Mental and schematic maps: back and forth between basic and applied research.

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***Abstract*—This paper aims to present the main results obtained in one of the three axes of the Wildtimes project (2018-2023), which situated itself at the border between basic research on psychological and neural mechanisms underlying the perception of time and space and more applied questions on how current knowledge on spatial and temporal cognition can contribute to the resolution of operational problems in dense transport networks. It will discuss : i) the advances made in terms of knowledge relating to mental representations of space and time, ii) the effects that transport networks have on these and the impacts that schematic maps and traveler's activity mobilizing them can have on their choices and on dynamic crowding regulation operations and, iii) the close interweaving of basic and applied questions and the way in which the results of work carried out in these respective fields can feed each other.**

Keywords*—*space-time relation, mental representations, basic research, applied research, schema effect, Wildtimes.

I. INTRODUCTION: THE WILDTIMES PROJECT INITIATIVE

The WildTimes project has been conceived with the objective to pave the way towards understanding time and space perception during real-world navigation and explore how the human brain may map time during complex travels. Indeed, the fast development of transportation modes over the last century has increased our collective reliance on them. One of the consequences of their most recent evolutions is that spatial distances between places have become less relevant than the time it takes to travel them (Tobler, 1961). Although in real-life situations the time it takes to reach a destination is crucial to decide which transportation mode to adopt (e.g. Chen & Mahmassani, 2004), very little is known regarding temporal as well as spatial cognition in this context.

To this end, the WildTimes project (2018-2023) involved three research teams : the French national railway company (SNCF) Experience, behavior & cognition team, the CEA-NeuroSpin specialized in temporal cognition and neurosciences, and the Gustave Eiffel University-LaPEA specialized in spatial cognition and virtual reality. They jointly developed basic research in order to better understand psychological and neural mechanisms underlying time and space perception, and more applied research focusing on how current knowledge on time and space cognition could help to solve some operational transit shortcomings and problems.

The project objectives were as follows:

- Assessing duration perception in real-time transportation contexts,
- Assessing the relationship between the perception of time and space in real-time transportation contexts,
- Trying to elaborate on the nature of the relationship between the representation of space and time as informed by experience,
- Understanding how network maps can benefit from incorporating travellers' mental mapping of space and time,
- Exploring the way in which an individual's space-time perception can both impact, and be used in, transit and navigation tools like mobility applications.

Focusing here on research questions only dealing with space-time cognitive interactions and mental and cartographic representations studied within the Wildtimes project, we will illustrate how a highly applied issue for a transport operator or a transport authority can interact with and benefit from more basic research, and how, in turn, it gives rise to new questions and fields for academic research. Through the description of a few studies, we will present the two lines of research, one situated in the basic research field and the other on the applied field, which have been simultaneously developed in the project. We will then describe how starting from applied research results we have been able to question more basic findings. We will conclude on the scientific outcomes of this approach, and on a more macroscopic reflection on how mixing basic and applied work might open unexpected opportunities not only from basic to applied research but also from applied question to basic ones.

II. BASIC RESEARCH: SPACE & TIME RELATION IN MAPS

A. *From spatial to temporal cognition in route planning*

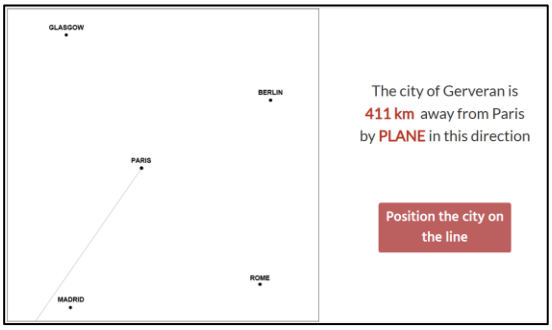
The concept of cognitive map is rooted in a famous seminal work of Tolman (1948), who conducted experiments with rats navigating mazes in search of food. In view of their behavior, he proposed that spatial cognition involves complex cognitive processes which support forming, storing, and retrieving cognitive spatial representations. He argued that the construction of *"something like a field map of the environment"* plays a crucial role in spatial learning and navigation. Since then, this concept has remained a prominent metaphor for understanding cognitive spatial representations and has also been extended to temporal representations, for instance through concepts such as temporal event maps (Deuker, Bellmund & Navarro, 2016).

