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RESEARCH ARTICLE

Metric and temporal relationships in collaborative map drawings

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ABSTRACT

While a number of studies have distinguished spatial and temporal memorization at individual level, none seem to have examined these two memorization modes in collaborative map drawing. After an initial review of the distinctions between spatial and temporal memorization at individual level, and a study of inhibition in collaborative memorization, we present several analyses carried out on 24 collaborative drawings from an urban spatial exploration. We compare metric and temporal measurements on these drawings to identify possible relationships between metric and temporal approaches, depending on whether group members proceeded individually or collectively in the urban exploration prior to the collaborative drawing phase.

- Based on 6 landmarks common to all drawings, an initial approach to metric and temporal measurements is carried out by comparing the distances obtained from the graphs created on the drawings, with the temporal measurements deduced from the video recordings. While the metric measures correlate well with the physical space (Google), they neither enable us to observe significant relationships between metric and temporal distances, nor to discriminate sufficiently between the groups.

- A second approach has therefore been taken, this time comparing the distances obtained from the starting point of urban exploration with landmarks' order of appearance in the videos. In this case, the correlations obtained between metric distances and landmarks' order of appearance prove to be significant for the group that interacted collectively in the urban space, but not for the groups that explored individually. Nevertheless, the group that repeated the collective exploration a month later showed relative independence from metric distances, in favor of a more global representation of the environment.

Keywords: collaborative map; landmarks, graphs; spatial memorization; temporal memorization; group dynamics; collaborative memory inhibition; transactive memory

1. Introduction

Two previously little-explored fields of research – collective spatial cognition and differentiation between spatial and temporal memory at individual level – are currently the subject of a growing body of research. Nevertheless, to our knowledge, no study has attempted to jointly probe two fields of research. And yet, clearly, all spatial explorations and collaborations are established over a given period of time, thereby intersecting with spatial and temporal regimes. To introduce the study presented here, we will outline recent changes in the study of spatial navigation and collective memorization. We will also discuss collective inhibition, transactive

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memorization and the distinctions between spatial and temporal memorization. Following this, two successive approaches will be presented when studying 24 collaborative drawings from an urban exploration, in an attempt to shed light on the relationships between spatial and temporal memorization in collaborative maps. The results obtained will be discussed in relation to the distinctions between spatial and temporal memorization.

1.1. The social turn in the study of space navigation

"Humans are ultra-social, yet cognition theories have often focused on the solitary mind. Over the past decade, a growing body of work has revealed how individual cognition is influenced by the presence of others. Not only do we quickly identify others in our environment, but we also align our attention with theirs, thus influencing what we perceive, represent and remember, even when our immediate goals do not involve coordination". Kampis[1].

A substantial number of studies have considered cognitive representations in a social and collaborative context. These studies have been mainly empirical, but also theoretical, in cognitive psychology and sociology, and in the study of brain areas. These studies were carried out by testing collaborative experiments in real-life situations, but also by means of virtual devices. The various means made possible by studying brain areas have provided new and original foundations for a better understanding of how behavior in space is, often, also socio-spatial behavior. The study of brain areas located in the hippocampal formation and related regions shows similar mechanisms are deployed from space perception to high abstraction levels. They make it possible to locate others' spatial locations, facilitating adaptive spatial decisions. These mechanisms highlight that spatial navigation and social navigation spring form the same continuum[1-3]. In terms of empirical studies, the most frequent involve navigation, collaborative orientation, route planning and more generally social relationships' impact on group navigation[4]. Experiments concern matters of leadership, decision-making mechanisms, feedback, suggestions and skills during navigation[5,6], and more generally group cohesion. The study of such groups is often limited to dyads[5,7,8], but human and animal crowds' behaviors enrich studies of social navigation[9,10,12,13]. Finally, Curtin K., M. & Montello D. R.[14] recently published a book on collective spatial cognition.

1.2. The social turn in the study of collective memorization

People often form and retrieve memories in the company of others. "Anyone who has given serious thought to memory recognizes that the act of remembering is influenced in part by the social dynamics that govern this activity". Depending on who I'm talking to, I may not tell the same story, evading or detailing specific elements at others' expense. Yet, for almost a century, cognitive research on memory has focused mainly on isolated individuals. The study of group memory has mainly made progress in history, anthropology, sociology and social psychology[15]. Early research on memory, such as Ebbinghaus's in 1964, or Bartlett's (1932)[16] focused exclusively on individual memory, considering it was quite complex enough already, hence discouraging addressing it in its social context. The only exception to this focus on individuals remembering processes in isolation is Vygotksy[17], who emphasized the mediate nature of cognition. In his discussion of development, Vygotsky recognized the powerful role social interactions can play in scaffolding memory.

1.3. Inhibition in collaborative memory or coordination in transactive memory?

In empirical and theoretical advances on collaborative memory's nature and influence, it is now widely demonstrated that collaboration effects are counter-intuitive, since individuals cannot remember so well when remembering takes place in a group[15]. Members of a group memorize and remember differently than they would if they memorized and remembered in isolation. Because of the group dynamic, group members fail to evoke memories that they were able to recall when alone. Therefore, the body of research on social memory overwhelmingly points to collaborative inhibition[18-22]. “Having found such robust collaborative inhibition when groups remember together, can we ever find collaborative facilitation? In other words, under what circumstances do collaborative groups perform as well as, or better than, or differently from nominal groups?”.

While the importance and effects of inhibition in collaborative memorization are now well-known, an apparently opposite phenomenon is also to be considered in collective memorization: transactive memory. This is described by Maupin et al.,[23], as follows: “In the literature on teams, transactive memory systems are defined as “a form of cognitive architecture that encompasses both knowledge held only by particular group members and the collective awareness of who knows what” (DeChurch & Mesmer-Magnus, 2010, p. 33[24]). Accordingly, transactive memory systems have been used to describe how team members distribute the cognitive load of encoding, storing, retrieving and communicating information relevant to task performance (Austin, 2003[25]; Lewis, 2003[26]; Wegner, 1986[27]). Indeed, the presence of an SMT within a work team can be evidenced by group dynamics, including task specialization, task coordination activities and task credibility actions that demonstrate that team members trust each other’s specialized expertise (Liang et al., 1995[28]; Moreland, 1999[29]; Moreland et al., 1996[30])”. As we can see, the changing, dynamic context of this memorization form is very different from a simple, shared restitution of a sequence of events. It is constructed by assigning each person a role in the memorization to be carried out, and a goal to be achieved. It can therefore be seen as a cognitive and memorial gain, as opposed to the reduction at work in the inhibition process of collaborative memory. As we shall see later in the distinction between several groups of subjects, these two forms of collaborative memorization can play more or less decisive roles.

