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On the Sense of Direction in Urban Navigation

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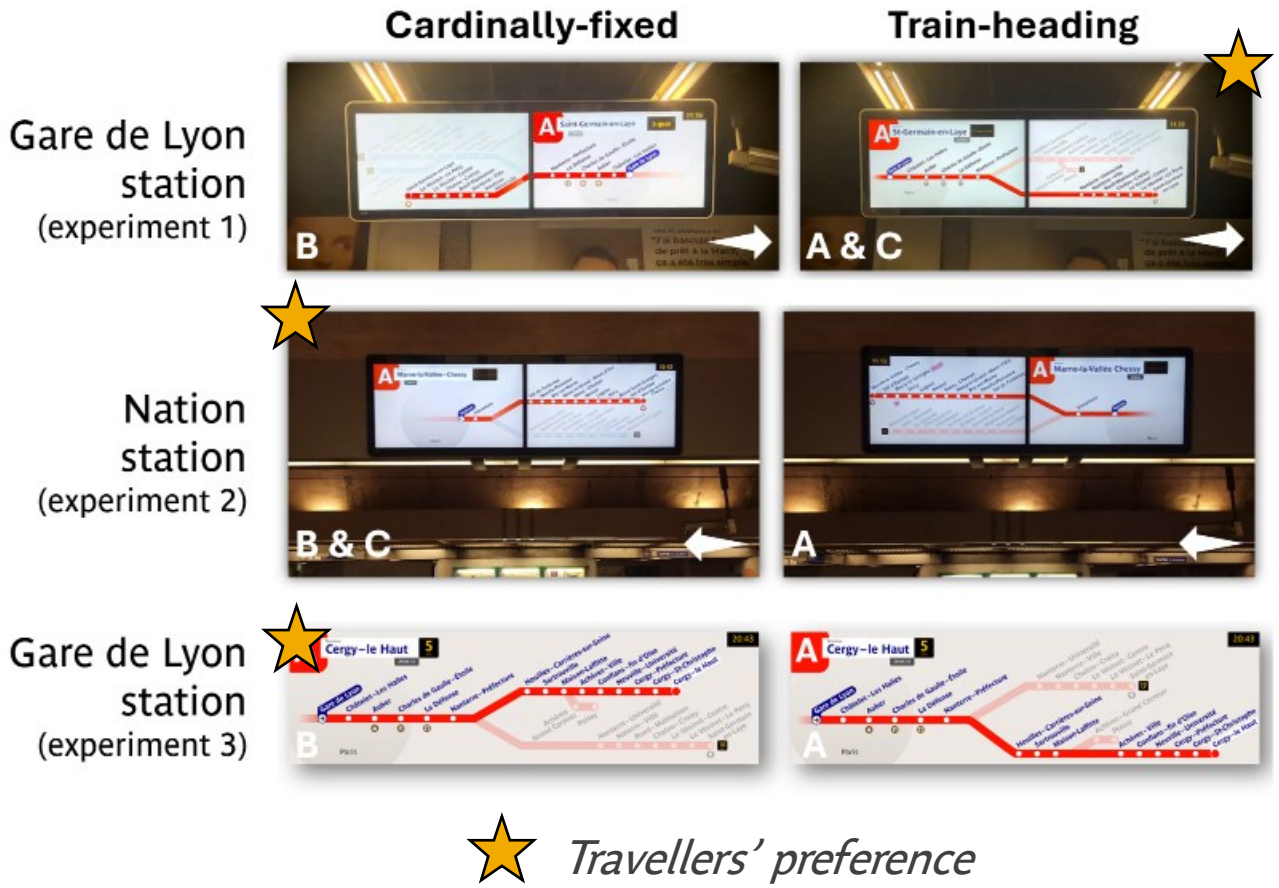
Research summary

We investigate **how passengers perceive directional information from horizontal transit maps displayed on railway platforms parallel to tracks**, specifically examining the RER A line in Paris, a west-east line.

Through three experiments (N=1,881) using video stimuli of actual platform displays, we tested preferences for map orientations aligned with **train direction**, **cardinal directions**, or **left-to-right** cultural reading pattern.

Contrary to our hypothesis that alignment with train movement would dominate orientation preferences, results revealed that **left-to-right reading direction emerged as the primary factor** influencing map orientation preference.

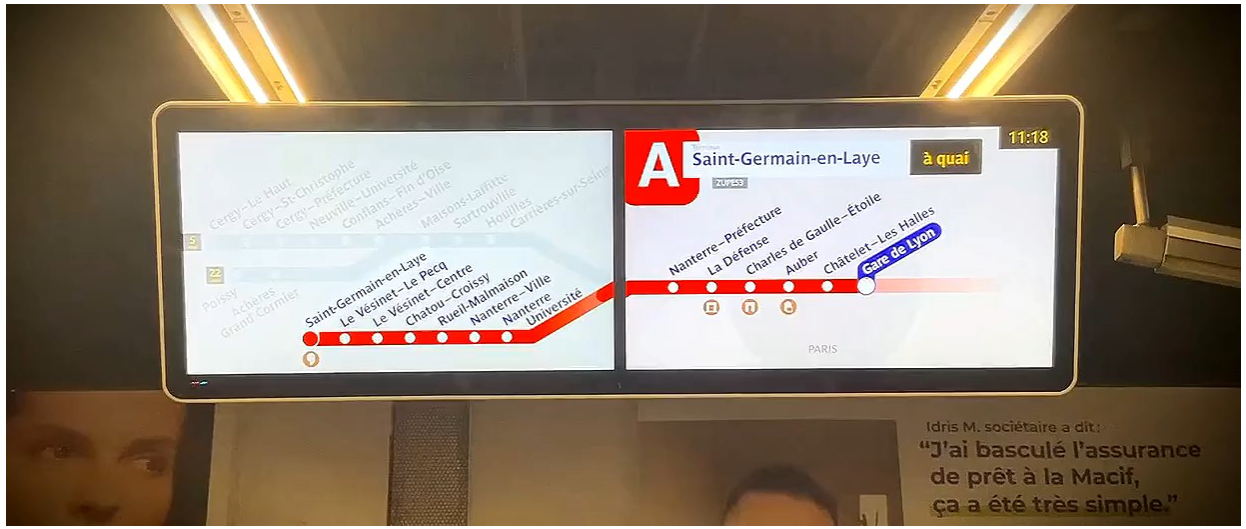
The sense of spatial direction during underground rail navigation may be underpinned by **unarticulated frames of reference that operate independently rather than integratively**, allowing navigation despite disorientation.



