Towards Design Recommendations for Tactile Maps

Experiments about Locating Positions in Tactile Maps

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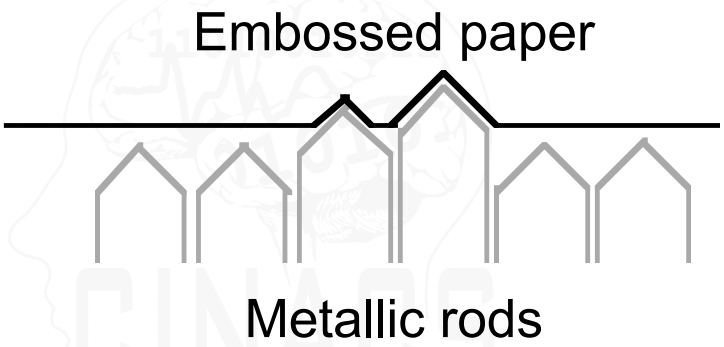
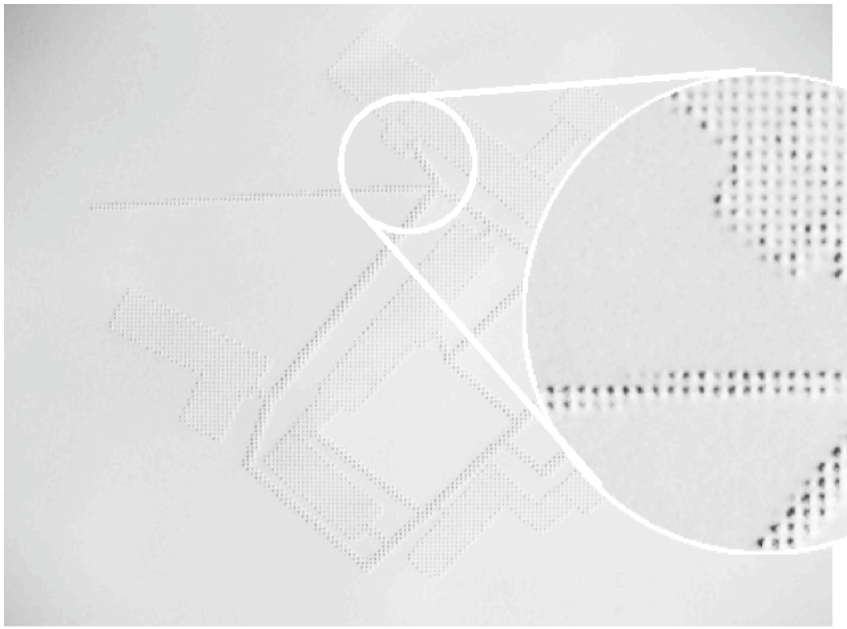
Research Topic

Context of Research

- Context: Communication of spatial representations
- Problem: Simple adoption of visual maps into tactual format not adequate for blind people
- Solution: Support computer-centred production of tactile maps by providing a set of design recommendations

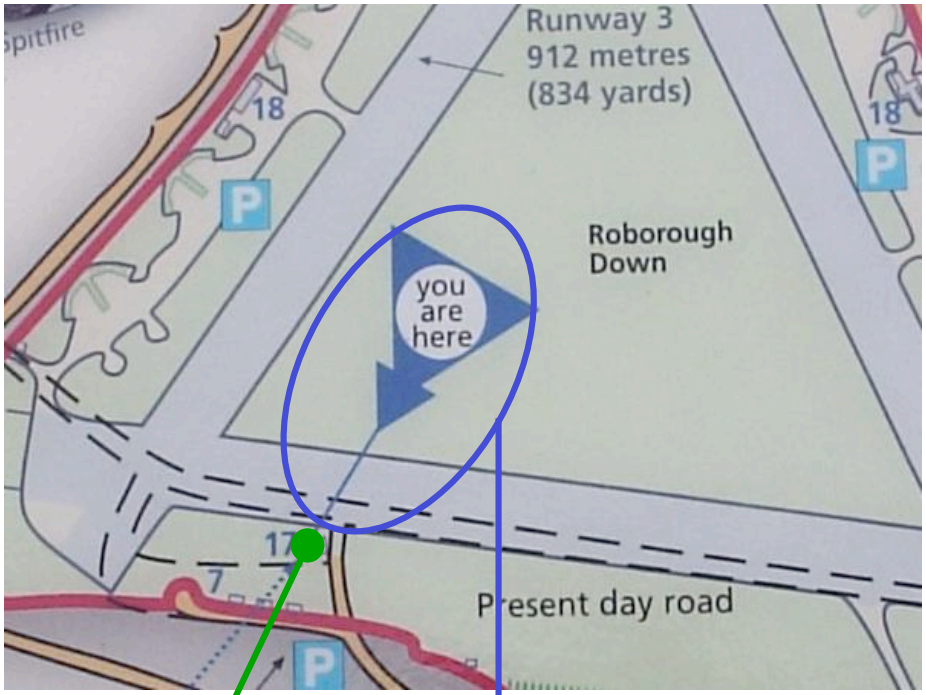
Computer-centred Production of Tactile Maps





- Tactile printer affords tactile maps as immediate print outs
  - Algorithmic, computer controlled process
  - Immediate, non-manual design & production

A special class of maps: You-Are-Here (YAH) Maps



Example: Visual YAH map 1

YAH Location Symbol:

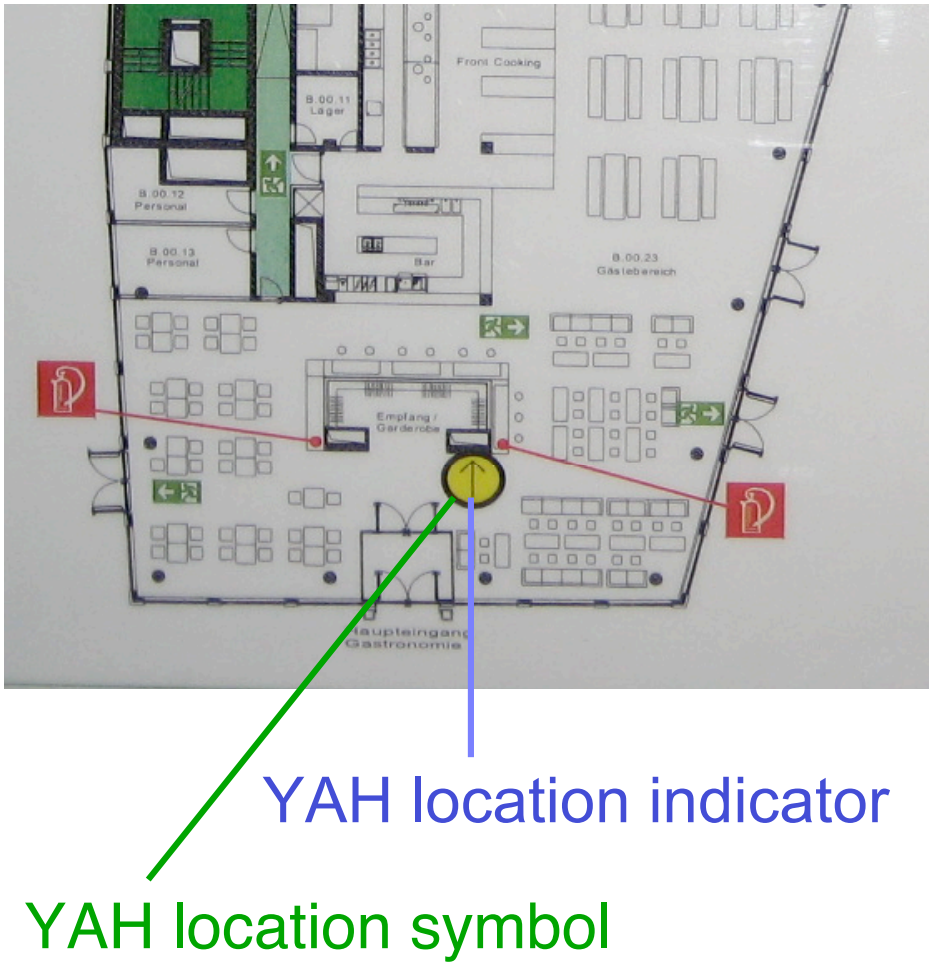
- Co-located with the representation of the map viewer's position (i.e. the YAH location)