1.4. Spatial and temporal memory

Does group memorization follow principles similar to those of individual memorization? If individual memorization develops spatial and temporal aspects, can the study of these characteristics also condition group memorization? Before proposing an experimental study, and in the absence, to our knowledge, of studies on spatial and temporal memorization at collective level, we need to examine the state of studies undertaken at individual level. These will enable us to envisage a number of hypotheses for collaborative memorization. A substantial body of research has focused on spatial and temporal memory particularities[31-36]. The main issues addressed in these studies are the distinction, relationships and independence between these memorization types. They also concern the priority of temporal memorization over spatial memorization depending on the nature of the objects and tasks to be performed. In the reported studies, several important points can be considered: The influence of the conditions of familiarity with the environment and the impact of self-perspective (i.e., centered on their own interactions with the environment) in the exploration of space; the influence of naming or pointing to objects in the mental map memorization activity; the role of temporal and spatial proximity in object recognition tasks, location judgments and distance assessments, the examination of the prevalence of temporal contiguity, the roles of the hippocampus and para-hippocampal cortex in spatial and temporal retrieval[32-36]. High personal familiarity was the most effective condition for improving memory of allocentric spatial contexts, while, conversely, self-perspective (i.e. focusing on their own interactions with the environment). Does such dissociation, well-confirmed at individual level, carry over to collective memorization?

1.5. Objectives

Following on from the comments made earlier on spatial and temporal memorization studies at individual level, we can ask whether spatial and temporal memorizations are distinct, related or independent at collaborative memorization level. From the point of view of individual memorization, self-perspective is likely to play an important role in temporal memorization, while, from the spatial point of view, naming or pointing to objects may be decisive. What happens to these two modes of memorization when they are being discussed and the subject of a collaborative drawing? If it is widely recognized that several people do not remember so well as the sum of their individual memories, does this deficit in collaborative memorization equally apply to spatial and temporal memorizations? By analyzing 24 collaborative drawings made after an urban exploration, we aim to find out whether the relationships between metric and temporal distances in the drawings studied make it possible to distinguish between a group that interacted collectively during the urban exploration and another one that carried out only individual exploration.

2. Materials and methods 1

While many studies have focused on spatial or temporal memory individually, none have jointly examined these aspects in collaborative map drawings. In an attempt to address this issue, we had three groups of walkers make collaborative drawings after exploring a 1.5 km^2 urban territory located in the St Denis plain north of Paris. These three groups of walkers, each made up of 6 sub-groups of 5 walkers, were composed as follows:

1) one group exploring individually (provided with a mere, paper form, outline of the boundaries of the area to be explored,),

2) an individual exploration group equipped with a navigation application for spatial orientation,

3) the target group, i.e., a third group equipped with the same navigation application as the second one, but enhanced with the ability to post and exchange photographs and follow other participants' trackings in real time. In addition, for further investigation, this third group repeated the same experiment one month later, in order to examine the possible effects of repeated memorization. Exploration time was limited to one hour before the collaborative drawing stage. The exploratory instructions were as follows: "A friend is coming to live in the Plaine St Denis district. Your exploration should enable you to point out areas of interest in the neighborhood". These three groups of walkers were each made up of 40 people, but all the collaborative drawings were produced by 5-participant groups, as was the in situ urban exploration of group 3, which interacted collectively.

2.1. Early approaches to metric and temporal measurements

2.1.1. Metric measurements

a) Choosing a labeled graph approach

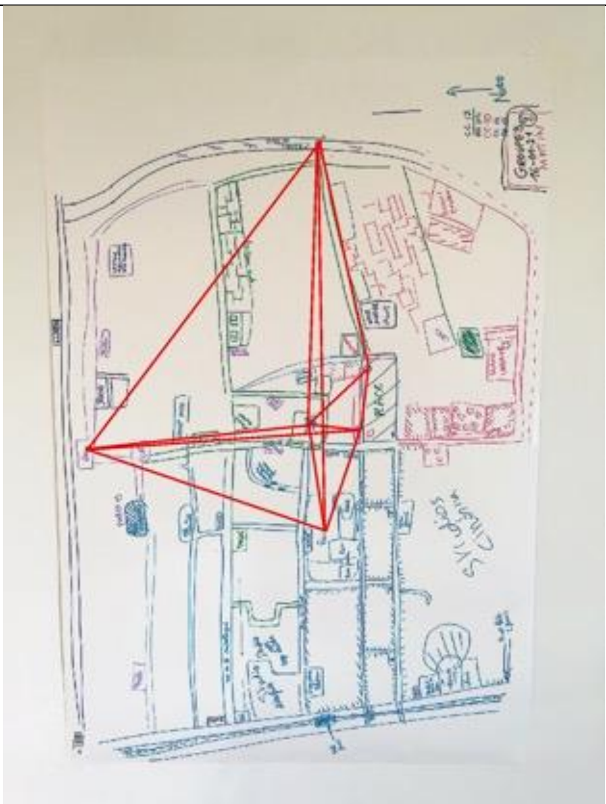
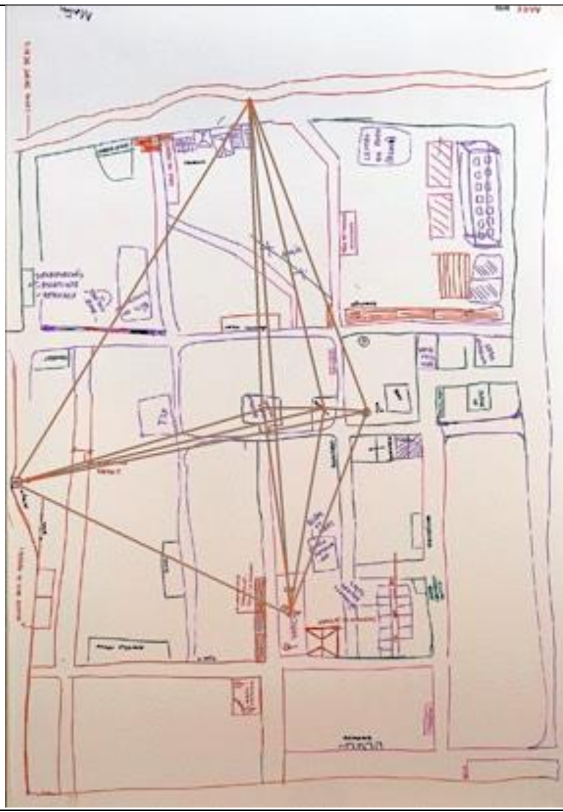
The study of all the collaborative drawings revealed 6 main landmarks common to all. As examples, we reproduce below the 6 collective drawings produced by the third group, i.e., the group that interacted collectively during the urban exploration of the district concerned. In an attempt to analyze these drawings, we have chosen to apply to them a graph constructed from 6 identical landmarks and to measure the distances between each of these nodes. There are therefore 15 edges and 15 distances between these 6 nodes. This is a global approach to the mental maps constructed by participants. Maps were called labeled graphs, since each edge of the graph is completed by a measurement of the distance between the 6 graph nodes. In this overview of all these collaborative drawings on which graphs are applied, we can notice a number of similarities and deformations in these graphs, in comparison with the one constructed in a Google map.