The cognitive spatial representations were presupposed to be analogous to their external counterparts and have been long supposed to be isomorphic representations of the external world, preserving properties such as distances, angles, and other spatial metrics within a coordinate system. Because a large body of research has shown that internal spatial representations are often incomplete, distorted and simplified (see e.g. Tversky, 2003), they are now considered as functional, rather than exact, representations of the physical world.

The functional role of spatial representations is to compile, from more or less empirical experiences, a set of topological knowledge that can be used to solve everyday spatial tasks (e.g. Warren et al., 2017). Space can be experienced by aimless exploration, but is generally discovered as part of a specific human activity, to get somewhere. Thus, among activities that rely on spatial representations, route planning is carried out to get to a particular place, and has been studied by cognitive psychologists for years. It is usually considered a complex cognitive activity comprising three phases (e.g. Denis, 1997). In the first phase, individuals must identify departure and destination points to examine their spatial relationship. In the second phase, they must identify and compare various route alternatives enabling them to reach their destination. In the third one, known as route selection, individuals engage in decision-making and select one route to execute from several alternatives (Abelson & Levi, 1985). Depending on the scale of the considered environment (Montello, 1993), route planning can be based on spatial representations derived from direct visual exploration (*vista* spaces) or navigation (*environmental* spaces). However, for much larger scale spaces such as the geographical space, integrating spatial information from navigation is no longer possible and individuals mostly use symbolic representations such as maps, which allow apprehending the whole space to be traveled. In addition to maps, mobility applications are also frequently used to skip the initial research phases, without however being able to provide a complete overview of the concerned space. They usually suggest alternative routes with information about their duration (and possibly other information), which can be useful in conjunction with maps, in which it is difficult to capture both spatial and temporal information (Tversky, 2000). In a series of studies, we considered these two means of providing individuals information about space and time and examined how they were processed.

B. *Distances, time and speed in mental maps*

Some cartographic work has attempted to faithfully represent time on maps; it has been shown however that decreasing travel times necessarily narrows the distances represented (Spiekermann & Wegener, 1994) and that speed is a major factor in spatio-temporal distortion (L'Hostis, 2013). While some work has explored the effect of travel speed on spatial and temporal perception of environmental space (Riemer et al., 2018), very little is known about its impact on mental representations of geographic space. Thus, in the first study developed in the project and presented here (Lhuillier & Gyselinck, in prep.), we investigated how speed information might shape the metric properties of spatial geographic mental representations, and how temporal and spatial information were jointly integrated into it. To do this, we asked participants of an online study to estimate the position of cities on a map, based on information either about travel time or distance (reference dimension). Time and distance information could be provided for three modes of transport corresponding to three different implicit speed ranges: slow train, fast train and airplane (reference speed). The actual position of the point to be positioned was evenly distributed between 350 and 1000 km away from a given reference point (Paris), and was used as a third independent variable in the analysis because of the expected scalar properties widely described in the literature related to the estimation of magnitudes (Petzschner & Glasauer, 2015). Durations provided in the instructions for the time reference dimension condition were computed on the basis of mean transportation modes speed for journeys in France (slow train = 90 kph, fast train = 250 kph, plane = 800 kph). The absolute distances of the coordinates estimated by the participants in relation to a reference point were collected. We computed z-scores for the distance errors between the actual position and the estimated position on the response axis to analyze distance compression or expansion index. To better understand how semantic information about speed contained in representations of transportation modes could influence spatial and temporal estimations, we provided clear instructions to participants. The responses had to be given considering only straight-line journeys, with no stops or slowdowns due to traffic or network logistics, with no "natural" constraints (relief, bodies of water, etc.), and assuming that the journey was made at a constant speed (with no acceleration or deceleration). Angular positioning errors were nullified by the presence of a straight line to which participants were instructed to respond (see Figure 1). Finally, the cities to be positioned were called by fictitious names randomly generated so that no participants' prior geographical knowledge could influence their answers. We expected position estimations to be biased by implicit speed information conveyed by the transportation mode. We also hypothesized that this relation would depend on prior knowledge and familiarity with transportation modes relative to each individual. Consequently, a short questionnaire was administered at the end of the study to record the frequency of use, as well as the subjective estimate of average speed for each transportation mode.