YAH Location Indicator *:

- Helps to find the YAH location
- Visually prominent entity
- Often incorporates a sign, the YAH symbol

* Also known as 'IDEO locator'

A special class of maps: You-Are-Here (YAH) Maps



Example: Visual YAH map 2

YAH Location Symbol &
YAH Location Indicator

- All-in-one solution
- Indicates position
- Attracts visual attention

Motivation & Goal

- Computer-centred production of tactile maps is a comparable young discipline
- Initial design recommendations have to be established
- Goal: Identify parameters that are essential for the production of useful and usable tactile maps

Efficiency in usage

Cognitive Adequacy

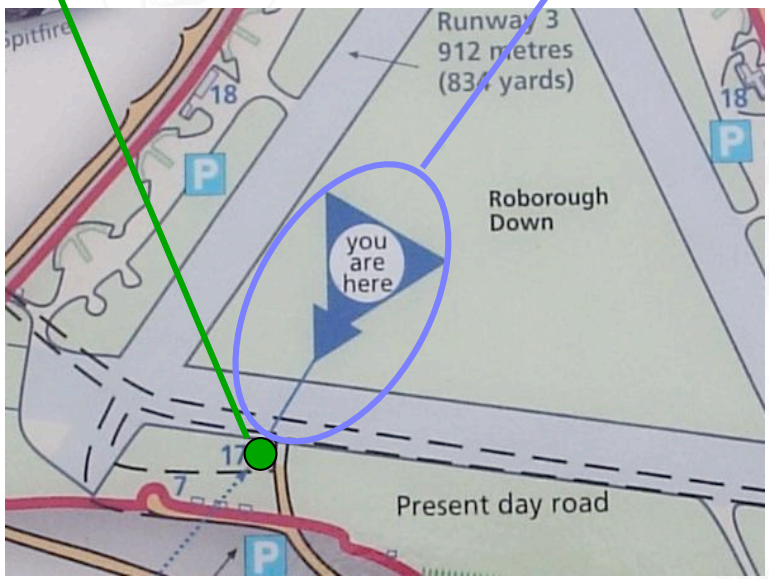
YAH Map Usage : Usage of YAH Maps

- From using a visual YAH map we may assume that using a tactile YAH map happens alike
  - Search for the YAH location symbol to locate the representation of the viewer's position in the map

YAH location symbol

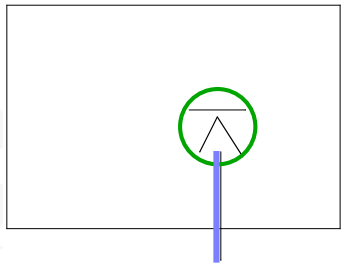
YAH Map Usage : Steps to Find the YAH Point

- 1: Search for the YAH location indicator
- 2: Usage of the YAH location indicator to find the YAH location symbol

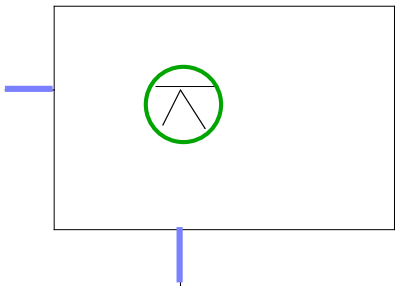


YAH Map Usage : Indicators to Find the YAH Point

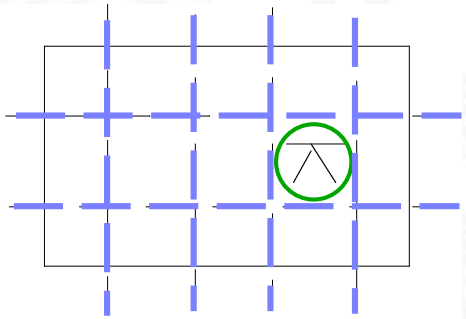
- YAH Location Indicator & YAH Location Symbol must be adopted for the tactile domain



Indicator line



Frame marks

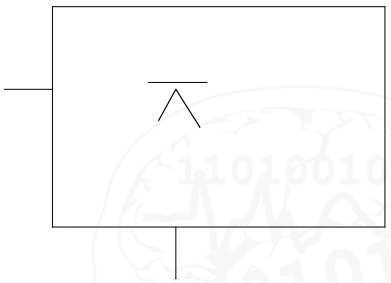


Grid

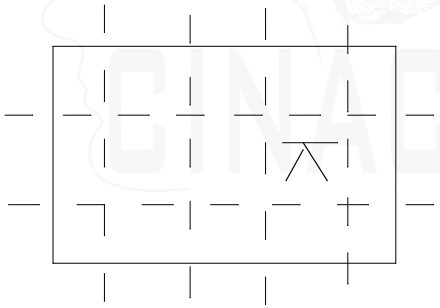
YAH location symbol

YAH location indicator

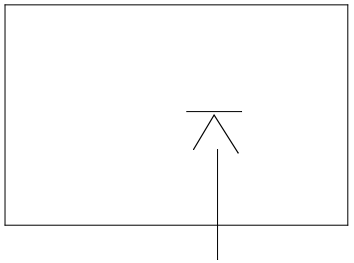
Usage of Indicators under a Cognitive Perspective



- Phase 1: 2 linear searches without distractors for the frame marks
- Phase 2: Frame marks ***point*** to the area where the YAH location symbol is located



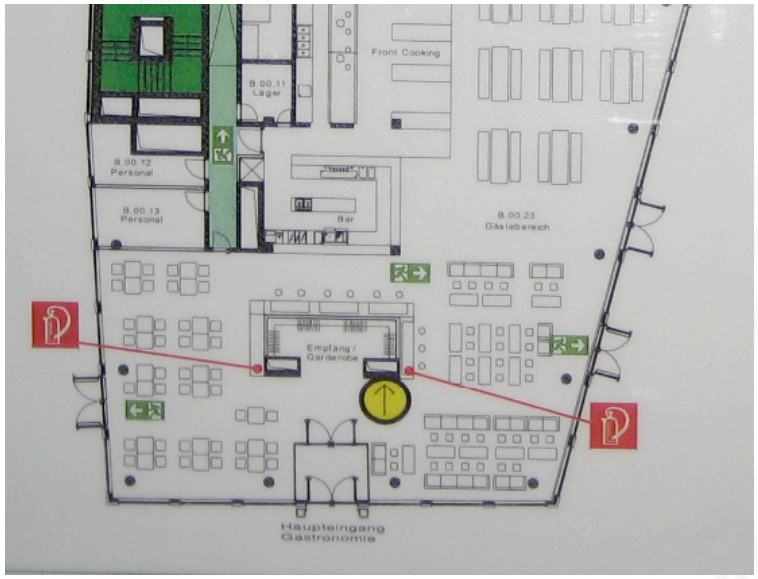
- Phase A.1: 2 linear searches with distractors along the frame borders for the coordinates
- Phase A.2: Grid lines ***guide*** to the area where the YAH location symbol is located



- Phase A.1: 1 linear search along one set frame border without distractors for start of indicator line
- Phase A.2: Indicator line ***guides*** to the position of the YAH location symbol

YAH Map Usage : Map Exploration

- From using a visual YAH map we may assume that using a tactile YAH map happens alike
  - Exploration of the map to obtain an overview of the displayed area (i.e. a learning task)



Research Questions

- To evaluate Efficiency in usage (in Find the YAH Point):
  - Among the three options, which type of indicator is the most efficient for finding the YAH location in a tactile map?
- To evaluate Cognitive Adequacy (in Map Exploration):
  - How much do the indicators impede the acquisition of a mental representation of the maps?