Table 1. Identification of the 6 landmarks

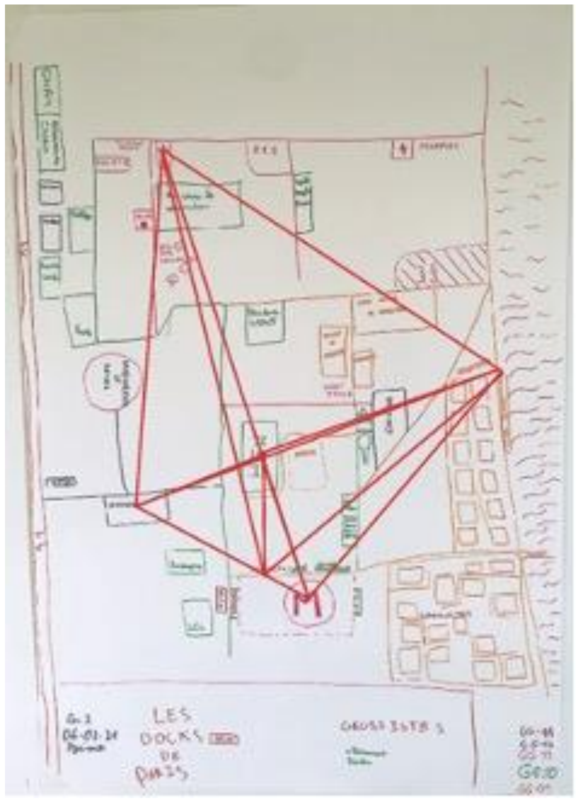
Identifying the 6 landmarks

landmarks	Code	Category	Addresses
Saint Paul de la plaine church	**E**	Place of worship	131 Avenue du Président Wilson, 93210 Saint-Denis, France
Quai Lucien Lefranc	**Q**	River canal	Quai Lucien Lefranc, 93000 Aubervilliers
Front Populaire metro station	**M**	Subway station	Front Populaire station, 93210 Saint-Denis
Maison des Sciences de l'Homme - Paris Nord	**MSH**	Research Institute	20 Avenue George Sand, 93210 Saint-Denis
Square Diderot	**S**	Parque	Square Diderot, 93210 Saint-Denis
Franprix	**F**	Feed magazine	8 Avenue George Sand, 93210 Saint-Denis

Presentation of graph drawings by 6 groups of 5 participants for the third group (interactive group).

	
CC3-1	CC3-7

CC3-8



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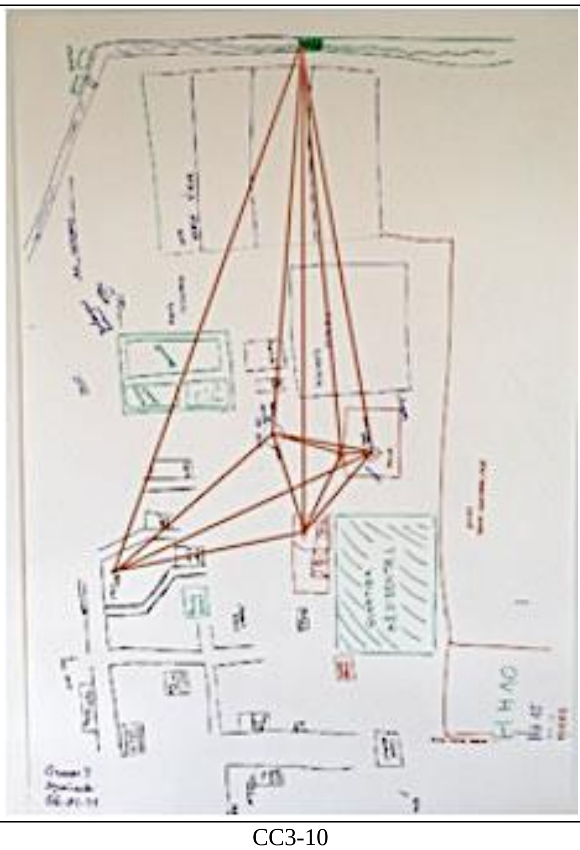

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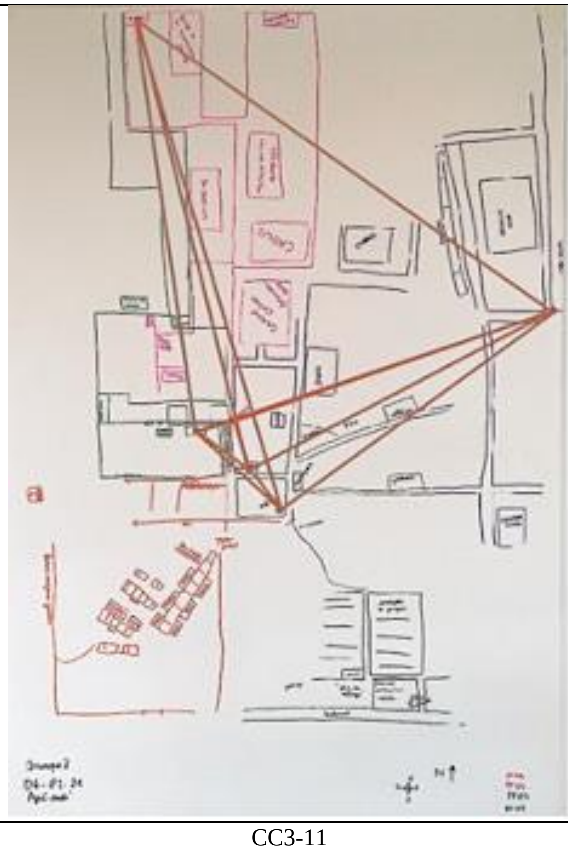


CC3-11

Google Map

Figure 1. Drawings of graphs based on 6 landmarks and comparison of 6 subgroups of 5 participants for group 3. The last picture shows the Google Map graph.