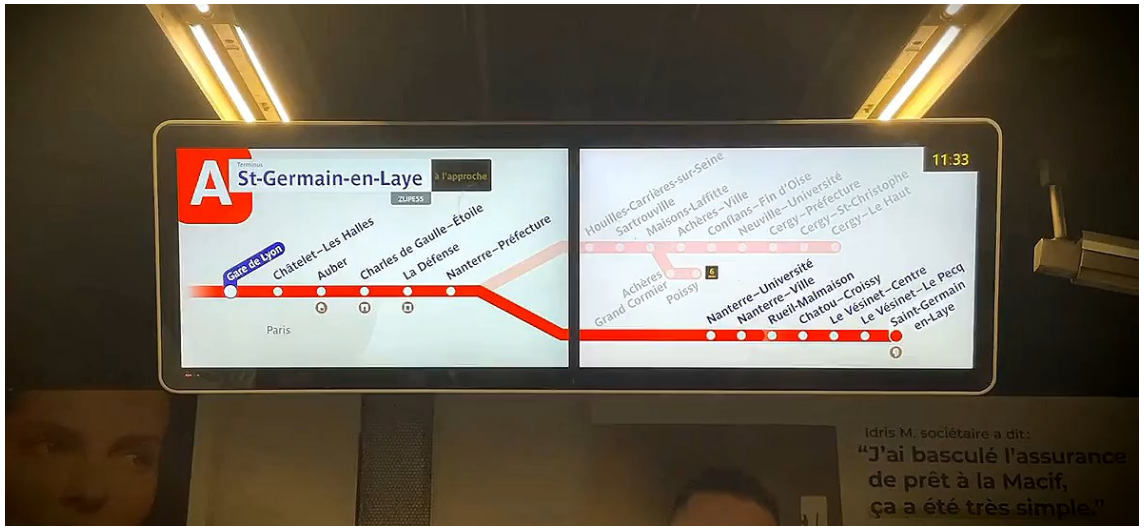
First exp.

Two possible orientations assessed at Gare de Lyon

Cardinally-fixed orientation



Train-heading orientation



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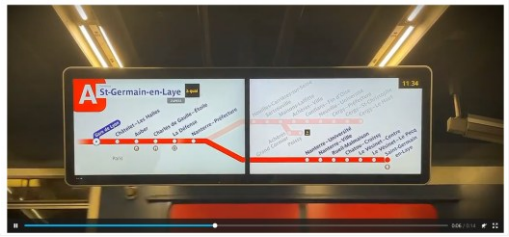
First exp.

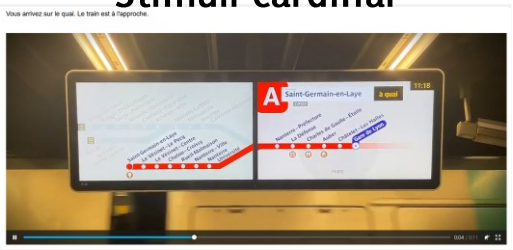
Group 1

Stimuli train-heading



Questions (x7)

Stimuli cardinal

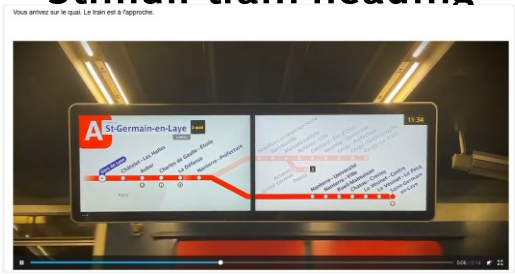


Questions (x7)

Group 2

Priming

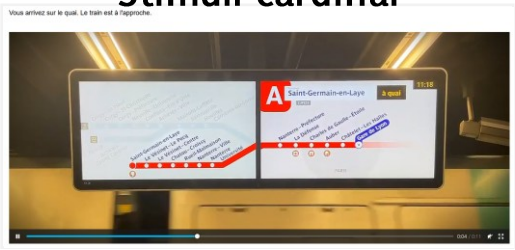
Stimuli train-heading



Questions (x7)

« Priming » orientation

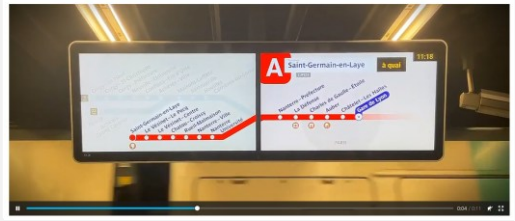
Stimuli cardinal



Questions (x7)

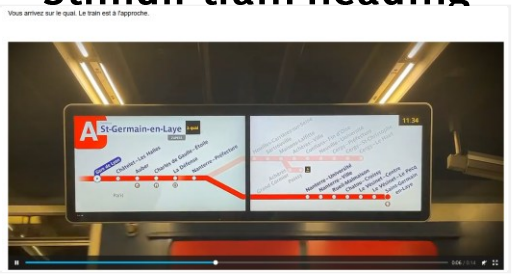
Group 3

Stimuli cardinal



Questions (x7)

Stimuli train-heading

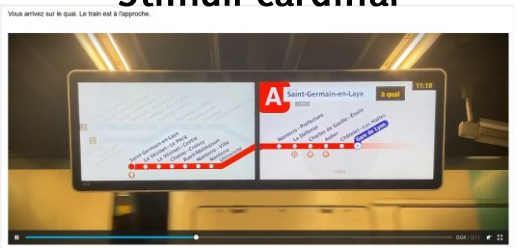


Questions (x7)

Group 4

Priming

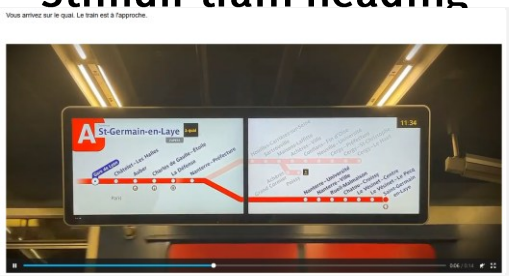
Stimuli cardinal



Questions (x7)

« Priming » orientation

Stimuli train-heading



Questions (x7)

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The instrument: a simple one-factor confirmatory analysis