Content

- (Pre-Study)
- Main Experiment
  - Design
  - Methodology
  - Results
- Discussion & Further Work

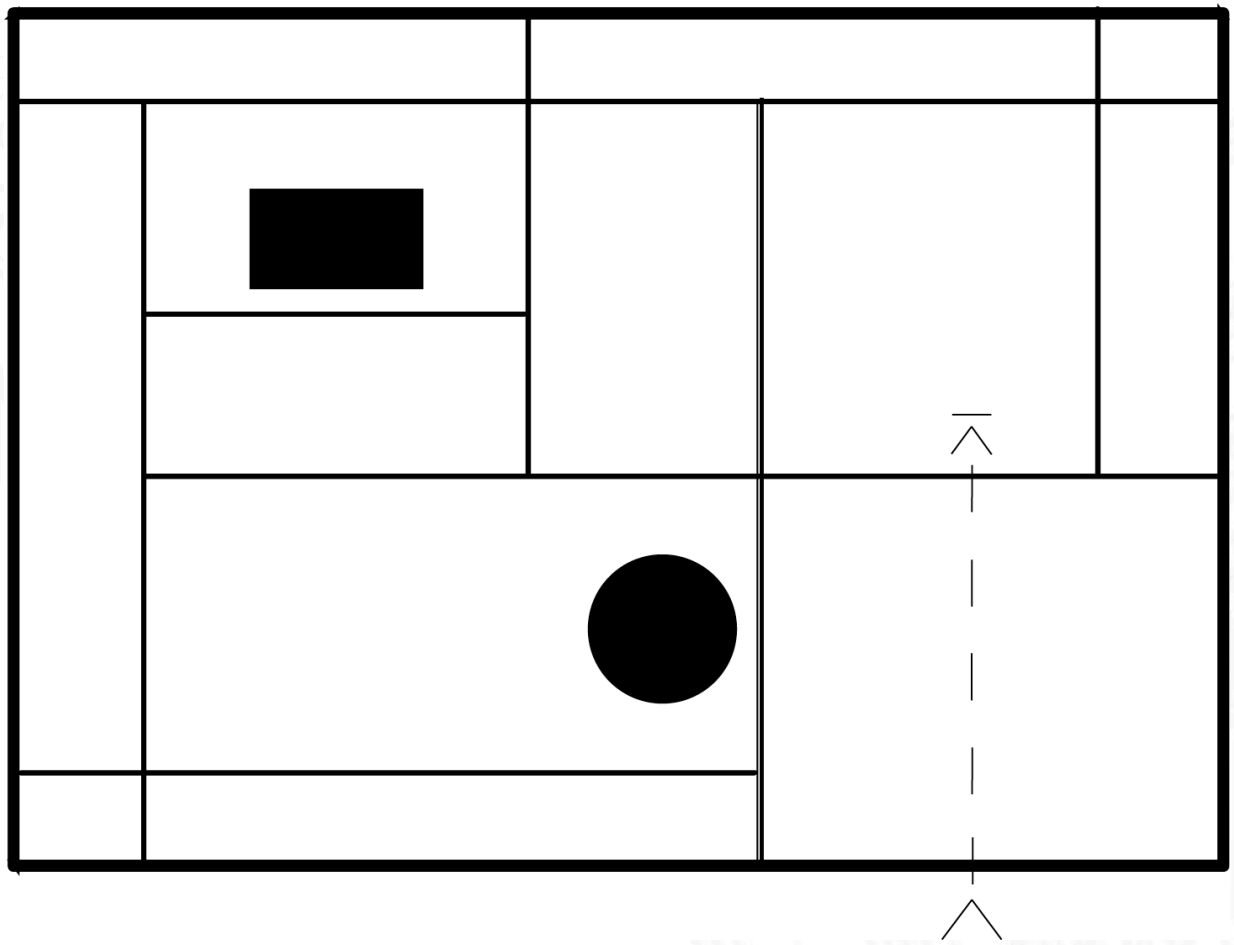
Main Experiment

Design

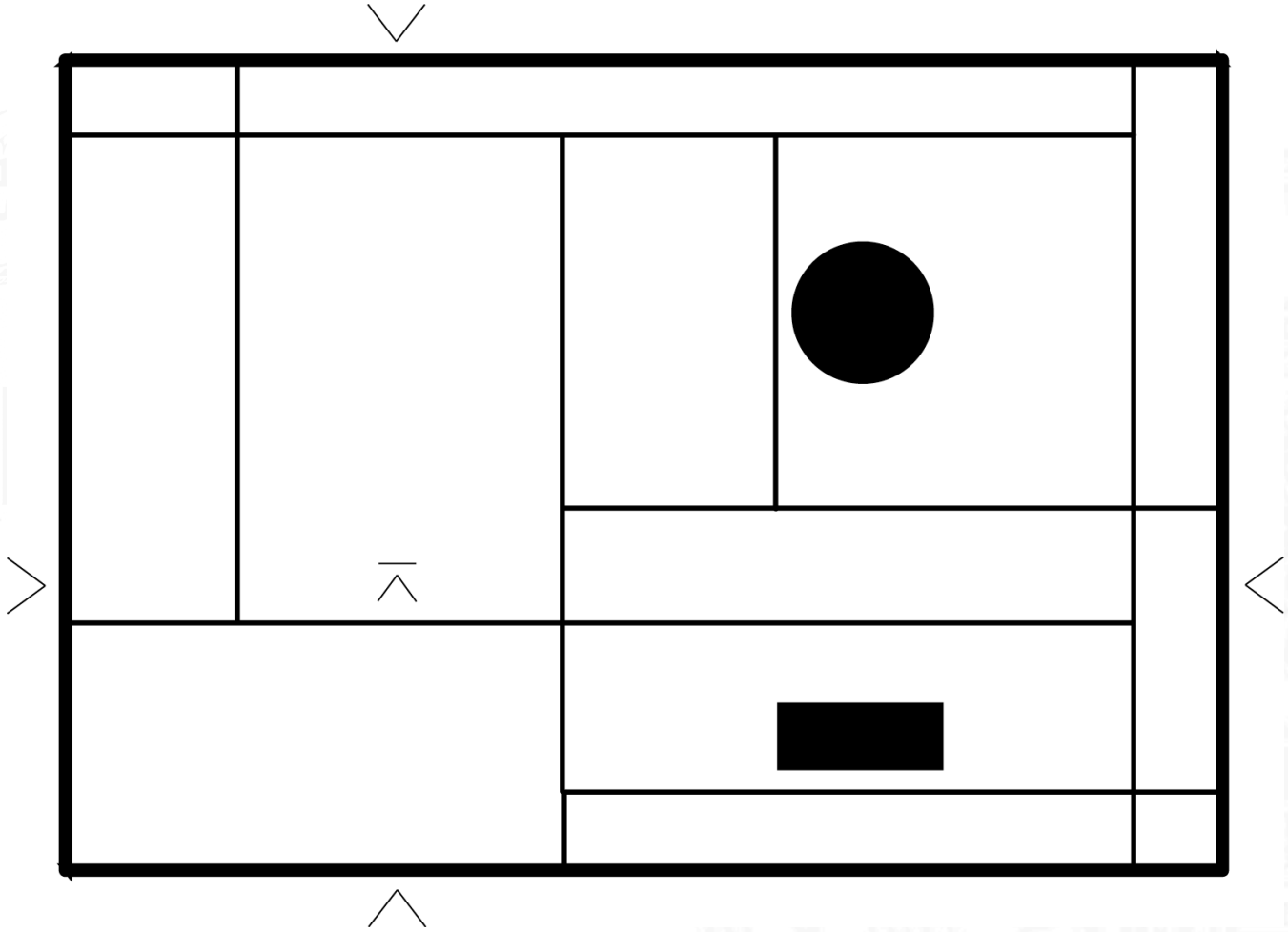
Design

- Within subjects design
  - Exploratory experiment (no control group)
  - 3 conditions per subject: Indicator Line, Frame Marks, Grid