b) Metric measurements, early results in relation to physical space

Table 6. Comparison of metric averages in all groups and Google comparison

CC1 - Comparison of average metric distances in the 6 subgroups			**CC2 - Comparison of average metric distances in the 6 subgroups**		
	Average metric distances in group 1	Google		Average metric distances in group 2	Google
EQ	7.89	9.41	EQ	9.45	9.41
QF	8.67	9.36	QF	8.78	9.36
QM	9.80	9.29	QM	9.27	9.29
QMSH	6.77	8.65	QMSH	8.19	8.65
QS	9.66	10.38	QS	11.01	10.38
EF	10.27	10.26	EF	9.19	10.26
EM	10.84	11.17	EM	10.29	11.17
EMSH	7.99	9.45	EMSH	7.08	9.45
ES	8.10	9.15	ES	8	9.15
FM	2.11	1.10	FM	1.37	1.10
FMSH	2.73	0.96	FMSH	2.17	0.96
FS	3.71	2.29	FS	3.28	2.29
MMSH	4.03	1.74	MMSH	3.39	1.74
MS	4.12	3.37	MS	4.08	3.37
MSHS	3.15	2.18	MSHS	3.02	2.18

CC3 - comparison of average metric distances for the 6 subgroups			**CC3 Bis - comparison of average metric distances for the 6 subgroups**		
	Average metric distances for group 3	Google		Average metric distances for group CC3 Bis	Google
EQ	11.37	9.41	EQ	10.35	9.41
QF	8.32	9.36	QF	8.14	9.36
QM	8.08	9.29	QM	8.08	9.29
QMSH	7.66	8.65	QMSH	7.45	8.65
QS	10.52	10.38	QS	10.05	10.38
EF	9.54	10.26	EF	10.72	10.26
EM	10.53	11.17	EM	10.97	11.17
EMSH	7.80	9.45	EMSH	9.44	9.45
ES	7.95	9.15	ES	9.93	9.15
FM	1.36	1.10	FM	0.88	1.10
FMSH	1.98	0.96	FMSH	1.42	0.96
FS	3.42	2.29	FS	2.91	2.29
MMSH	3.02	1.74	MMSH	2.07	1.74
MS	4.51	3.37	MS	3.29	3.37
MSHS	2.97	2.18	MSHS	2.97	2.18

c) Correlations between metric measurements in the 4 groups and measurements in the Google map

Table 3. Measurement of r-correlations between graph edge measurements for each group and measurements obtained from Google Map

MEASURING CORRELATIONS r BETWEEN GROUPS WITH GOOGLE MAP Each group is made up of 6 sub-groups of 5 people each	
COLLECTIVE CARDS GROUP 1	**0.97**
COLLECTIVE CARDS GROUP 2	**0.778**
COLLECTIVE CARDS GROUP 3	**0.965**
GROUP CARTESS GROUP 3 BIS	**0.983**

These coefficients indicate a strong correlation between the groups' measurements and those of Google, particularly in groups CC1, CC3 and CC3 bis, but do not enable us to significantly distinguish between them.

2.1.2. Time measurement

To measure the time between these 6 landmarks, we filmed all the collaborative drawings continuously, then used video editing software (Final Cut Pro) to record the appearance times in seconds for each of the 6 landmarks.

We performed these temporal measurements in two stages. In the first step, entitled 1) Landmark appearance speed, we measured only the landmark appearance speed from the start of the collaborative drawing movie. In the second step, entitled 2) Calculation of temporal distances between all landmarks, we took advantage of this initial tracking to calculate all the temporal distances between all landmarks, i.e., 15 temporal distances, so that we could compare them later with metric distances.

d) Landmark appearance speed in seconds from 0

Table 4. Video analysis of collaborative drawings: temporal measurements averages in landmark appearance in all groups

	CC3	CC1	CC2	CC3 Bis
MSH	526	1,384	1,229	832
Quai	1,759	2,213	1,269	1,524
Metro	793	4,576	1,492	1,003
Franprix	2,134	4,582	3,301	2,352
Square	1,645	5,090	3,263	2,913
Church	3,952	6,638	3,573	2,079
End	6,210	8,588	7,684	6,947
Max. duration	10,000	10,000	10,000	10,000

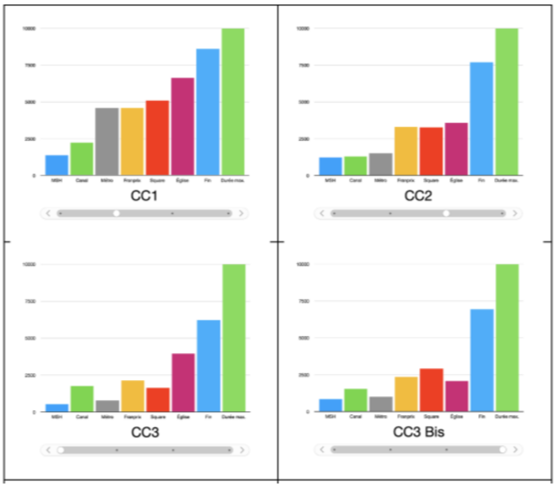


Figure 2. Histogram showing landmark appearance speeds in each group

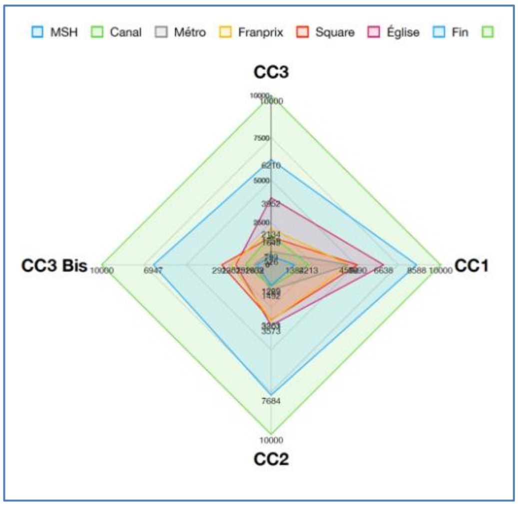


Figure 2 Bis: Speed Radar-Legend: Light green: reference frame, Light blue: actual duration, Violet: St Paul's church, Red: square, Orange: Franprix, Green: canal, Grey: metro, Dark blue: MSH

The table of landmark appearance speeds in collaborative drawings is visualized in the form of a histogram and a radar. In the histogram, we can clearly distinguish between groups, and see that these speeds increase from group CC1 to group CC3 Bis. In the radar display, these velocities are represented in a single graphical ensemble, allowing us to see the deformations in each group relative to the speed of landmark appearance. In the radar display, each landmark is shown in a different color, allowing us to position temporal distances relative to their appearance times. The radar as a whole is clearly shifted towards the CC1 pole, which induces an overall lengthening of landmark appearance. In contrast, the CC3 Bis pole is the most contracted, with the exception of the square (in red). Finally, the quadrilateral involving the church is stretched not only towards CC1, but also towards CC3 (in purple).