- **Mixed design across experiments**: Within-subjects evaluation of screen orientations with between-subjects factors for order and priming; participants rated seven screen aspects on 0-100 scales after 40-second viewing periods
- **Strong scale validation metrics**: Single-factor solution explained 68.9% variance with excellent internal consistency ($\alpha = 0.917$) and sampling adequacy (KMO = 0.910)
- **Mixed fit indices**: Excellent CFI (0.950) and SRMR (0.066); elevated RMSEA (0.134) attributed to low degrees of freedom, with Kenny et al. (2015) suggesting good SRMR and CFI as more meaningful indicators
- **Conservative hypothesis testing using non-parametric approaches** (Wilcoxon, Vandekar's S, Spearman, McNemar, Fisher's exact) with Holm-Bonferroni correction for family-wise error control

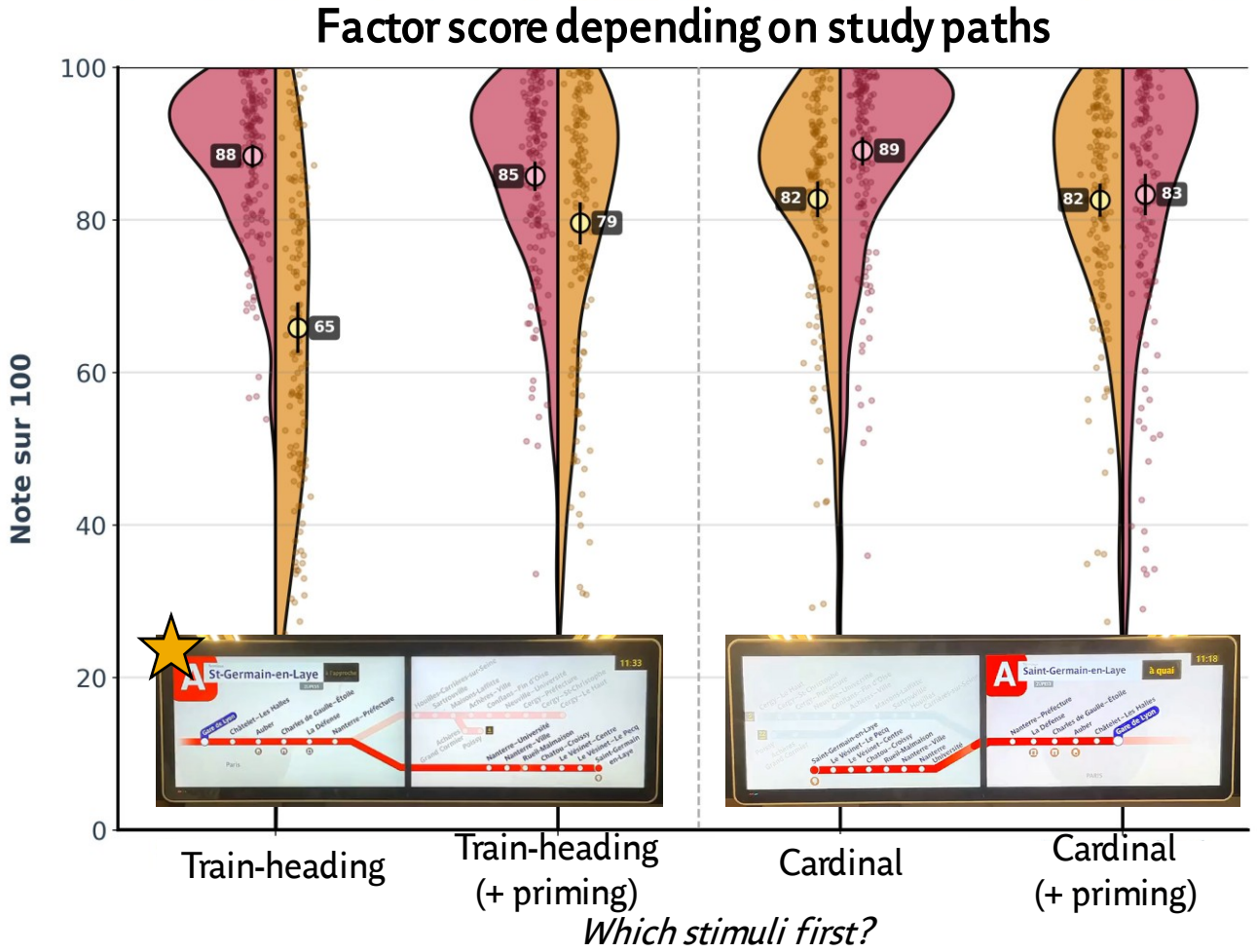
VAT scale questionnaire

1. To what extent did you find the information on the screen easy to understand?
2. To what extent did the screen help you orient yourself?
3. To what extent did you find interaction with the screen intuitive?
4. To what extent did you find the screen useful?
5. How would you rate your level of satisfaction regarding the screen?
6. To what extent does the information displayed on the screen seem relevant to you?
7. To what extent did you find the information on the screen readable?

First exp.

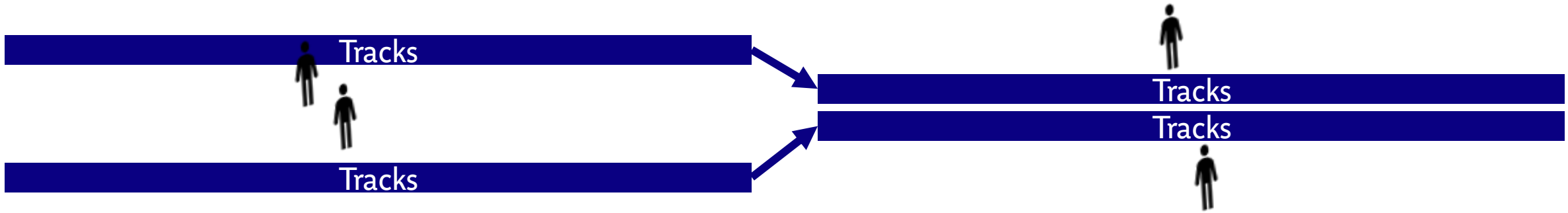
617 participants

All participant groups preferred train-heading orientation over cardinally aligned orientation, with varying effect sizes.