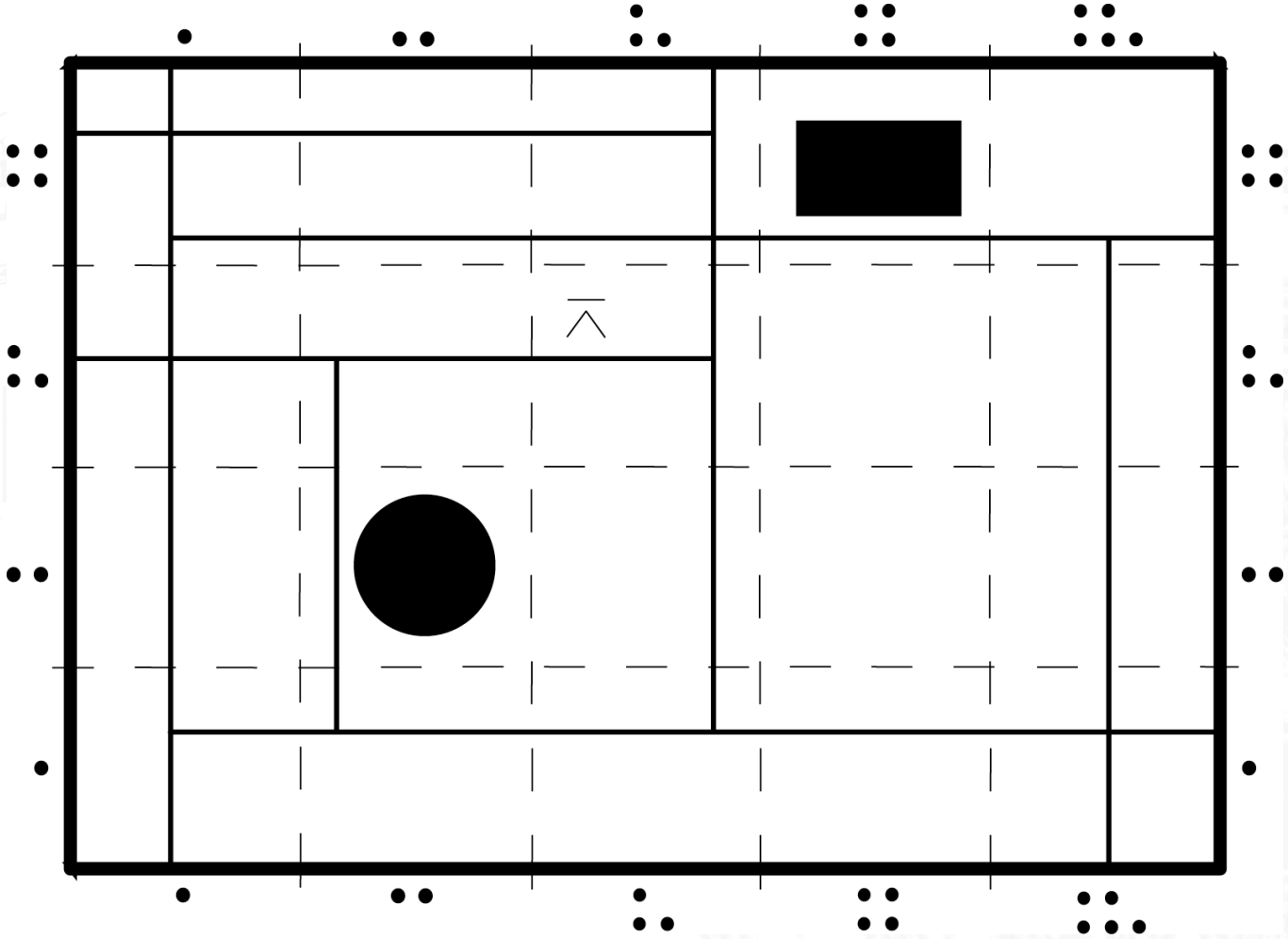
Condition Indicator Line



Condition Frame Marks



Condition Grid



Design

- Within subjects design
  - Exploratory experiment (no control group)
  - 3 conditions per subject
  - 4 tasks per conditions + 2 tasks per experiment
  - Each task defines one stage of an experimental run

Stages of One Experimental Run and Subjects' Tasks

[FindYAHpoint]	Find the YAH Point as fast as possible!
[ExploreMap]	Explore the map until you are confident in knowing the area so that you could describe routes!
[DescribeRoutes]	Describe two routes between landmarks: From A to B and from B to C!
[DrawMap]	Draw a map of the area!
[RankRefFind]	Rank the indicator types according to how helpful they were for you in finding the YAH point!
[RankRefExplore]	Rank the indicator types according to how hindering they were for you in the exploration of the map!

Design

- Within subjects design
  - Exploratory experiment (no control group)
  - 3 conditions per subject
  - 4 tasks per conditions + 2 tasks per experiment
  - Each task defines one stage of an experimental run
  - Qualitative and quantitative measures were used

Quantitative Measures

[FindYAHpoint] Performance of the test subjects (in seconds) to locate the YAH point.

[ExploreMap] Performance of the test subjects (in seconds) to learn the whole map.

Qualitative Measures

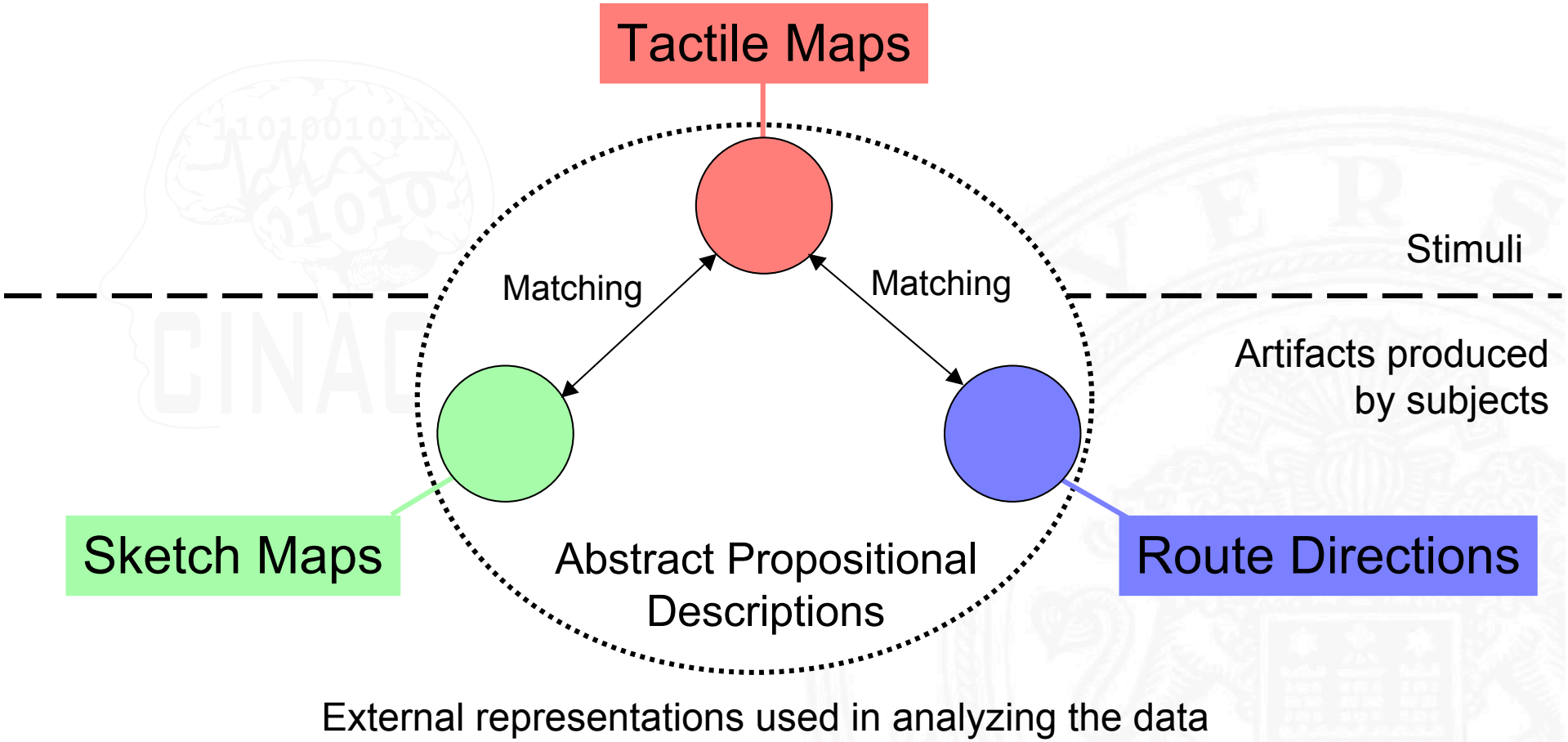
[DescribeRoutes]	Ratings of the externalised route knowledge (in verbal route directions)
[DrawMap]	Ratings of the externalised survey knowledge (in sketch maps)
[RankRefFind]	Ratings by test subjects
[RankRefExplore]	Ratings by test subjects