The city of Gerveran is **411 km** away from Paris by **PLANE** in this direction

Fig. 1. Example of a test trial for the city positioning task on map, with space as a reference dimension and plane as a reference speed (Lhuillier & Gyselinck, in prep.).

Results show that the fastest modes of transport (fast train and airplane) lead to a metric compression when the reference dimension is time (compared to the slow train), but have no effect on spatial positioning when the reference dimension is space (which was to be expected, as 50 kilometers in slow train is still 50 kilometers in fast train). This suggests that spatial positioning is influenced by both speed and travel time information, so that traveling at high speed appears to lead to a shrinking of mental representations of geographical space, in the same way that geographical space is shrunk to graphically represent high-speed transport networks in plastic maps (Forer, 1978; Spiekermann & Wegener, 1994). However, the mechanisms underlying this effect are not clearly identified: at a very basic level, it could simply be that the temporal magnitudes given in the instruction influence the perception of spatial magnitudes, so that - even at different speeds - 30 minutes are simply considered to be 'spatially shorter' than 45 minutes. But this interpretation, based on the supposed existence of a common system dedicated to estimating spatial and temporal magnitudes (Walsh, 2003), does not seem to coincide with the fact that this effect is not linear in our data: only fast train and plane seem to lead to significant compression, in similar proportions, as if representational categorization ("fast modes ≠ slow modes") influenced position estimations but not really magnitude estimation (see Figure 2). In addition, responses to the questionnaire showed that the average subjective speed estimated for the slow train had a significant influence on the position estimates: the slower the train, the more compressed the estimations. This expected pattern does not manifest for fast modes, which lead to compressed distances whatever their estimated subjective speed. Ultimately, this exploratory study highlights the complexity of the mechanisms involved in spatio-temporal integration in the context of mental representations on a geographical scale.

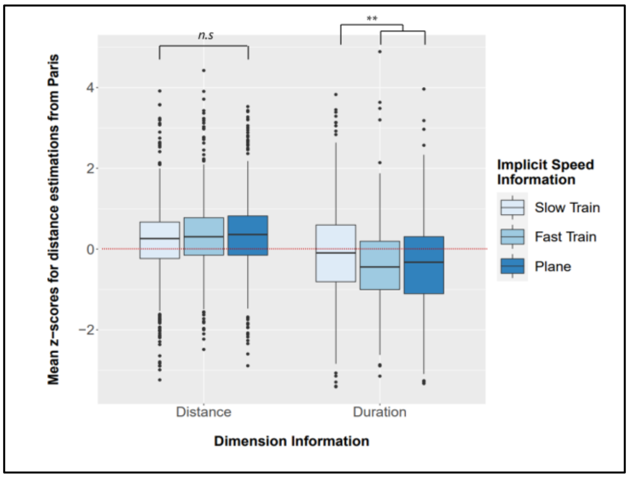


Fig. 2. Distance errors for the city positioning task on map, by reference dimension information (travel distance or duration) and implicit speed information (slow train, fast train or plane). While implicit speed information had no effect on distance errors when spatial information was provided, both fast train and plane estimations were significantly compressed compared to slow train when temporal information was provided (*p.* <.01).

