 route planning tasks, we ask them to fill in the on-line questionnaire. We ended the experiment by providing highlights on the purpose of the study and by giving the gift voucher. The experiment took 30 minutes on average.

D. Data analysis

For each route we coded if the participant choose the eastern or western option, or if he/she made an error. A trial was coded as an error if the participant does not indicate a transfer for a route needing one (omitted to cross the station), or if he/she choose an invalid route (the participant chose another route than the two of interest).

E. Hypotheses

In literature on route planning, it has been extensively observed that people tend to choose the shortest route [7, 13, 14]. In our case, the shortest route on the schematic map is the eastern one (90 mm vs 145 mm, in the control condition). It is also the one with the fewest number of stops (3 vs. 4) between Juvisy and Corbeil-Essonnes. Consequently, our first hypothesis is that participants should choose more extensively the eastern route rather than the western one.

In accordance with previous results observed in literature [12], and because all our modifications of the schematic map were proposed to lengthen the western route or to give to participants the feeling that the western route will take

more time, we should observe that participants in the modified designs should choose even more the eastern route than in the control condition. We also could expect an additional effect of design modifications for the combined designs modifications. Thus, participants should choose more the eastern option in the Directness + 20% and the Directness + 20% + Juvisy conditions rather than in the 20% ratio condition. Concerning network knowledge, and in particular frequent passenger awareness and sensibility of map changes [15], we should expect +40% ratio as being possibly more difficult to accept for our participants who were systematically familiar with Île-de-France Network. More subtle design interventions could so be expected as being the most profitable for impacting behaviours. Finally, a more complex, albeit symbolic, representation of Juvisy station, could lead participants to prefer choosing Viry-Châtillon as preferred transfer station.

III. RESULTS

A summary of percentages of eastern choices, western choices and errors for each schematic map design is presented in TABLE II.

As we can observe in TABLE II, in average the percentage of errors is around 20%, except for the Directeness + 20 % + Juvisy condition where it exceed 40%.

As hypothesized, for all our condition we observe that participants chose more the eastern route rather than the western one.

Concerning the percentage of choice of the eastern route we observe that the Vertical, Directness, Ratio 20% and Ratio 40% conditions lead to a higher percentage of eastern routes than the control condition. However, the 20% ratio leads to a higher percentage of choices towards the eastern route compared to the 40% ratio, confirming our prediction.

TABLE II. PERCENTAGE CHOICE DEPENDING ON SCHEMATIC MAP MODIFICATION

	East choice	West choice	Errors
Control	66,0	12,8	21,3
Vertical	69,8	12,5	17,7
Acute angle	59,4	13,5	27,1
Directness	69,8	11,5	18,8
20%	70,8	10,4	18,8
40%	67,7	12,5	19,8
Directness + 20%	61,5	12,5	26,0
Directness + 20 % + Juvisy	47,9	11,5	40,6

In order to test the significance of changes in the percentage distribution in the three categories depending on the map design we ran an X_2 test. The test almost reach the significance, $X_2(14) = 23.318$, $p = 0.055$.

To better investigate the variations between maps, we conducted X_2 for each comparison between two conditions. The test reach the significance for the comparison between the Directness + 20 % + Juvisy and the 20 % conditions ($X_2(2) = 12.03$, $p = 0.002$), the Directness + 20 % + Juvisy and the 40 % conditions ($X_2(2) = 10.19$, $p = 0.006$), the Directness + 20 % + Juvisy and the Vertical conditions ($X_2(2) = 12.59$, $p = 0.002$),), the Directness + 20 % + Juvisy and the Control conditions ($X_2(2) = 8.51$, $p = 0.014$),), and between the Directness + 20 % + Juvisy and the Directness conditions ($X_2(2) = 11.64$, $p = 0.003$). These results indicate that the repartition of participants' responses in the Directness + 20 % + Juvisy is atypical compare to other conditions. Indeed, we observe that they make more errors and less eastern route choice than in other conditions.

We also analyse the few situations where participants could choose to make a transfer at Juvisy or Viry-Châtillon stations. We observe that transfers are mostly made at Juvisy for all schematic map conditions (between 75% and 100% of transfers), expect for the condition where Juvisy station appears to be more complicate. Indeed, in this condition 55 % of transfers were made at Juvisy and 45% at Viry-Châtillon.

No significant differences were found based on socio-economical and transportation user profile data collected.

IV. DISCUSSION

The mains aims of our study were to evaluate how map design can influence the understanding of high density transportation network, and route choices of potential user, in a really ecological paradigm.

A first finding is the replication of length effect on route choice [15]. It has previously been observed in literature that augmenting the length ratio between the two routes of 40% is more effective than 20% [8] to impact travellers' route choice. However this result has to be modulated by the travellers' network knowledge [15]. Our results are in line with this last finding, showing that travellers familiar to the network were less sensitive to a 40% ratio modification than they were to a 20% ratio modification. It appears that when participants have certain knowledge of the network their awareness of large modifications could leave them in contradiction between map design and topographical knowledge. This finding refute the basic assumption that the more the route appears disadvantageous the less it will be taken, and highlight various questioning about design choices, such as for which kind of travellers we design maps?

A second relevant finding of our study concerns the impact of design complexification on travellers' route choice. Indeed, the two schematic maps design combining two or three modifications (Directness + 20 % ratio and Directness + 20 % ratio + Juvisy modification) unexpectedly lead to minor eastern route choice than non-compositional design modification. Moreover, we observe that a more complex representation of Juvisy station design leads to a higher percentage of errors, as well as to a report of the transfer station towards Viry-Châtillon represented as a simpler station. These results support previous findings on comprehension of schematic map complexity [12], and deepen them as they show that schematic map complexity is interpreted as a complexity in the real network, leading to changes in behaviour.

Finally, we would like to highlight that our study, conducted in a far more ecological context than previous research provides the same patterns in terms of results that the

previous on line studies presenting simplified paradigms. Hence, even if our results do not always reach significance due to the fewer number of data collected compared to online studies, they allow to validate previous results and both methodologies to explore questions in the field.
Following those first results, we've started working on new studies tackling spatiotemporal representations (including transport frequency) and travellers' degrees of network and mass transit knowledge in order to understand which elements are mainly depending on diagrammatical representation of transport systems and which ones are mainly depending on conventional and design choices.

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