e) Calculation of temporal distances between all landmarks

Time measurement of landmark appearance in Final Cut (seconds) from the start of each video

Table 5. Example of calculation of temporal distances between landmarks, CC1 group example)

Example of CC1 - Average landmark appearance timing

	CC1-1	CC1-2	CC1-3	CC1-5	CC1-7	CC1-8	
MSH	436	80	137	102	7	87	141
Metro	1058	100	537	1,090	104	1,369	709
Franprix	932	816	541	1,069	660	1,005	837
Square	1,324	689	380	384	302	1,081	693
Quai	428	256	513	465	689	424	462
Church	1,134	1,215	1,465	0	0	1,258	845
END	1,527	1,224	1,507	1,824	1,268	2,219	1594

Example of CC1 - Average temporal distances between each Landmark

		Quai	MSH	Franprix	Metro	Church	Square	End
		462	141	837	709	845	693	1,594
Quai	462	0	321	375	244	383	231	1,132
MSH	141		0	696	568	704	552	1,453
Franprix	837			0	128	8	144	757
Metro	709				0	136	16	885
Church	845					0	152	749
Square	693						0	901
End	1594							0

2.1.3. Comparing metric and temporal measurements

Table 6. Comparison of metric and temporal averages in all groups Each group is made up of 6 collaborative drawings

CC1 - Comparing metric and temporal distance averages				**CC2 - Comparing metric and temporal distance averages**			
	Average metric distances in group 1	Average temporal distances in group 1	Google		Average metric distances in group 2	Average temporal distances in group 2	Google
EQ	7.89	8.19	9.41	EQ	9.45	10.98	9.41
QF	8.67	8.02	9.36	QF	8.78	9.69	9.36
QM	9.80	5.22	9.29	QM	9.27	1.40	9.29
QMSH	6.77	6.86	8.65	QMSH	8.19	1.63	8.65
QS	9.66	4.94	10.38	QS	11.01	9.49	10.38
EF	10.27	0.17	10.26	EF	9.19	1.28	10.26
EM	10.84	2.91	11.17	EM	10.29	9	11.17
EMSH	7.99	15.06	9.45	EMSH	7.08	12.61	9.45
ES	8.10	3.25	9.15	ES	8	1.48	9.15
FM	2.11	2.73	1.10	FM	1.37	8.29	1.10
FMSH	2.73	14.89	0.96	FMSH	2.17	11.32	0.96
FS	3.71	3.08	2.29	FS	3.28	0.20	2.29
MMSH	4.03	12.15	1.74	MMSH	3.39	3.03	1.74
MS	4.12	0.34	3.37	MS	4.08	7.52	3.37
MSHS	3.15	11.81	2.18	MSHS	3.02	11.12	2.18

CC3 - comparison of metric and temporal distance averages			
	Average metric distances for group 3	Average temporal distances for group 3	Google
EQ	11.37	9.52	9.41
QF	8.32	5.08	9.36
QM	8.08	2.92	9.29
QMSH	7.66	4.59	8.65
QS	10.52	1.49	10.38
EF	9.54	4.43	10.26
EM	10.53	12.44	11.17
EMSH	7.80	14.11	9.45
ES	7.95	8.02	9.15
FM	1.36	8	1.10
FMSH	1.98	9.67	0.96
FS	3.42	3.59	2.29
MMSH	3.02	1.67	1.74
MS	4.51	4.41	3.37
MSHS	2.97	6.08	2.18

CC3 Bis - comparison of metric and temporal distance averages			
	Average metric distances for group CC3 Bis	Average temporal distances for group CC3 Bis	Google
EQ	10.35	3.67	9.41
QF	8.14	5.50	9.36
QM	8.08	3.47	9.29
QMSH	7.45	4.62	8.65
QS	10.05	9.21	10.38
EF	10.72	1.83	10.26
EM	10.97	7.14	11.17
EMSH	9.44	8.29	9.45
ES	9.93	5.54	9.15
FM	0.88	8.97	1.10
FMSH	1.42	10.13	0.96
FS	2.91	3.71	2.29
MMSH	2.07	1.57	1.74
MS	3.29	12.68	3.37
MSHS	2.97	13.84	2.18

2.2. Results and implications 1

2.2.1. Correlations. comparative analysis

Group 1	
Average metric distances:	665.6
Average time distance	664.1
Standard deviation for metric distances	303.9
Group 2	
Average metric distances:	604.3
Average time distance	600.3
Standard deviation for metric distances	366.3
Group 3	
Average metric distances:	660.2
Average time distance	587.3
Standard deviation for metric distances	339.1
Group 3 Bis	
Average metric distances:	657.8
Average time distance	667.8
Standard deviation for metric distances	382.0

2.2.2. Perspective

There is a high correlation between metric distances and Google distances (0.92), while there is a low negative correlation between temporal distances and metric distances (-0.08) and between temporal distances and Google scores (-0.11).

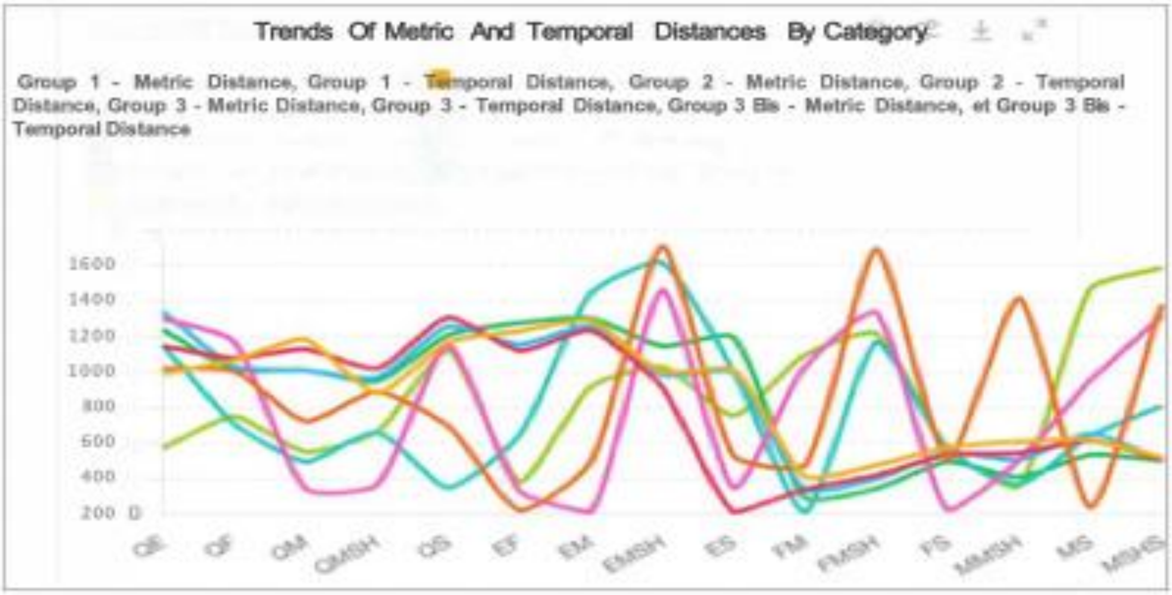


Figure 3. Trends in metric and temporal distances by category.
The x-axis is the fifteen relationships between the 6 main landmarks

3. Comments

Group 1:

Metric distances fluctuate considerably from one category to another, with notable peaks and troughs.