C. *Space and time in cartographic representations.*

In an attempt to further investigate the close relations between mental and graphical representations of the geographical scale described above, a second study has been conducted, focusing more specifically on cartographic representations. Various graphical cartographic representations of geographical space-time were considered in order to capture whether non expert individuals can interpret a specific representation that exhibits both pieces of information. A space-time representation is complex, as it involves taking into account properties that introduce specific spatial or temporal deformations (L'Hostis & Abdou, 2021), including spatial inversion (Bunge, 1962). Spatial inversion occurs as soon as an optimal path begins in the opposite direction to the final destination of the journey; this configuration is caused by the coexistence of slow and fast networks. Spatial inversion poses problems for cartography, particularly for conventional maps and their users. The experiment carried out (Lhuillier, L'Hostis & Gyselinck, subm.) tested three formats for cartographic representation of distances or travel times for human users (see Figure 3). Participants were presented one type of map in an online experiment: a conventional topographic map (faithfully representing travel distances), a unipolar anamorphic map (faithfully representing travel times) and a shriveled map (offering a three-dimensional solution for representing space-time; L'Hostis, 2013). They were then asked to estimate as quickly as possible the shortest route (in terms of travel time or distance) between two alternatives. The transport networks represented featured low-speed (50 km/h) and high-speed (100 km/h) roads symbolized by different colors. In this way, the optimal response could include or exclude spatial inversion. The results show that distances are more easily and correctly estimated on the topographic map, but that travel times are very poorly understood. This result is reversed for unipolar anamorphic maps. The shrivelled map, on the other hand, achieves median results in each task, but significantly improves the correct detection of spatial inversions compared to the conventional topographic one. However, this material also appears much more difficult to interpret, as shown by the significant increase in response times compared to the other two formats. In short, such results could have interesting implications for the design of innovative cartographic formats, particularly for users performing route planing in complex multimodal networks, and are a good example of a bridge between basic and applied research.

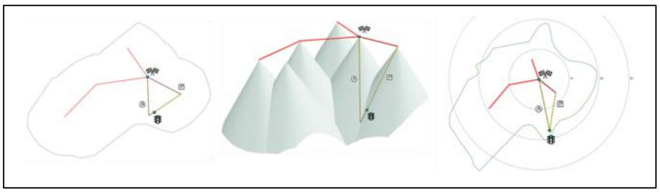


Fig. 3. Cartographic material used in Lhuillier, L'Hostis & Gyselinck (subm.). From left to right : topographical map, shrivelled map and unipolar anamorphosic map.

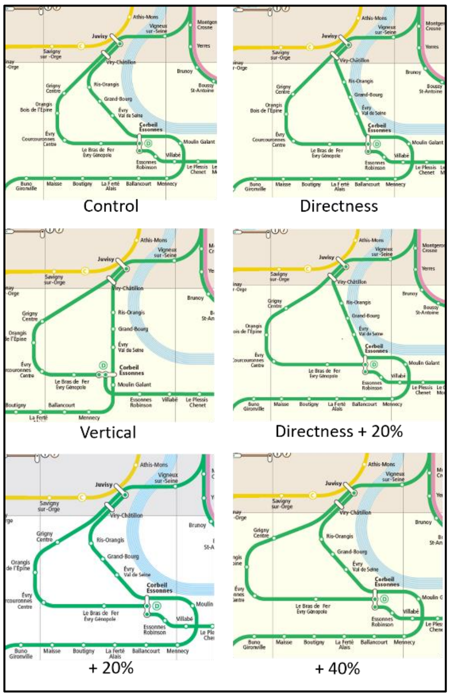
III. APPLIED RESEARCH: HOW TO USE NETWORK SCHEMATIC MAPS TO IMPACT ROUTE CHOICE IN MASS TRANSIT