Expectations

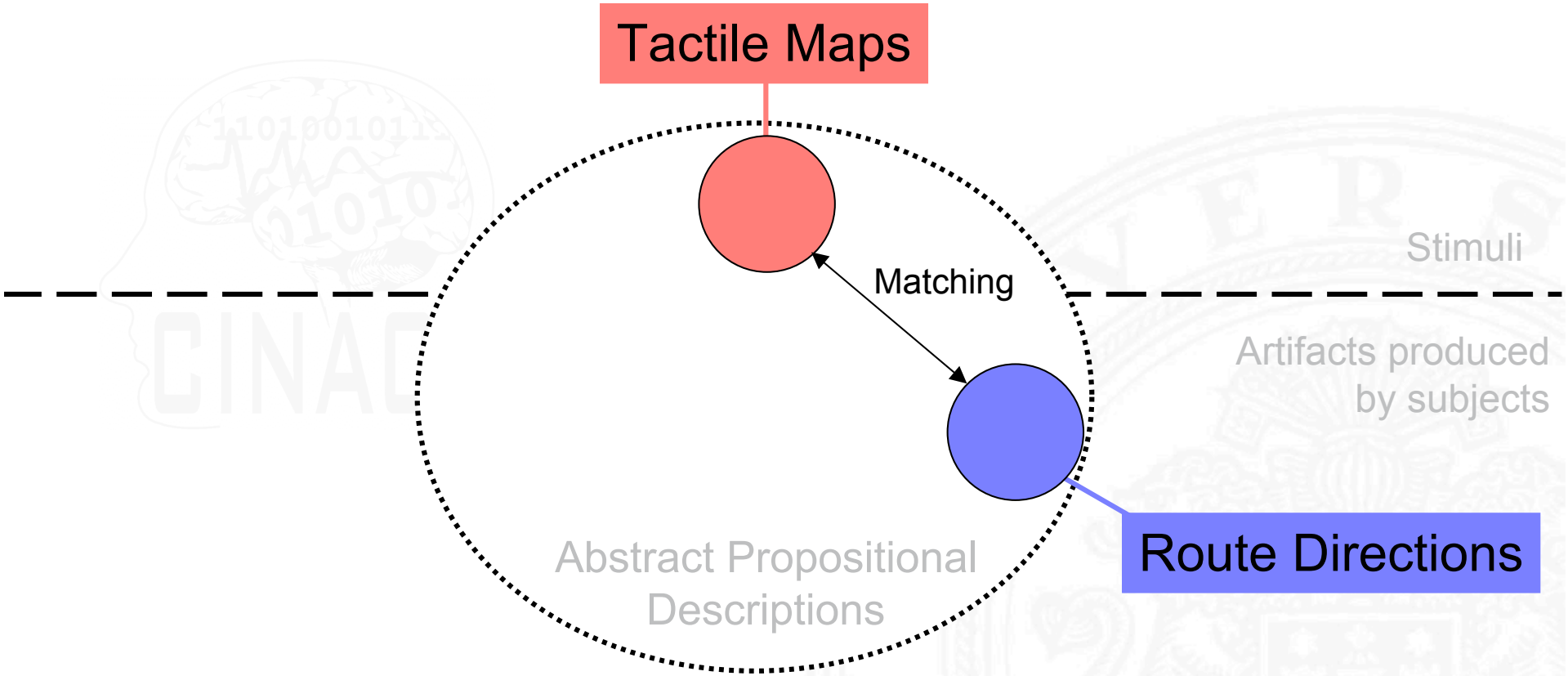
- Efficiency in usage (Phase A):
  - Subjects perform best with Guiding line
  - Subjects perform worst with Grid
- Cognitive Adequacy (Phase B):
  - Subjects perform best with Frame marks
  - Subjects perform worst with Grid

Main Experiment
Methodology

Methodology of Evaluation



Evaluation of Route Directions



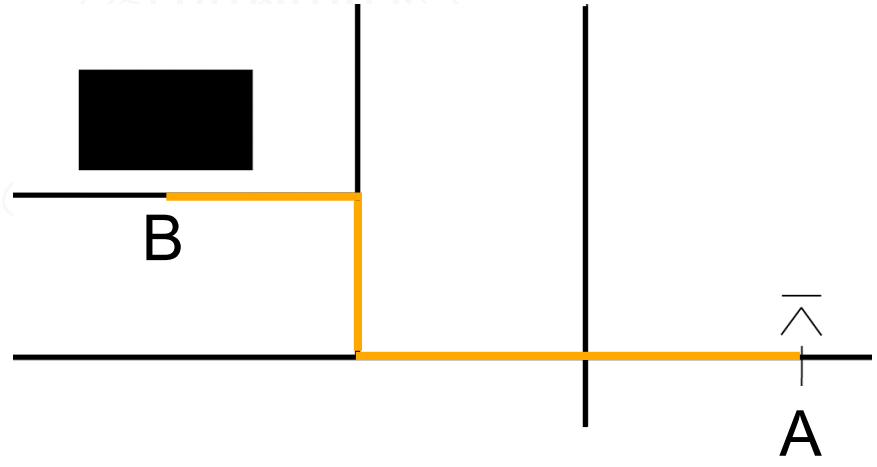
Verbal Route Directions to Abstract Route Representation

Individual Verbal Route Direction (with *German originals*)	**Individual Abstract Route Representation**
Walk the path to the left. *Gehe den Weg links runter,*	*GO(left)
straight ahead at the first junction, *an der ersten Kreuzung geradeaus,*	BE_AT(first intersection) *GO(straight)
at the next junction walk to the right, *an der nächsten Kreuzung gehe nach rechts,*	BE_AT(next intersection) *GO(right)
then to the left immediately. *dann sofort wieder links.*	*GO(left)
Then, the building should be at the right side. *Dann müßte das Gebäude auf der rechten Seite liegen.*	BE_AT(building, right)

Method adopted from Denis (1997), Representation format proposed by Tschander et al. (2003)

Extraction of Abstract Route Representations from Tactile Maps

Example: Indicator Line Condition, Route from A to B



BE_AT(YAH, front)
*GO(left)
BE_AT(first intersection) *GO(straight)
BE_AT(second intersection) *GO(right)
BE_AT(next intersection) *GO(left)
BE_AT(building, right)