Temporal distances are more stable but show some variability

Group 2:

Similar variability in metric distances, although some categories show distinct peaks

Temporal distances are generally smaller and more stable than in Group 1.

Group 3:

Metric distances vary considerably, with some categories showing higher distances

Time distances remain relatively constant, but with occasional peaks

Group 3Bis

Metric distances are variable, similar to other groups

Time distances show significant peaks in a few categories

3. Materials and methods 2

3.1. Second approach to metric and temporal measurements

Following these results and observations, it would seem that another approach is possible, and that the order of appearance of landmarks may be as interesting as the speed of their restitution. We therefore present a second approach to metric and temporal measures, in which metric measures are established from the starting point of urban exploration (MSH), while temporal measures are considered according to the order of appearance of landmarks from the starting point of exploration, then synthesizing these results for each group.

3.2. Results and implications 2

3.2.1. Temporal approach to landmarks according to their order of appearance

Table 7. Order of appearance of landmarks in all four groups.

	CC1		CC2		CC3		CC3 Bis
		MSH	155	MSH	102	MSH	139
MSH	141	Quai	212	Metro	177	Metro	167
Quai	482	Metro	261	Quai	308	Quai	254
Square	693	Square	544	Square	376	Church	347
Metro	709	Franprix	550	Franprix	537	Franprix	392
Franprix	837	Church	596	Church	774	Square	486
Church	845	End	1 281	End	1 418	End	1 158
End	1 594						

The summary of these orders of appearance presented in the following table leads us to make the following remarks:

- Groups all start at the MSH (the exploration starting and return points) and end at the furthest point, the church, with the exception of group 3 bis, which ends at the square.
- The quay is the second-most distant point, immediately after the MSH in groups 1 and 2, but only in third place in groups 3 and 3Bis.
- The metro (namely the arrival and departure point for the urban exploration site) comes second, directly after the MSH in groups 3 and 3 bis.
- Finally, while the Franprix store occupies the same position in all groups, the square occupies a more indeterminate position (3rd in group 1, 4th in groups 2 and 3 and, more surprisingly, in group 3 bis, since it occupies last place.
- This last group reveals a succession of landmarks somewhat atypical of other. Can we deduce from this that the exploration chronological order is becoming secondary to a knowledge of space that is more allocentric than egocentric?

3.2.2. Temporal approach to landmarks according to their order of appearance and relationship to metric distances from the exploration starting point

Landmarks	Timing of landmark appearance (seconds)				Metric distances from starting point (MSH)
	CC3	CC1	CC2	CC3 Bis	
MSH	526	1,384	1,229	832	0
Quai	1,759	2,213	1,269	1,524	8.65
Metro	793	4,576	1,492	1,003	1.74
Franprix	2,134	4,582	3,301	352	0.96
Square	1,645	5,090	3,263	2,913	3.02
Church	3,952	6,638	3,573	2,079	9.45

3.2.3. Implications

a) High and moderate correlations: in blue on the network diagram

CC3 and Distance: 0.730 (strong positive correlation)

CC3 and CC1: 0.722 (strong positive correlation)

CC3 and CC2: 0.748 (strong positive correlation)

CC1 and CC2: 0.833 (strong positive correlation)

CC2 and CC3 Bis: 0.864 (strong positive correlation)

b) Low and very low correlations: in red on the network diagram

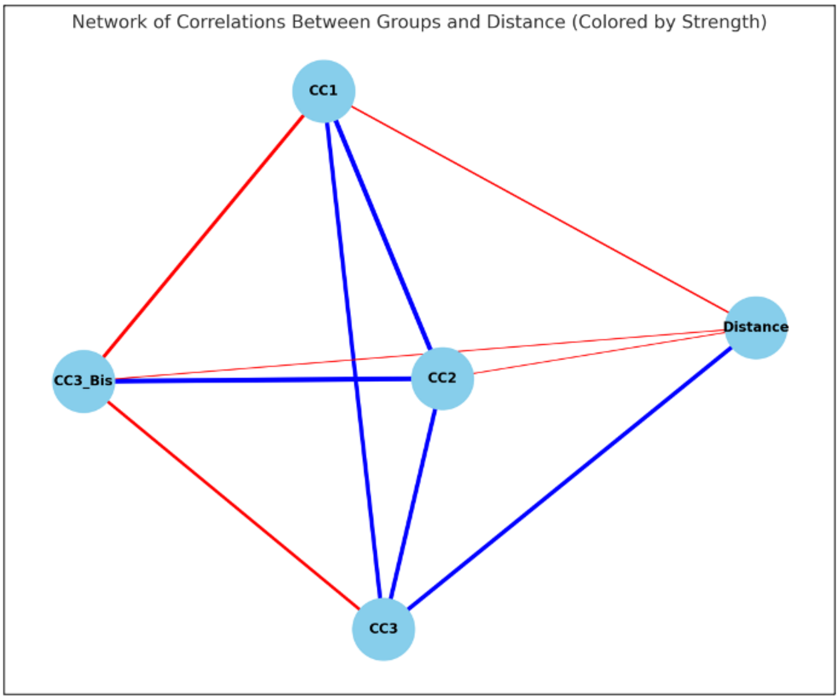
CC1 and Distance: 0.315 (low positive correlation)

CC2 and Distance: 0.186 (very low positive correlation)