On a more applied side, SNCF was interested in better understanding the time-space relationship underlying some practical problems encountered every day by travelers, especially in mass transit areas. Indeed, while the transportation network in large cities is already well developed, the demand continues to increase, resulting in more and more passengers on it, especially during rush hours, while infrastructure cannot grow as easily. Previous research by Guo, Zhao, Xhong, Mishra, and Wyman (2017) has shown that when planning a route using a schematic transportation map, travelers might over-interpret the information displayed when choosing their route (see also Xu, 2017). They demonstrated, through a route selection task, that modifications to a schematic map (such as lengthened lines) can impact the route chosen by participants. One of the first questions addressed in the Wildtimes project was about the possibility of mitigating passenger congestion in the Paris (France) network by limiting bottlenecks on specific lines or areas by influencing passengers' route choices through the adaptation of schematic transport maps.

A. Network schematic map design impact on route-planning.

Thus, building on the work initiated by Guo et al. (2017) Morgagni and Grison (2019) designed a study based on a real case. A route choice paradigm was developed, focusing on a problem specific to a section of the network, to test if schematic map design changes could redirect passengers from a direct route to a route involving a transfer. Two hundred and fifty-six participants, who were users of the transportation system but not familiar with the specific section studied, were presented with numerous route choices on the real transportation schematic map and had to select the best option for themselves. Design modifications were applied to the map to change the shape of the routes to make the direct alternative longer compared to the one involving one connection (*see Figure 4*). Results showed that it was possible to modify participants' choices by up to 3.4% toward the route with one transfer compared to the actual schematic map. One interpretation of this result might be that participants interpreted the length of lines on the schematic map as reflecting travel time. With the objective of limiting this travel time, some of them chose to make a transfer.

A second study was developed to replicate the result on a larger sample while validating the possibility to carry this kind of study online. 2,482 non-residents of the region participants, were confronted with the same choice (Grison, Leprévost, Morgagni, 2022). In comparison to the previous study, one substantial change was made as it was impossible to present the entire transportation schematic map on the computer screen at once. Thus, only the part of the schematic map displaying the line concerned by the route choice task was presented at each trial. Finally, two types of modifications to the transportation schematic map regarding the design of transfers between lines were integrated. In this case, the modification of lines impacted route choice by up to 7.6%. However, the most impactful modifications were those concerning transfers; where up to 75% of participants changed their route selection to avoid transfers that seemed more complex to them. These results confirm that people who didn't have a travel experience of the transportation network can be more influenced by schematic map modifications when making choices than those having at least a partial knowledge of it. They also show that modifications of transfers might have a greater impact on route choice than adjustments of length lines, and they question the relative importance of such factors and their representation in route planning (a doctoral work has been since then developed on that question). Altogether, these studies demonstrate that the way information is presented on transportation schematic maps is interpreted by travelers as real information; in this way, the length or complexity of schematic maps is interpreted as real. This underscores the impact of such schematic representations on the mental representations of routes from which travelers plan their journeys.



Control
Directness
Vertical
Directness + 20%
+ 20%
+ 40%

Fig. 4. The 6 modified versions of the map studied on Morgagni and Grison (2019) and Grison, Leprévost, Morgagni (2022).

From these results, two questions have been put forward: (1) To what extent can the schematic maps influence traveler's route choice and the representation of city residents? (2) What are the implications of applying these kind of changes to more dynamic route planning aid tools, such as those available today on smartphones applications? While the first question pertains to personal and collective representations and opens the way to more basic research that will be addressed in section IV, the following sections will address the question of the integration of schematic and cartographic information in more dynamic route planning aid tools.