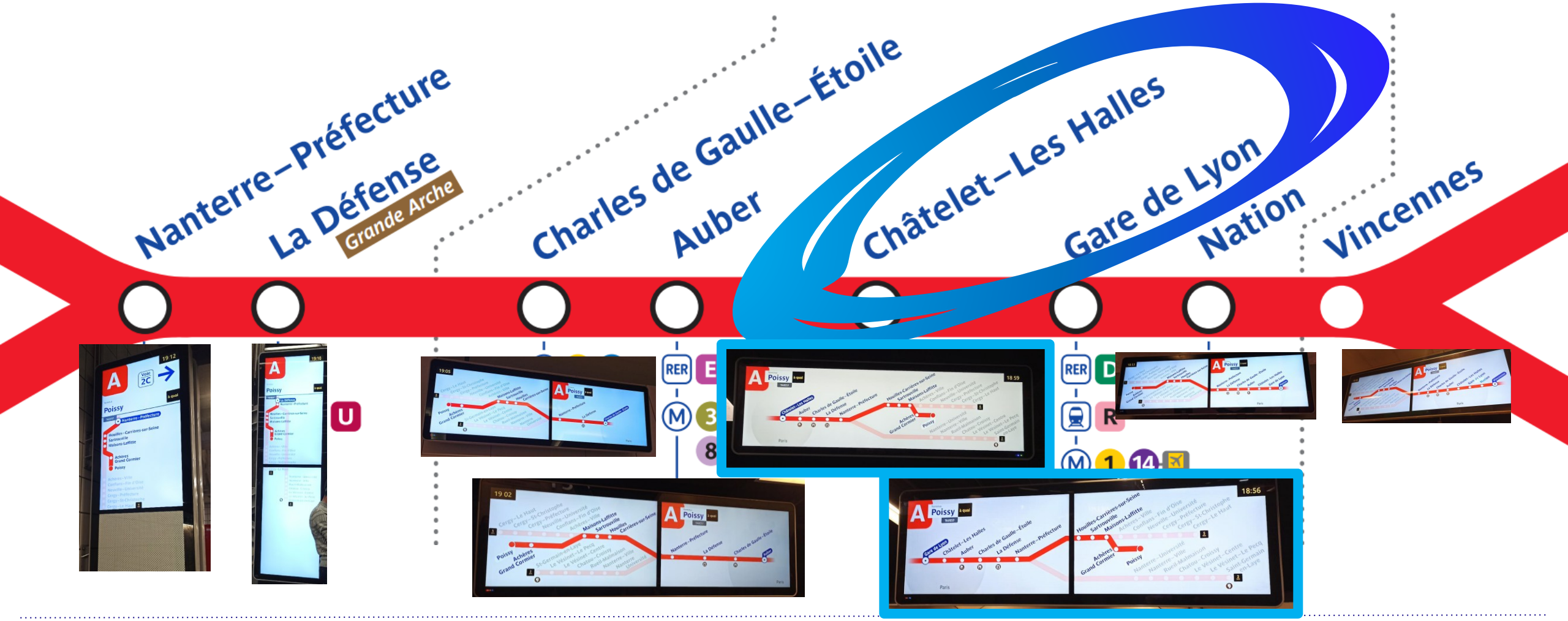
- Without orientation priming: **Strong preference for train-heading orientation**
  - Train-heading first: Large effect ($Mean_1$=88.27 vs $Mean_2$=65.47, S=0.67, p<.001)
  - Cardinally-coherent first: Medium effect ($Mean_1$=88.99 vs $Mean_2$=82.44, S=0.24, p<.001)
- With cardinally-coherent priming: **Weaker but persistent preference for train-heading**
  - Train-heading first: Small effect ($Mean_1$=85.82 vs $Mean_2$=79.93, S=0.19, p=.007)
  - Cardinally-coherent first: Statistically significant but negligible effect ($Mean_1$=83.47 vs $Mean_2$=82.42, S=0.03, p=.01)

But we have inverted decks at Nation!



Second exp.

Only Chatelet and Gare de Lyon feature central decks



Second exp.

Inverted decks also invert the left-to-right mapping over the two orientations we test on screens

Cardinally-fixed orientation

Train-heading orientation

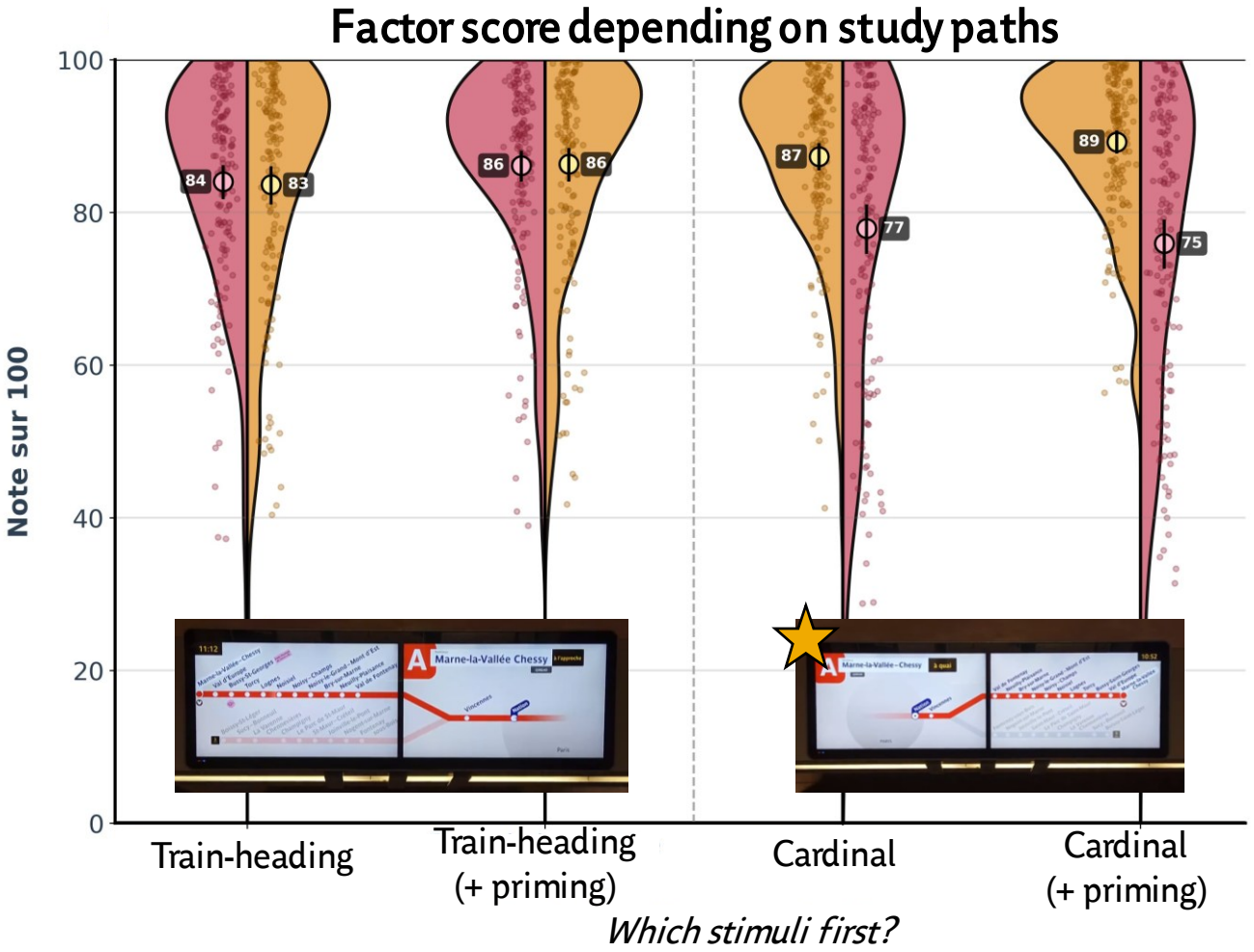
Second exp.