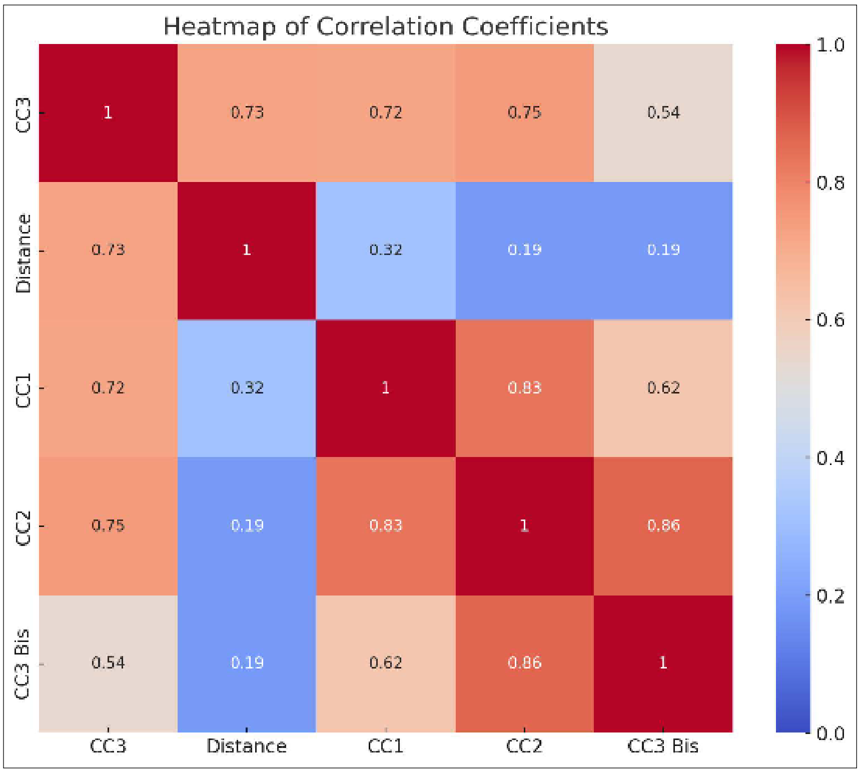
CC3 Bis and Distance: 0.191 (very low positive correlation)

CC3 Bis and CC3: 0.541 (moderate, but at the lower limit)

CC3 Bis and CC1: 0.618 (moderate)



In the graph above, we can clearly see the positive correlation between the CC3 group, which carried out the collective urban exploration before the collaborative drawing phase, and the other groups, which have negative correlations with metric distances. Group CC2, which carried out the exploration individually (but with a navigation tool), has positive relationships with CC1 and CC3. Conversely, the CC3 Bis group has negative relationships with CC1 and CC3.



The correlation coefficient map shows all correlations between groups and metric distances from the starting point of exploration. Red and orange indicate strong and moderately strong correlations; blue and light blue indicate low or very low correlations.

4. Discussion

Our approach was carried out in two stages. In the first, metric distances were established by joining 6 landmarks common to all map drawings in the form of 6-node graphs, then comparing with the same graph constructed in Google Map. Temporal distances were obtained in two stages. In the first, the appearance of each landmark is measured in seconds from the start of the collaborative drawing in the video recordings. In the second step, this timing is used to obtain temporal distances between all landmarks in all drawings, and then by groups. This first approach revealed high correlations between the metric distances between the drawn maps and the Google Map, but no significant relationships between metric distances and temporal distances, nor any distinction between the groups that carried out the urban exploration individually and the group that carried out the urban exploration collectively. However, visual representations of the speed at which landmarks appeared (bars and radars) enabled us to observe interesting differences between groups. Generally speaking, landmark appearance times were reduced from group CC1 to group CC3 Bis.

A second approach based on a new method for obtaining numerical and temporal measures in collaborative maps. Rather than the metric measures obtained in the graphs derived from the drawings, we focused on distances to the starting point of exploration (MSH). For temporal measures, we chose to focus on the order of appearance of landmarks in the video recordings. This second approach enabled us to observe a high correlation between the order of appearance of landmarks and metric distances to the starting exploration point in the group that interacted collectively to the exclusion of the other groups. Somewhat unexpectedly, this same group repeated the experiment a month later and prove, this time, to free itself from this relationship to metric distances in favor of autonomous memorization. These findings prompt us to revisit and question the remarks made at the start of this study concerning spatial and temporal memorization.

4.1. Temporal and spatial organization in episodic memory

4.1.1. Conditions for differentiation

Curiel & Radvansky[31] in an article on the mental organization of maps, make a key point of direct relevance to our study. They observe that naming objects led to temporal organization, but pointing to them led to spatial organization, suggesting that mental map organization is sensitive to the emphasis placed on different types of map information during learning. However, it is clear from the collective videos of our experiments that these two modes are highly intertwined. Verbal mentions and pointing on the drawing are permanently associated.

These forms of differentiation are usefully complemented in an article by Penaud[33], which focuses on allocentric and egocentric memory. Their study shows the extent to which the conditions of memory experience condition the distinction between spatial and temporal memorizations. Recall that high personal familiarity was the most effective condition for enhancing the memory of allocentric spatial contexts, while conversely, self-perspective was the most effective for enhancing the memory of temporal context. While the absence of familiarity with the territory explored may have favored temporal memory at individual level in the first three groups, reiteration of the experiment in group 3 Bis may have favored a more allocentric apprehension of urban space. This observation needs be confirmed.

4.1.2. Integrating spatial and temporal memories

The question arises as to whether these differentiations between spatial and temporal memorization imply their independence or integration. In a second study by McNamara et al.[35] concerning representation and integration in the memorization of spatial and non-spatial information, knowledge integration was assessed by comparing performance levels under two conditions. a) when a city or building name was primed by a fact about a neighboring city or building, and b) when a city or building name was primed by a fact about a distant city or building. Results showed that responses in condition a) were faster or more accurate, or both faster and more accurate, than responses in condition b). Synthesizing all their results, the authors conclude that spatial and non-spatial information are encoded in a common memory representation. On the scale of our initial investigations, admittedly limited in the number of collaborative drawings studied, this common framework is yet to be explored in greater depth.

4.1.3. Predominance?

Finally, does this possible integration of spatial and temporal memories suggest the predominance of one or the other? Although it is not possible to answer this question without specifying the conditions of observation and experimentation, Curiel & Radvansky[32]] and Clark and Bruno[36] shed light on this matter of predominance, while making different implications. Thus, Curiel & Radvansky[31] note an important point concerning the predominance of temporal regimes over spatial regimes: “When naming cartographic objects, evidence of spatial organization was weak, whereas temporal organization was observed when a coherent temporal order was present”. Reviewing the literature on the subject, they note that, in some studies of how maps are learned and organized in memory from a recognition perspective, it can be observed that, while temporal information influences the organization of mental maps, the same is not true of narrative comprehension, where spatial effects can be observed.

Finally, in a 2021 study, Clark and Bruno[36] question whether episodic memory is necessarily organized according to a particular temporal organization or whether this is a task-specific phenomenon. Through their study, they observe that, although there was evidence of spatial contiguity under certain conditions, participants showed recall performance consistent with temporal contiguity, which confirms that episodic memory has a stable and predictable temporal organization. Several other studies seem to confirm this prevalence of temporal memory over spatial memory.