B. *Route planning based on dynamics aid tools.*

A second series of studies was developed to test whether modifications in the information provided to passengers would still impact their route choice when applied to more dynamic aids such as route planning application. Route planning aids displayed on smartphones apps are structurally different from schematic transportation maps in various ways, especially because they cannot display the entire network diagrammatic structure. They so directly propose alternatives to passengers and provide additional information such as estimated travel time or crowding levels. The question was then to understand whether the schematic map could have a role to play in passenger decision-making processes despite these changes. Thus, in their study, Prabhakar, Grison, and Morgagni (2024) proposed a route choice paradigm to 582 non-users of the Paris network participants. The experiment was displayed on-line directly on smartphone participants who were given a mock-up of a mobility application in which various route choices were proposed for a same itinerary. The presentation of route alternatives followed either a symbolic format, such as that provided by Citymapper, a time-based format, such as the one proposed by Transit, or a more classical schematic representation (*see Figure 5*). Results showed that it was possible to change participants' route choices toward a longer route by up to 17% when it was represented as shorter on the schematic transportation map, even when the real time was indicated compared to the symbolic condition. This first experiment reveals the interaction between spatial and temporal information given to travelers as well as potential leverage that schematic representation of the network could exert, even in limited formats such as those proposed by smartphone apps.

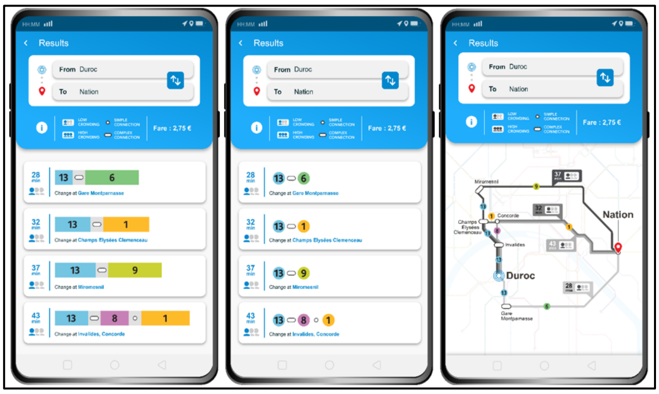


Fig. 5. The 3 variations of the mobility assistant: temporal, symbolic and spatial.

In a second study, the question of how spatial and temporal representations of routes influence travellers' choices was explored. More specifically, we investigated whether the cartographic format could induce perceptual biases, leading travelers to choose longer routes, and whether this effect could vary depending on whether the cartographic representation was based on temporal or spatial information.

To do so, as in the previous study, 693 participants were presented with fictitious route choices in an online paradigm displayed on a smartphone. They were assigned to one of six possible conditions developed as follows: cartographic based on time, cartographic based on space (geographic), cartographic not based on time or space (schematic), non-cartographic based on time, non-cartographic based on space, non-cartographic not based on time or space (see figure 6).

The results show that participants in the cartographic format conditions were more likely to take a longer route, on average by 12%. Spatial or temporal-based formats, however, appeared to play the same role as the schematic one in influencing participants' choices. It seems that, regardless of how the cartographic representation is constructed, if it contains the same amount of information, it will produce the same effect. This could be explained either by the fact that time or space displayed on the cartographic information are interpreted similarly in the context of transportation route choice, or that such formats induce cognitive load, prompting participants to base their decisions on much more basic, low-level processes.

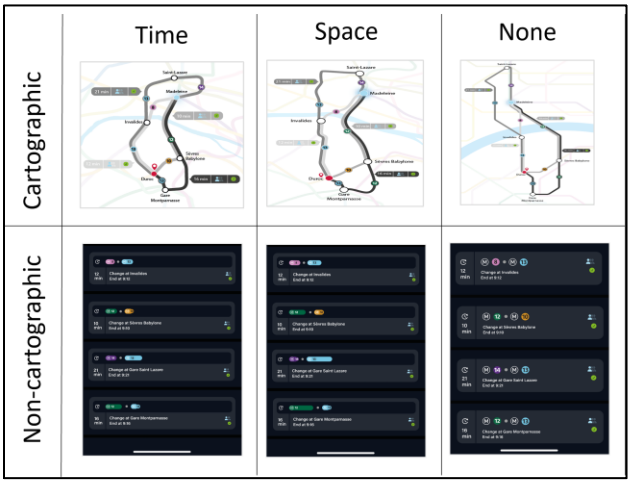


Fig. 6. The 6 variations of the mobility assistant, from top left to bottom right : cartographic based on time, cartographic based on space (geographic), cartographic not based on time or space (schematic), non-cartographic based on time, non-cartographic based on space, non-cartographic not based on time or space.