Matching of Individual Route and Extracted Route Representation

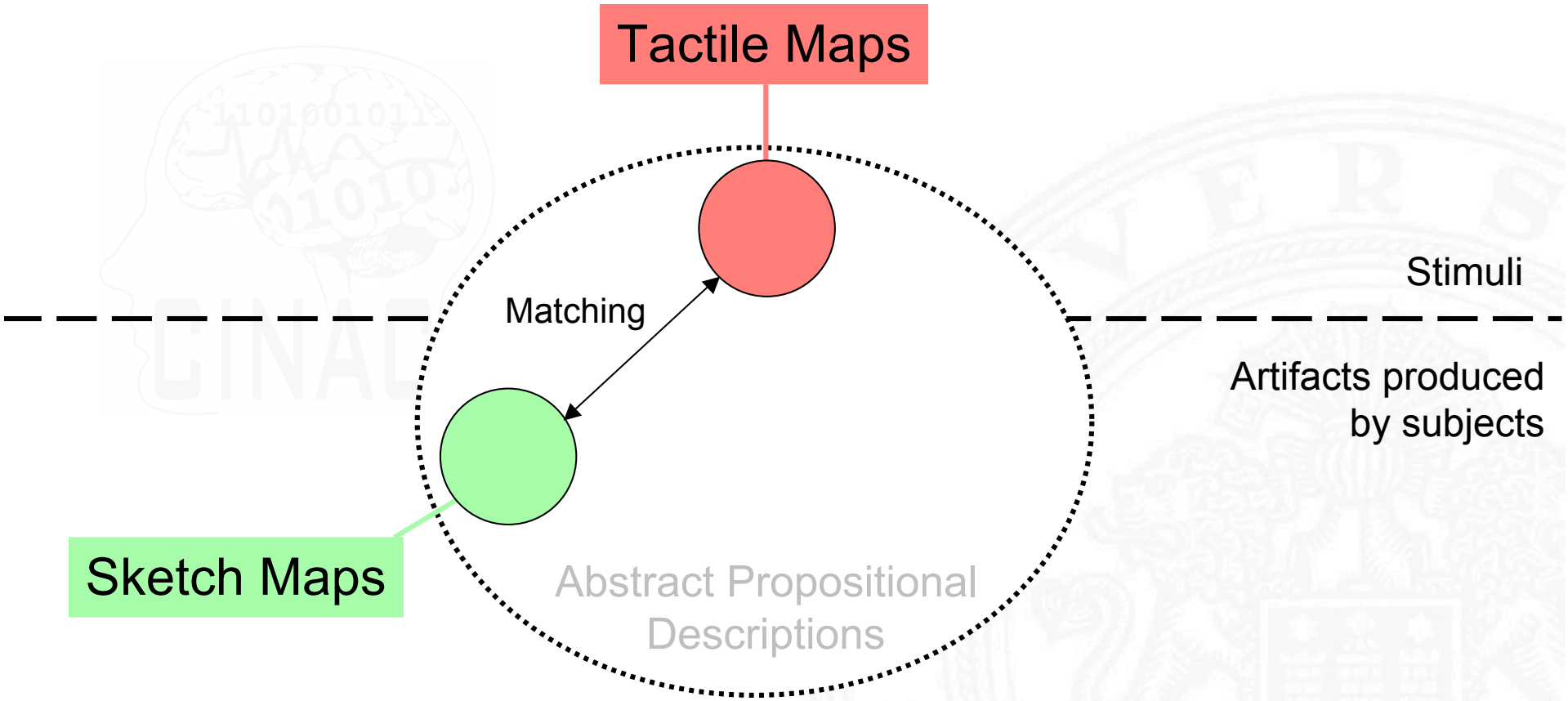
- Each step of an individual route instruction was matched with the corresponding step of the extracted abstract route representation
- A weight was assigned to each step and of the instruction according to its impact for successful route following
  - Orientation towards the start landmark
  - Mandatory actions on route
  - Orientation towards the final landmark
  - Optional reorientation with landmarks/track segments

Example: Matching of Individual Route and Extracted Route

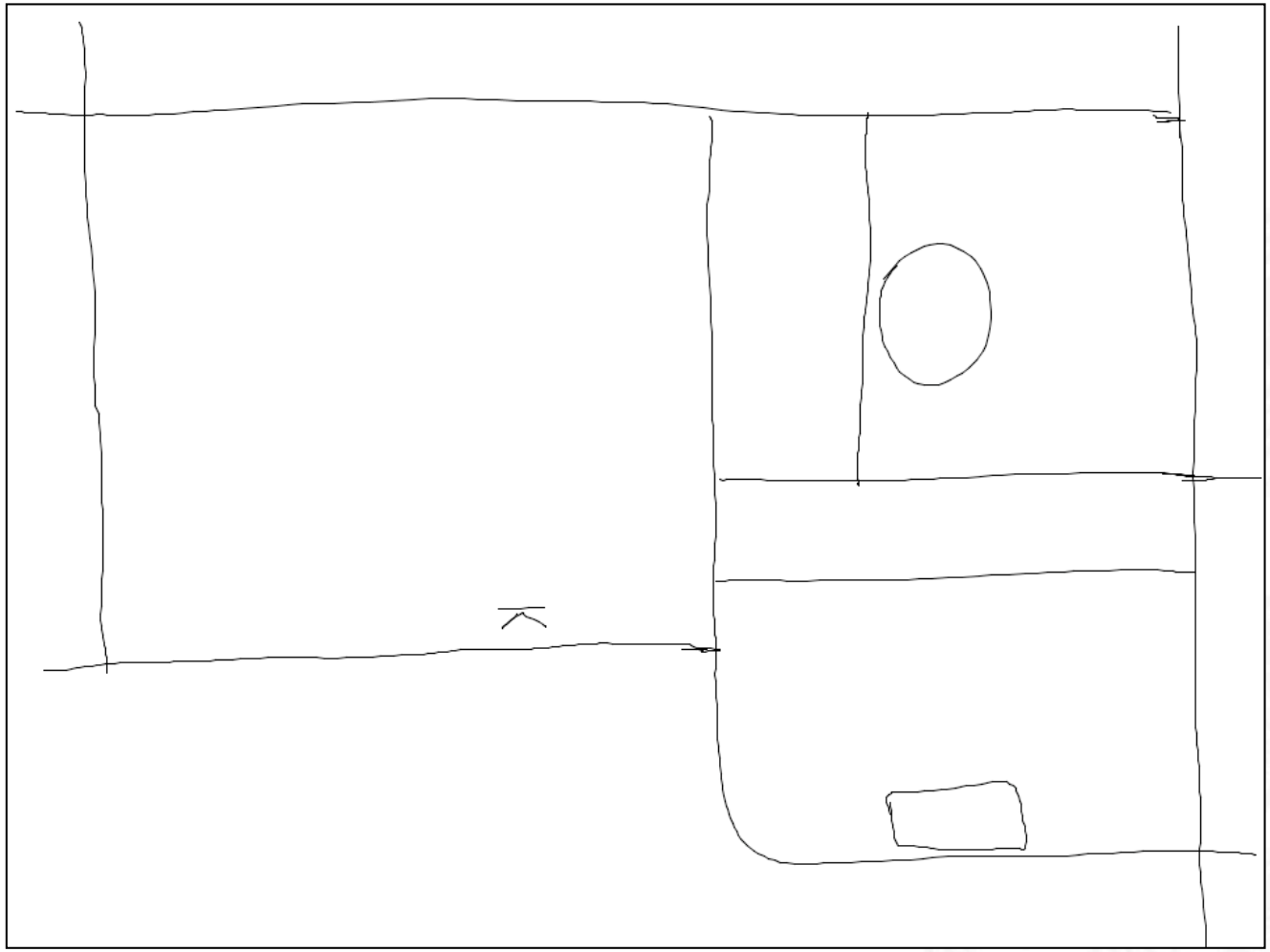
Individual Abstract Route Instruction	**Extracted Abstract Route Instruction**	**Match-ing**	**Weight**	**Sum**
	BE_AT(YAH, front)	☐	1/6	0
*GO(left)	*GO(left)	☑	1/6	0.166
BE_AT(first intersection) *GO(straight)	BE_AT(first intersection) *GO(straight)	☑ ☑	1/12 1/12	0.166
BE_AT(next intersection) *GO(right)	BE_AT(second intersection) *GO(right)	☑ ☑	1/12 1/12	0.166
*GO(left)	BE_AT(next intersection) *GO(left)	☐ ☑	1/12 1/12	0.083
BE_AT(building, right)	BE_AT(building, right)	☑	1/6	0.166
			Total	**0.75**

A weighted sum can be computed for each individual route instruction.