Is it just alignment with the reading direction?

Experiment 2 Hypotheses:

- **H1**: Participants will prefer maps oriented in train direction despite resulting right-to-left reading experience
- **H2**: Direction-aligned map preference will be stronger when aligned with left-to-right reading (Exp.1) vs. creating right-to-left reading (Exp.2)
- **H3**: Participants with higher spatial reasoning abilities will show reduced preference for egocentric alignment
- **H4**: Map orientation will influence spatial language choice, with increased allocentric descriptors when map conflicts with reading direction

Opposite results at Nation



H1 invalidated: No groups preferred train-heading orientation over cardinally aligned orientation. Strong preferences for cardinally-coherent orientation emerged in specific conditions:

- With priming, cardinally-coherent first: Medium preference ($Mean_2$=88.11 vs $Mean_1$=77.40, S=0.34, p<.001)
- Without priming, cardinally-coherent first: Medium preference ($Mean_2$=87.74 vs $Mean_1$=78.12, S=0.29, p<.001)
- No significant preference when train-heading viewed first (both p>.05)

H2 invalidated: Results revealed consistent pattern favoring orientations providing left-to-right reading (train-heading in Exp.1, cardinally-coherent in Exp.2)

Second exp.

614 participants

H3: Spatial Reasoning and Map Orientation Preferences

Hypothesis: Participants with higher spatial reasoning abilities (SBSOD scores) would show reduced preference for egocentric alignment and increased preference for allocentric (north-up) orientation.

Measurement:

- The SBSOD is a validated self-report measure of environmental spatial ability developed by Hegarty et al. (2002).
- It assesses individuals perceived navigational abilities and spatial orientation skills with a 15-item questionnaire (statements like "I am good at giving directions" and "I easily get lost in a new city")
- Correlation analysis between SBSOD scores and orientation preferences

Results: H3 invalidated

- No meaningful relationship between spatial abilities and orientation preferences (Spearman's $\rho = 0.055$, $p = .538$)
- Map orientation preferences appear independent of individual spatial abilities

How good is your sense of direction?

The Santa Barbara Sense of Direction Scale is a self-reported measure of navigation-related abilities. In general, people who score better on this scale are better at real-world navigation. (Scoring instructions at hegarty-lab.psych.ucsb.edu/node/226)

	STRONGLY AGREE → STRONGLY DISAGREE						
1. I am very good at giving directions.	1	2	3	4	5	6	7
2. I have a poor memory for where I left things.	1	2	3	4	5	6	7
3. I am very good at judging distances.	1	2	3	4	5	6	7
4. My "sense of direction" is very good.	1	2	3	4	5	6	7
5. I tend to think of my environment in terms of cardinal directions (N, S, E, W).	1	2	3	4	5	6	7
6. I very easily get lost in a new city.	1	2	3	4	5	6	7
7. I enjoy reading maps.	1	2	3	4	5	6	7
8. I have trouble understanding directions.	1	2	3	4	5	6	7
9. I am very good at reading maps.	1	2	3	4	5	6	7
10. I don't remember routes very well while riding as a passenger in a car.	1	2	3	4	5	6	7
11. I don't enjoy giving directions.	1	2	3	4	5	6	7
12. It's not important to me to know where I am.	1	2	3	4	5	6	7
13. I usually let someone else do the navigational planning for long trips.	1	2	3	4	5	6	7
14. I can usually remember a new route after I have traveled it only once.	1	2	3	4	5	6	7
15. I don't have a very good "mental map" of my environment.	1	2	3	4	5	6	7

SOURCE: M. HEGARTY *ET AL* / *INTELLIGENCE* 2002 KNOWABLE MAGAZINE

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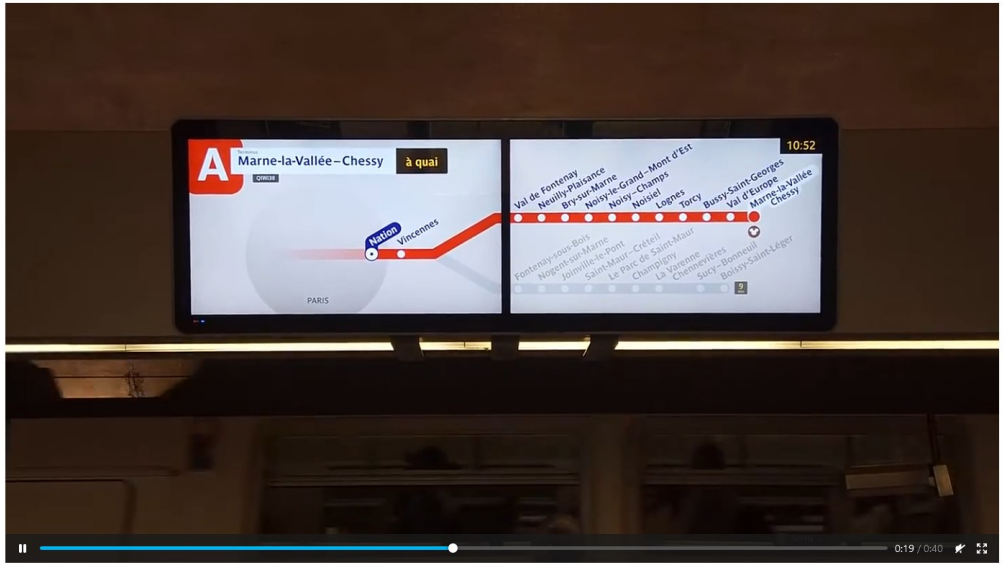
Second exp.