IV. FROM APPLIED TO BASIC RESEARCH: WHAT ARE SPATIAL MENTAL REPRESENTATIONS OF METROPOLITAN AREAS?

As shown by the previous work of the Wildtimes project, and in particular the results obtained on the differences in route choice tasks of Parisians when facing a paper transit map – whether they commute or not in their daily life –, the implications for transport plans and spatial cognition are noteworthy. These results underscore the necessity of examining the potential impact of the representations of the region in which they reside. The results obtained could indeed suggest that spatial representations at a geographical scale could i) be at the heart of the cognitive processes of selection we tried to account for and ii) give us the opportunity to access to more general knowledge of how functional devices can impact spatial perception at that same scale.

In order to understand the reasons why residents, even those who do not commute in their everyday life, seemed to be more resistant to schematic mapping changes than people who do not have any kind (direct or indirect) of knowledge of the concerned transport network at all, we designed and conducted two studies (Prabhakar, Grison, Lhuillier, Leprévost, Gyselinck, & Morgagni, 2023). The paradigm deployed for this purpose was carried with residents and non-residents of three different large European cities such as Paris, London, or Berlin. Residents were asked to place on a blank sheet of paper (or screen, depending on the study) the positions of various well-known landmarks (e.g. Eiffel Tower for Paris) using a common and central landmark (e.g. Notre Dame de Paris) as a reference point. Non-residents of the city were firstly trained to learn a specific schematic or topographic representation of a new city before being asked to place the same landmarks. The representation was conceived by using for each metropolitan area the transport authorities schematic maps for the firsts and the real geographic positions for the seconds.. The positions of placed landmarks were then compared to their geographical positions as well as to their respective positions on the transportation network schematic map. In total, 1,615 participants took part in the two studies, the first being carried out in person and the second online. Results are consistent between the two and have shown that participants who were living in the targeted city region reported positions that were on average more similar to the schematic than to the geographical layout (see figure 7 for an example of distortion). When participants faced a previously unknown region during the training phase, their productions were closer to the representation they were trained on. We called this effect "*schema effect.*"

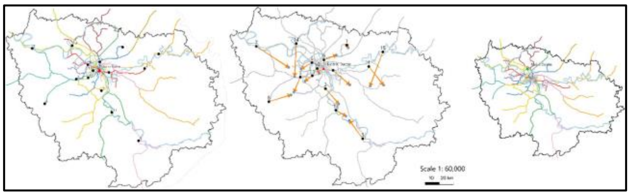


Fig. 7. Veridical and plotted landmarks positions by private transport users. The black line outlines the region (Ile-de-France), and coloured lines represent train and metro lines. Left: Black dots show actual landmark position. Centre: Black dots show actual landmark position blue dots show average plotted position, and orange arrows show the difference between the locations of each landmark. Right: Anamorphic map of the region.