Evaluation of Sketch Maps



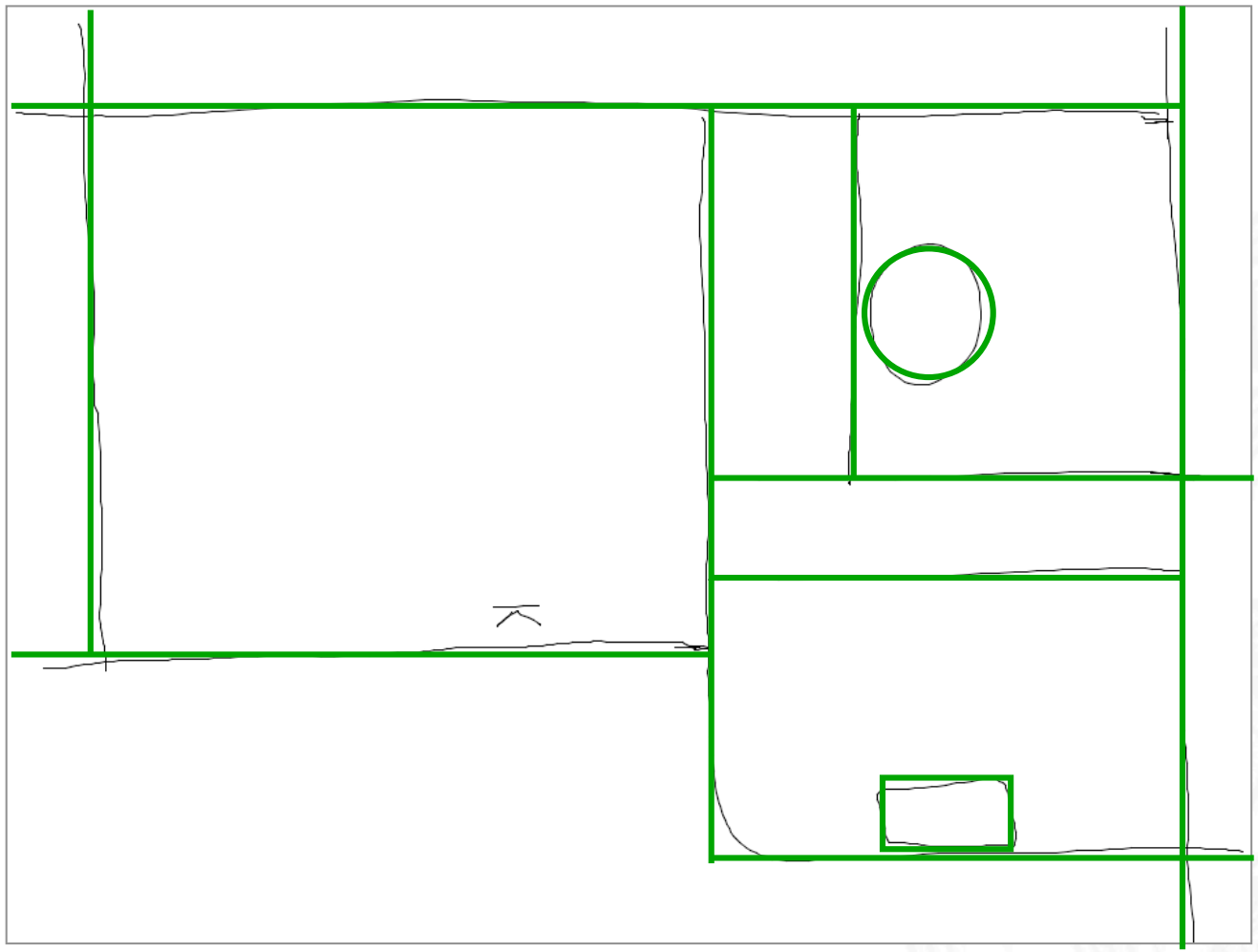
Example: Some Individual Sketch Map



Abstraction of Individual Sketch Maps

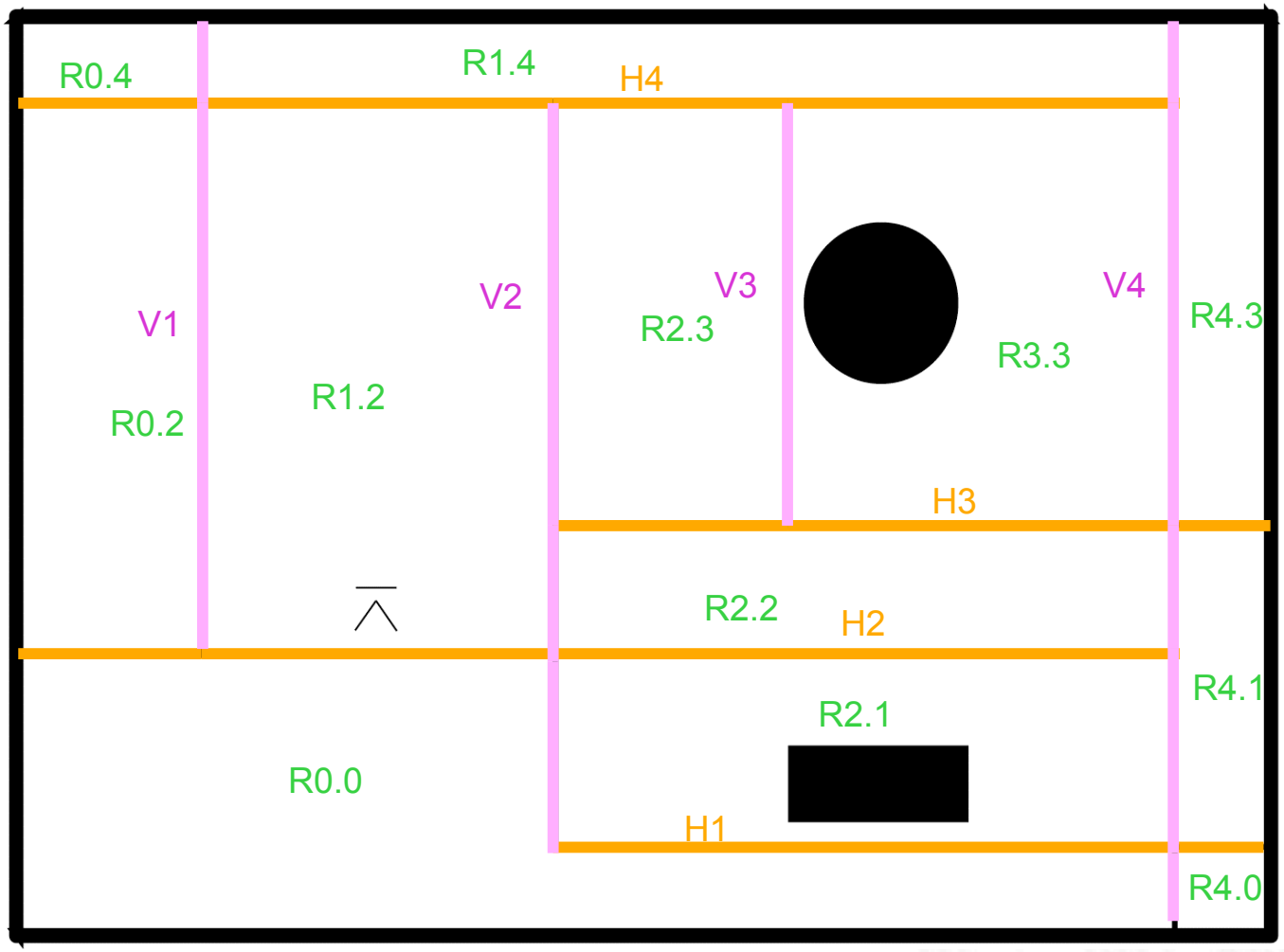
- Geometric details was abstracted
  - Strokes slanted up to 6° were made horizontal lines
  - Strokes with orientation 90°± 6° were made vertical lines
  - Gaps in lines of up to 6mm were collapsed
  - Overshots of up to 3mm were omitted
  - Double strokes were omitted
  - Round corners were „sharpened“
  - Geometric shapes were replaced by a prototype

Example: Abstracted Individual Sketch Map



With abstract sketch maps, topology and geometric positions of landmarks can be coded propositionally

Example: Encoding the Structure of a Tactile Map



- Horizontal & Vertical lines are labeled
- Regions are labeled

Example: Encoding the Structure of a Tactile Map

Es gibt vier horizontale Wege.