614 participants

H4: Map Orientation and Spatial Language Choice

Une personne à côté de vous cherche à localiser l'arrêt **Vincennes**.



Comment décririez-vous la position de l'arrêt **Vincennes** par rapport à l'arrêt **Nation** à la personne à côté de vous ?

Choisissez la réponse que vous préférez.

Vincennes est à **droite** de Nation	Vincennes est à **gauche** de Nation	Vincennes est à l'**est** de Nation	Vincennes est à l'**ouest** de Nation

Second exp.

H4: Map Orientation and Spatial Language Choice

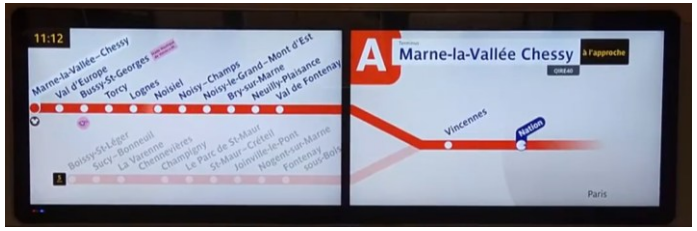
Hypothesis: Map orientation will influence spatial language choice, with increased use of allocentric descriptors when map orientation conflicts with left-to-right reading direction.

Measurement:

- Spatial reference frame task adapted from Man and Tree test (Li and Gleitman, 2002). Participants chose descriptors ("to the right," "to the left," "to the east," or "to the west") to describe "Vincennes" relative to "Nation".

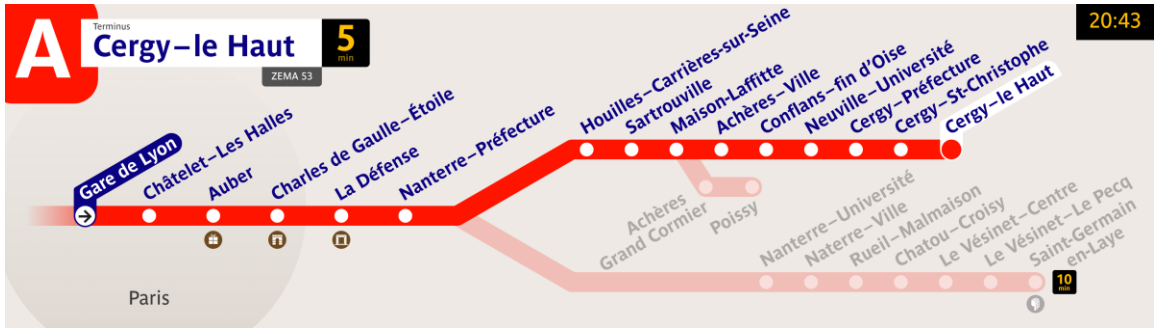
Results: H4 validated

- Cardinal descriptor use:
  - In cardinally-coherent maps: 19.8% (95% CI [16.8%, 23.2%])
  - In train-heading maps: 14.6% (95% CI [12.0%, 17.7%])
  - Difference was statistically significant (McNemar's test, $p < .001$)
- Spatial misattribution (incorrectly equating left position with west):
  - In train-heading maps (where east was on the left): 10.8% (95% CI [8.5%, 13.5%])
  - In cardinally-coherent maps: only 1.7% (95% CI [0.9%, 3.1%])
  - This 6-fold increase in errors was statistically significant (McNemar's test, $p < .001$)

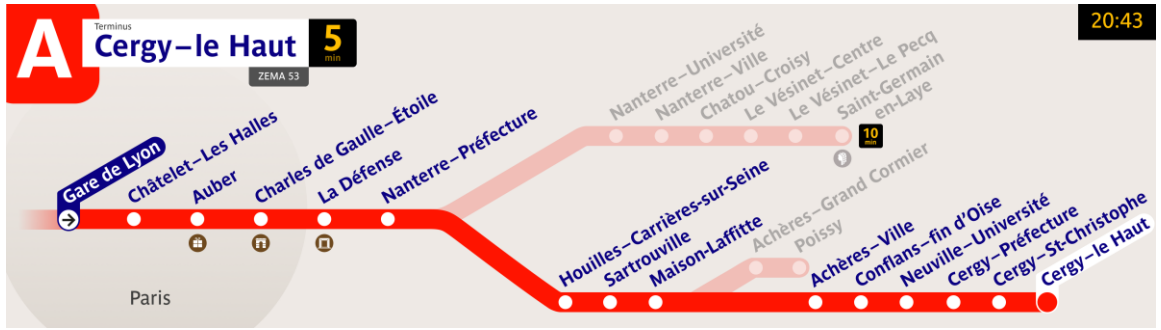


What about north-south up-down preferences?

Cardinally-fixed orientation



Train-heading orientation



H5: Participants exposed to maps with non-standard cardinal alignment would misplace branches relative to true geographical positions, with reduced errors among those completing prior orientation tasks

H6: Participants with higher spatial reasoning abilities would demonstrate stronger preferences for geographically consistent map orientations

Third study

521 participants

Before instrument administration, a masking task…

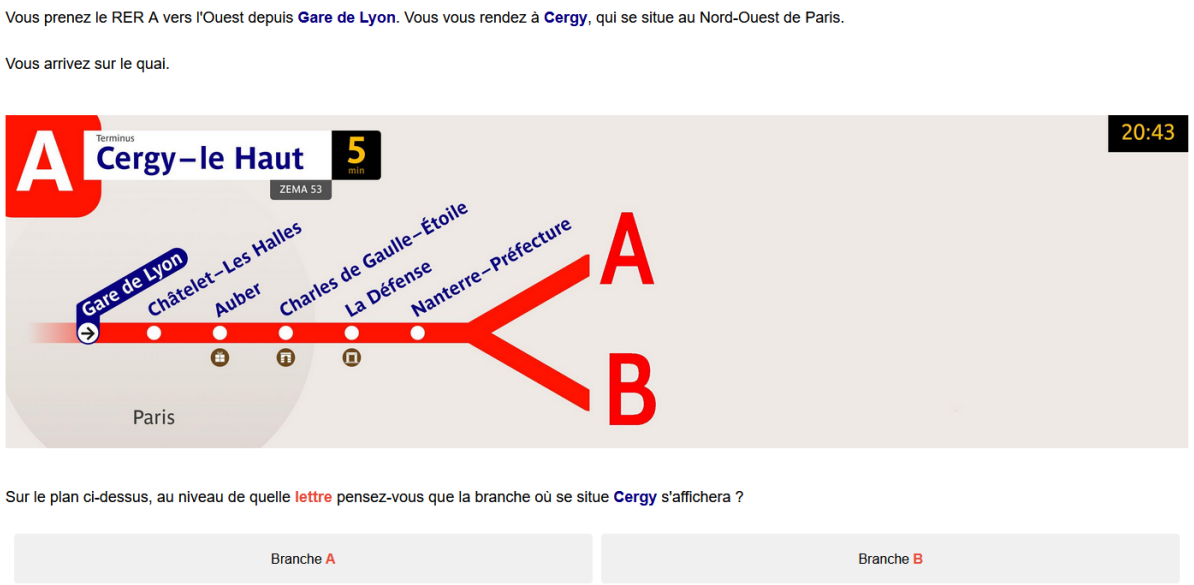
Masking task design:

- Participants shown display with east-west inversion and asked to locate north branch on partially masked section.
- Task assessed intuitive geographical expectations for branch placement.

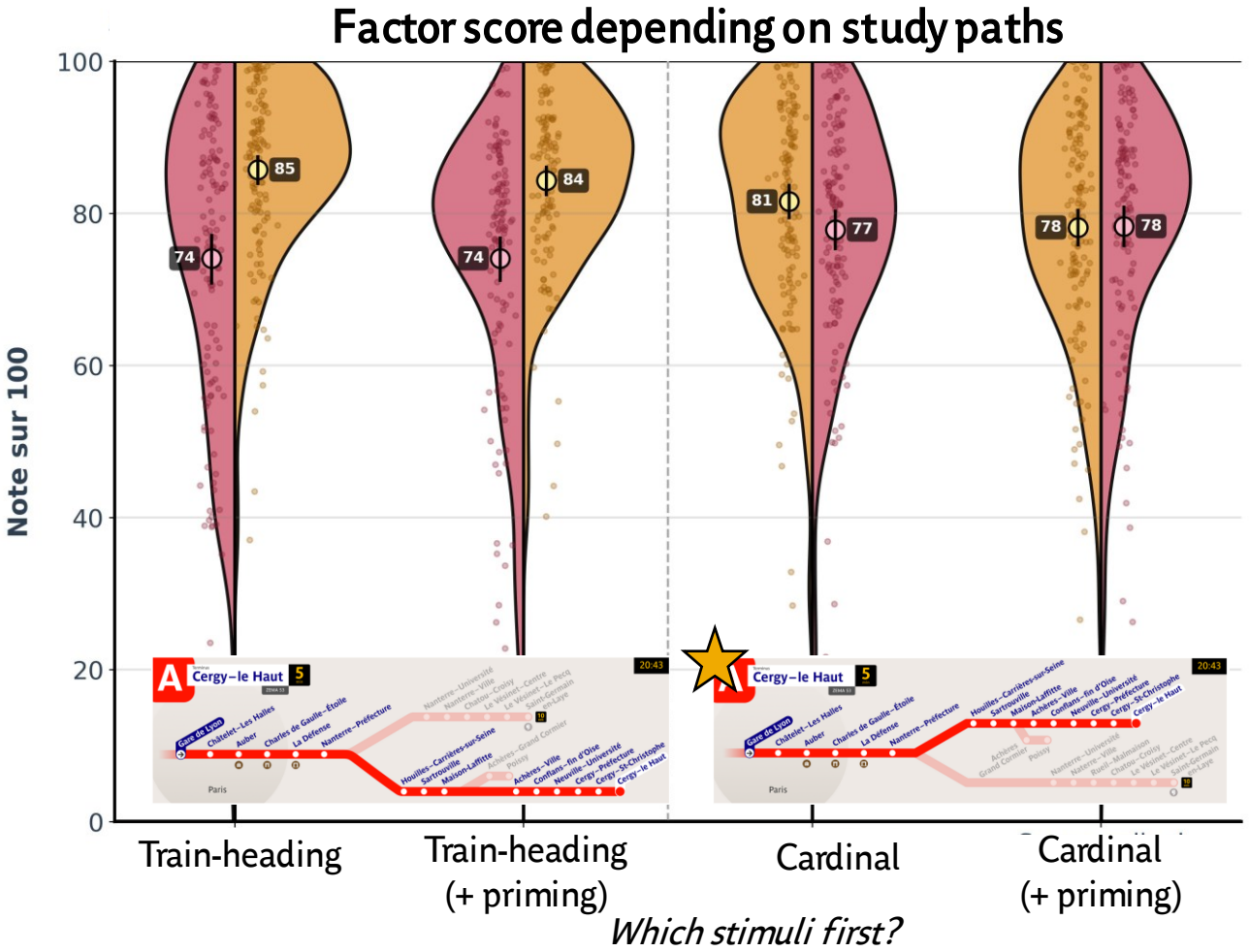
H5: Participants exposed to maps with non-standard cardinal alignment would misplace branches relative to true geographical positions, with reduced errors among those completing prior orientation tasks

H5 results - fully supported:

- Vast majority (86.2%, 95% CI [83.5%, 88.8%]) incorrectly placed branches relative to true geographical positions
- Error rate significantly exceeded chance levels ($p < .001$)
- Prior exposure to cardinally-coherent maps somewhat reduced errors (82.5% with priming vs 89.7% without, $p = .027$)
- Even with priming, error rates remained remarkably high



Experiment 3: North-South Branch Orientation Preferences



Consistent preference for north-at-top placement, even when geographically inaccurate:

- Without priming, north-top first: Small preference for north-top ($Mean_2$=82.35 vs $Mean_1$=78.91, S=0.11, p=.025)
- Without priming, north-bottom first: Medium preference for north-top ($Mean_2$=86.04 vs $Mean_1$=75.49, S=0.33, p<.001)
- With priming, north-bottom first: Medium preference for north-top ($Mean_2$=85.02 vs $Mean_1$=75.23, S=0.34, p<.001)
- With priming, north-top first: No significant preference (p=.935)

H6 not supported: No correlation between spatial abilities and preferences for geographically consistent orientations (ρ=-0.050, p=.399)

Key insight: Preferences driven by conventional orientations rather than geographical accuracy or individual spatial abilities

Conclusion: Independent Frames of Reference in Urban Navigation

- **Left-to-right reading direction emerged as dominant factor** in map orientation preferences, aligning with mental time representations (Tillman et al., 2021) - though digital administration and exclusively French sample limit generalizability across cultures with different reading directions (Maass & Russo, 2003)

- **Transit maps function more as temporally-oriented diagrams than geographically-oriented maps**, emphasizing temporal sequence and conceptual relations over spatial relations (Tversky, 2011)

- Systematic preference for conventional orientations despite geographical inaccuracy (86.2% error rate) demonstrates **dissociation between navigation success and spatial awareness** (Vertesi, 2008)

- The "peculiar flexibility" of directional sense in urban transport: **egocentric and allocentric reference frames operate independently rather than integratively** (Fernandez Velasco & Casati, 2020)

- This cognitive independence enables successful navigation despite disorientation, **reflecting the topologically constrained nature of transit networks where sequential decision-making supersedes continuous spatial orientation** (Augé, 2002; Ekstrom et al., 2018)

Thank you!