In sum, we showed that the shape of participants' mental representations of Greater Paris, London & Berlin was closer to that of transit maps than to the topographical reality. What cognitive mechanisms are at work behind this "*schema effect*" ? A first hypothesis could be that residents integrate the shape of a transit map they are familiar with as a plausible representation of the topography of their city. However, numerous representational biases have also been described in previous literature, suggesting that metric properties within spatial representations would always be distorted in a schematic fashion (e.g. "*cognitive graphs*", Chrastil & Warren, 2014). For instance, cognitive simplification processes have been observed such as systematic alignment effects (e.g. Tversky, 1981) or angular regularization (e.g. Hirtle & Mascolo, 1992), which would facilitate efficient spatial processing at the expense of topographical accuracy (Behrens et al., 2018). More importantly in the context of metropolises, segmentation effects are known to lead to distances compression or expansion in relation with the presence of borders (e.g. Carbon & Leder, 2005) or categorical regions (e.g. Holden et al., 2015) such as central and peripheral areas of cities (e.g. Friedman & Montello, 2006). A third study (Leprévost, Grison, Prabhakar, Lhuillier & Morgagni, 2024) was conceived to address these two hypotheses by assessing, as an example, the center-periphery distortion and clarify if it could be due to other cognitive processes involved in sketching a map or placing landmarks. Adjusting our previous experimental online design, 413 Parisians and Londoners participants living across center, and periphery of those metropolitan areas were asked to position well known landmarks on a respectively white background presenting a single, central or peripheral, reference point. Results showed again that both populations appear to reproduce transit maps simplification when asked to sketch the configuration of their respective cities by placing landmarks. If both represented their respective city center larger than it is and inversely for their suburbs, Parisians seemed to compress their periphery even more than Londoners. Globally, no other cognitive processes like personal living areas (center or periphery), angular relationship simplification (Costa & Bonetti, 2018) or increased distance linked to a barrier or clutter (Thorndyke, 1981) confound effects were found.

Taken together, these studies show that transit maps explain part of the distortions in mental maps, even when accounting for potential cognitive confounds, and they contribute to building the representation of our living regions and influence how various locations are perceived.

V. LEARNINGS

Despite its importance in individuals' choice of transport modes, and their route choices, we still observe a lack of work on the integration of time in the study of mental representations of geographical space. Contributing to fill in this gap, we reported some of the results obtained within the Wildtimes project. We first described how implicit speed information might shape the metric properties of representations of the geographical space, leading to distorsions in its cognitive counterpart. We then asked what cartographic representation better integrate time and space information, and how they can be perceived to be accurately interpreted by individuals. Although still in their infancy as concerns geographical space, this initial work has opened up new avenues of research into exploring the interrelations between time and space in cognitive maps. A series of studies focused on schematic representations was then presented. They showed how far the way time information is represented in maps or more dynamic mobility applications can influence travellers route choices, which suggests a possible lever for transport autorities and operators. Illustrating a clear phenomenon of serendipity, some of the results obtained have led us to question the importance of the schematic representations used in metropolitan areas, which bias the cognitive representation of residents (being them transport users or not) of these regions in comparison to the topographical representation of the geographer.

Additionnally, the close interweaving of basic and applied issues tackled in the course of this project has led us to adopt a situated approach to spatial and temporal cognition, as a set of skills enabling individuals to travel around in the wild. We had the opportunity to question the ecological validity of knowledge acquired under controlled laboratory conditions, by confronting models against real-life situations. This has led us, for example, to carry out experimental tasks with mobile EEG (Vallet & van Wassenhove, 2023) or direct estimations of durations and distances during real high-speed train journeys (Nédelec et al., *subm.*). We also tried to observe how the perception of time (Lamprou-Kokolaki et al., 2024) and space (Lhuillier et al., *in prep.*) was affected by movement in realistic yet controlled settings through the use of virtual reality. These examples of situated research are obviously an attempt to improve the generalisability of results constrained to specific laboratory situations (Hammond & Stewart, 2001) by adopting so-called '*in situ*' designs (see Vallet & van Wassenhove, 2023, for a review). At the same time they are an opportunity to exploit the mobility everyday context as a field in which behaviour is engaged by real objectives and motivations, most of the times poorly reproduced in the laboratory. As illustrated in the described studies, whether it is a question of network constraints, cognitive limitations or design preferences, mobility problems introduce new factors into the variability of spatial and temporal cognition mechanisms. This observation therefore calls for a more situated approach to experimentation in spatial and temporal cognition, in which basic and applied questions should no longer be entirely dissociated.

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