4.2. The effects of group dynamics and collaborative inhibition

Is the difficulty in revealing relationships between metric and temporal relations in the first part of our study due, at least in part, to the inhibition in collaborative memorization mentioned at the start of this chapter? Counter-intuitively, many people remember less well than the sum of their individual memories. Now, what is the context of this group dynamic that can inhibit participants' recall? They are confronted with an ambivalent, even antagonistic situation: the difficulty of remembering one's journey individually, whether egocentric or allocentric, and conforming to other participants' memories in an unstable, emergent process. There are usually five main elements in group dynamics: interaction, goals, interdependence, structure and cohesion. If the objectives are common to all, interaction modes are central to the process, in this case, single or double interactions (only at collaborative drawing level, or in the urban space and then at drawing level). Cohesion is fostered here by the fact that the group is of a common age, and that they are all students. Interdependence is limited to experimentation, and remains brief. The distribution and articulation of roles during the experiments is a subject in itself that has not been studied, but it is of great importance in the group dynamics that emerge from watching the videos of collective drawings. Indeed, in these groups in the process of forming, we can observe processes of differentiation and adjustment corresponding to the gradual emergence of a more or less clearly defined and articulated roles system. Note that according to Rajaram[37] "Collaborative inhibition can diminish, disappear or even reverse depending on group members' learning history and prior knowledge, learning circumstances, the nature of their memory and the nature of their relationship".

In contrast to the importance of collaborative inhibition, we must add the impact of transactive memory. This is a form of collective cognition that enables team members to know "who does what" within the group. For Maupin et al.[23], this definition should be broadened to include "who has what capabilities". "Transactive memory systems (also sometimes called transactive knowledge systems; Brauner & Becker[38], are used to describe awareness of both shared and differentiated knowledge and skills, with members of a dyad or group specializing in some types of knowledge or skills and being aware of their unique abilities". How should we view the relationships, or even antagonisms, between these two opposing collaborative memorization forms? In our study, it should be noted that Group 3 (the interactive group) was able to develop a transactive type of memory (i.e., a division of roles during urban exploration) in the course of its collective exploration, which the other groups did not develop. This benefit is perhaps due to the better performance observed in the second approach used.

4.3.The methodology used

Added to the question of metric precision in collaborative drawing, the question arose as to the speed with which a number of urban landmarks were drawn on the collaborative map. The speed with which urban landmarks were drawn seemed to be better when comparing the four groups of walkers (individual route, assisted route, interactive route, route repeated a month later). While the metric precision of a graph drawn from six landmarks on a Google map compared with the metric precision of a graph produced on a collaborative drawing poses no difficulty, measuring temporal distances between each moment when a landmark was positioned on the collaborative drawing is trickier, since it had to be done in two stages: 1) according to a continuous timing from the beginning to the end of the drawing, 2) in relation to a subtractive calculation between the six landmarks in their temporal appearances. This difficulty was compounded by another: in what common space could these metric and temporal distances be compared? Once the data had been obtained to compare the metric and temporal distances in each of the groups, visualization in the form of metric and temporal curves failed to yield any convincing results. It was therefore with the order of appearance of the landmarks confronted with the distances to the starting point of the exploration that we attempted to bring this investigation to a conclusion, with a particularly significant result in the group that interacted during the urban exploration (live observation of all GPS trackings, transmission and reception of photographs in 5-walker sub-groups). This interactive group, who repeated the experiment a month later, seems to have freed itself from any relationship between metric and temporal data. Could this be the result of an allocentric rather than egocentric memorization of places?

5. Conclusion: What are the relationships between metric and temporal distances in collaborative map drawings?

Following issues of distinctions of spatial and temporal memorization at individual level, we can wonder whether spatial and temporal memorization are distinct, related or independent at collaborative memorization level. From the standpoint of individual memorization, self-perspective is likely to play an important role in temporal memorization, while from the spatial point of view, naming or pointing to objects may be decisive. What happens to these two modes of memorization when discussed and the subject of a collaborative drawing? While it is widely recognized that several people remember less well than the sum of their individual memories, does this deficit in collaborative memorization equally apply to spatial and temporal memorization? By analyzing 24 collaborative drawings made after an urban exploration, we aimed to find out whether the relationships between metric and temporal distances in the drawings studied make it possible to distinguish between a group that interacted collectively during the urban exploration and another group that carried out only individual exploration.

The first approach used to analyze possible distinctions between spatial and temporal memorization in collaborative drawings was a graph-based analysis based on 6 landmarks common to all our maps, in order to conform to an overall memorial approach likely to represent a mental map of the space traveled. While this approach validated a good metric representation of the physical space (Google) for the three groups that were distinguished (individual route, assisted route, interactive route, route repeated one month later), it failed to reveal any significant relationship between the metric and temporal approaches, or to distinguish between the groups. Nevertheless, temporal data visualizations enabled us to appreciate different behaviors in terms of landmark appearance speeds across groups.

The second approach used, taking a different approach to metric and temporal distances, enabled us to clearly appreciate a relationship in terms of metric and temporal distances in the group that benefited from collective interactions, both in urban exploration and in the construction of the collaborative drawing. This positive relationship was observed only in this group, to the exclusion of the others. Somewhat surprisingly and interestingly, the positive correlation between metric and temporal distances in this same group was no longer observed when the experiment was repeated a month later. This observation suggests the benefits of memorizing the space explored, although it is not possible, at this stage, to assess the extent of individual or collective gains in terms of memorization. This gain in memorization seems to be more autonomous than a function of the order in which landmarks appear, to the benefit of a global apprehension that is allocentric rather than egocentric. Finally, it should be noted that the order of appearance of the cues was fairly well correlated between all groups, with the exception of the test group, which navigated individually without a navigation tool (CC1), and the interactive group, which repeated the experiment one month later (CC3 Bis).

These initial results indicate a possible relationship between spatial and temporal memorization for walkers who had the opportunity to collaborate both in an urban exploration situation, but also at the level of the collaborative map, and are of course to be considered in relation to the small number of subjects tested (24 five-subject groups), but also in relation to effects as different as inhibition in collaborative memorization or, conversely, the effects of a transactive memory. It is likely that the group that interacted in the urban space before the collaborative drawing phase implemented a transactive form of memory, where each individual's role and contributions were of utmost importance, which is not true of groups with only one collaborative experience. Further investigation would now be required to confirm these initial results, which link metric and temporal distances, and to better define the collaboration contexts and conditions.

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Conflict of interest

The authors declare no conflict of interest.

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