APPENDIX

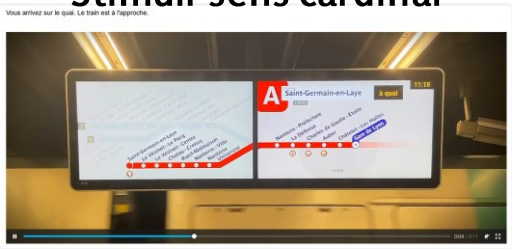
Étude 1

Groupe 1

Stimuli sens marche

Questions (x7)

Stimuli sens cardinal

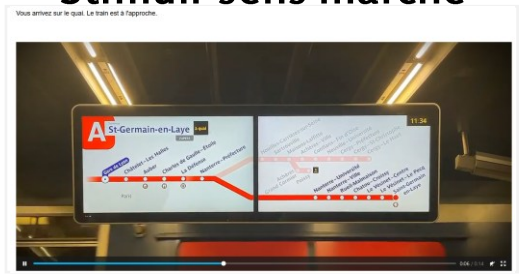


Questions (x7)

Groupe 2

« Priming » orientation

Stimuli sens marche



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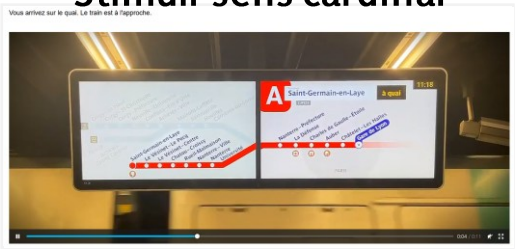

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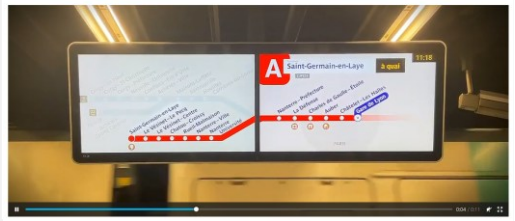
Groupe 3

Stimuli sens cardinal



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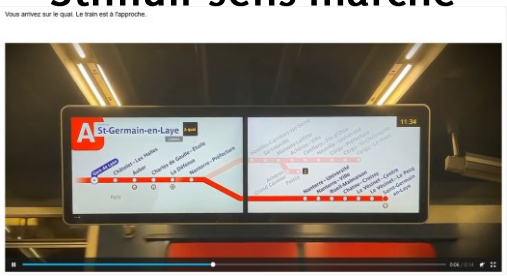
Stimuli sens marche



Questions (x7)

Groupe 4

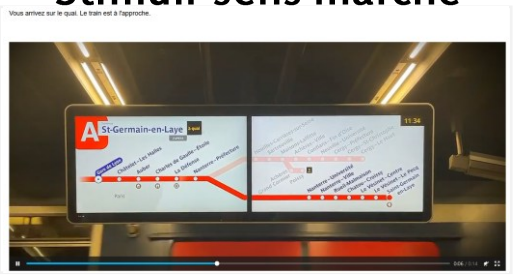
« Priming » orientation

Stimuli sens cardinal

Questions (x7)

« Priming » orientation

Stimuli sens marche



Questions (x7)

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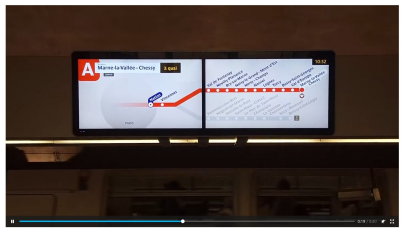
Étude 2

Groupe 1

Stimuli sens marche

Questions (x7)

Stimuli sens cardinal



Questions (x7)

Q. BONUS

Groupe 2

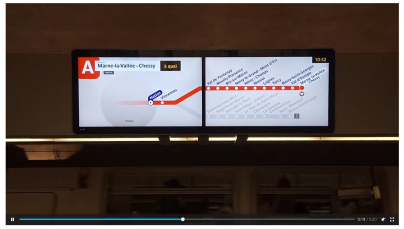
« Priming » orientation

Stimuli sens marche

Questions (x7)

« Priming » orientation

Stimuli sens cardinal



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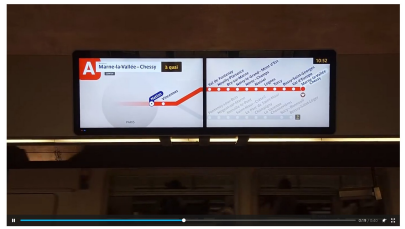
Q. BONUS

Groupe 3

Stimuli sens cardinal



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Q. BONUS

Groupe 4

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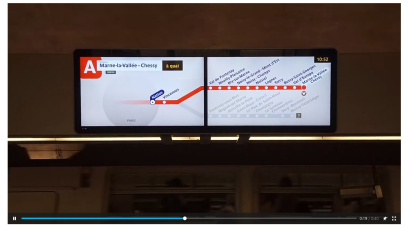

Questions (x7)

« Priming » orientation

Stimuli sens marche

Questions (x7)

Q. BONUS

GROUPE RATP

Étude 3

Groupe 1

Q. BONUS

Stimuli sens marche

Questions (x7)

Stimuli sens cardinal

Questions (x7)

Groupe 2

« Priming » orientation

Q. BONUS

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Groupe 3

Q. BONUS

Stimuli sens cardinal

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Stimuli sens marche

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« Priming » orientation

Q. BONUS

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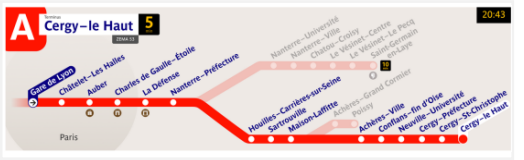

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GROUPE RATP