Es gibt vier vertikale Wege.

V4 startet am nördlichen und endet im südlichen Kartenrand.

V4 hat vier Kreuzungen und fünf Abschnitte.

V4 kreuzt H4.

V4 kreuzt H3.

V4 kreuzt H2.

V4 kreuzt H1.

H4 startet am westlichen Kartenrand und endet in V4.

H4 hat drei Kreuzungen und vier Abschnitte.

H4 kreuzt V1.

H4 kreuzt V2.

H4 kreuzt V3.

H2 startet am westlichen Kartenrand und endet in V4.

H2 hat zwei Kreuzungen und drei Abschnitte.

H2 kreuzt V1.

H2 kreuzt V2.

V1 startet am nördlichen Kartenrand und endet in H2.

V1 hat eine Kreuzung und zwei Abschnitte.

V1 kreuzt H4.

V2 startet an H4 und endet in H1.

V2 hat zwei Kreuzungen und drei Abschnitte.

V2 kreuzt H3.

V2 kreuzt H2.

H1 startet am östlichen Kartenrand und endet in V2.

H1 hat eine Kreuzung und zwei Abschnitte.

H1 kreuzt V4.

H3 startet am östlichen Kartenrand und endet in V2.

H3 hat zwei Kreuzungen und drei Abschnitte.

H3 kreuzt V4.

H3 kreuzt V3.

V3 startet H4 und endet in H3.

Das runde Gebäude befindet sich an V3.

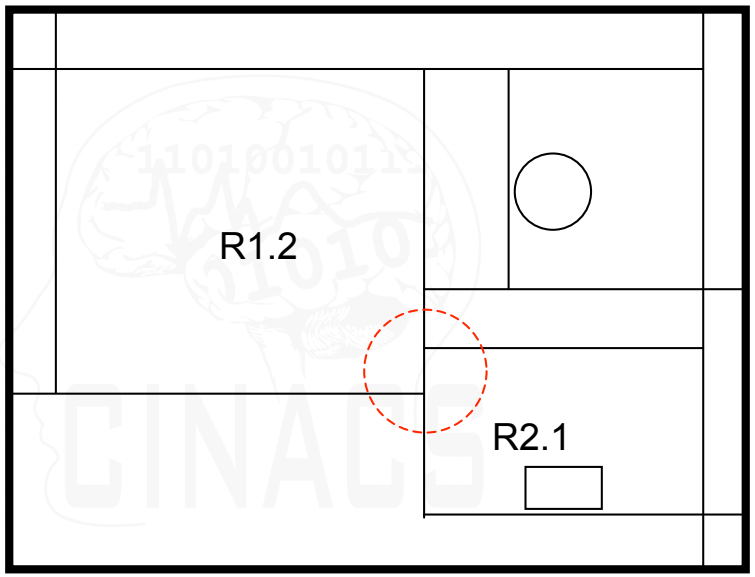
Das rechteckige Gebäude befindet sich an H1 westlich von V4.

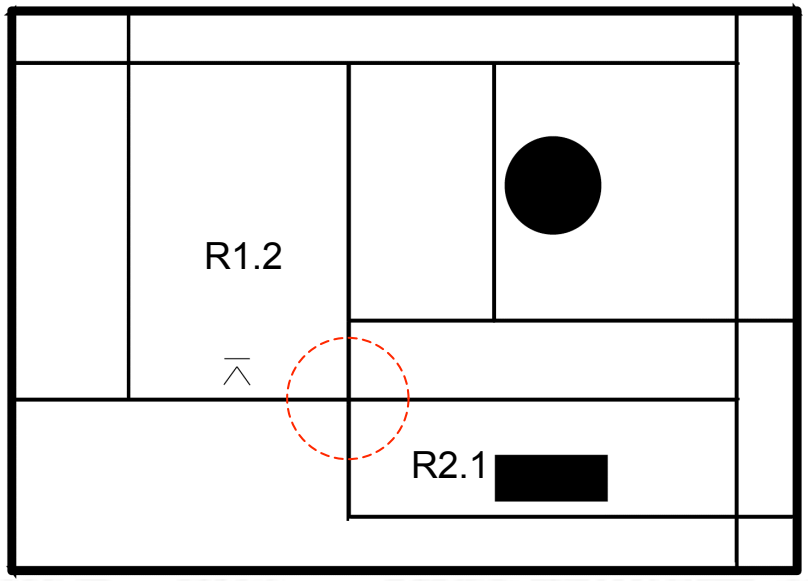
Der YaH-Punkt befindet sich an H2 östlich von V1.

Matching of Abstracted Sketch Map and Tactile Map

- The propositional encoding of the map template is matched to the abstracted sketch map.
  - Matching of segments and regions
  - Matching of the topology of regions with landmarks (neighbourhood relation)
  - Matching of geometric position of landmarks in regions and along segments
- The completeness of the external representation of survey knowledge is measured.

Example: Matching of Abstract Sketch Map to Tactile Map





There are four vertical lines.	✓	There are four vertical lines.
There are five horizontal lines.	F	There are four horizontal lines.
Three regions bear one landmark.	✓	Three regions bear one landmark.
Region R1.2 is adjacent to region R2.1.	F	{Ø}
[…]		[…]

Main Experiment
Results

Results from Observations (FindYAHpoint & ExploreMap)

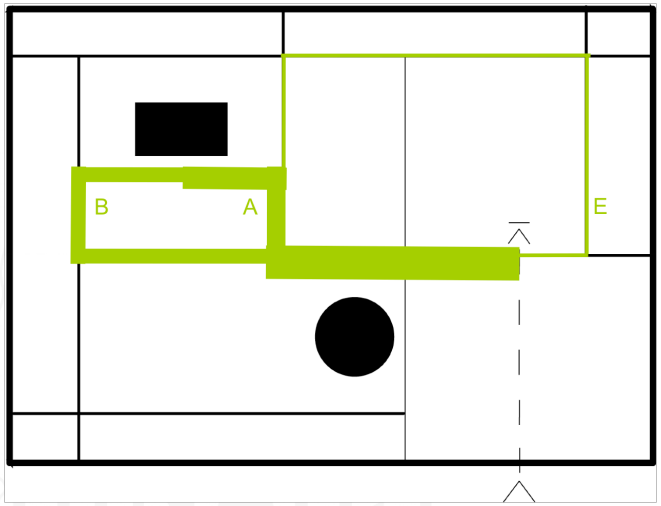
	Mean time to find the YAH point (in s)	Mean time for exploring the map (in s)
IL	27.09	256.58
FM	19.36	328.50
GR	144.92	491.25

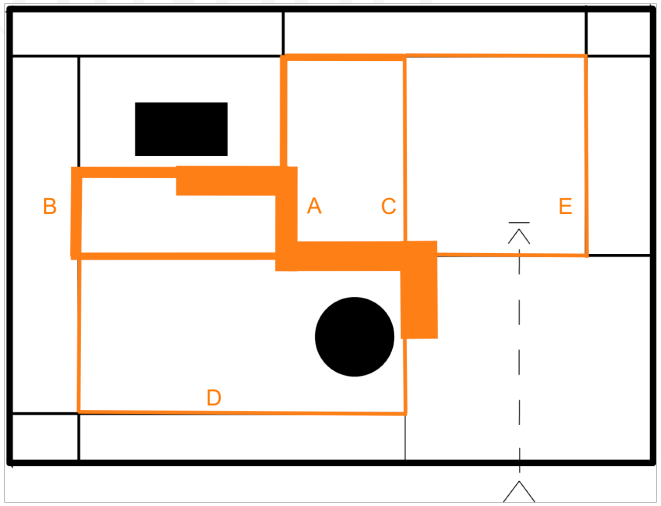
- There is a statistical significant difference between
  - Grid condition and Indicator Line conditions
  - Grid condition and Frame Marks condition
- No statistical significant difference between Frame Marks condition and Indicator Line condition

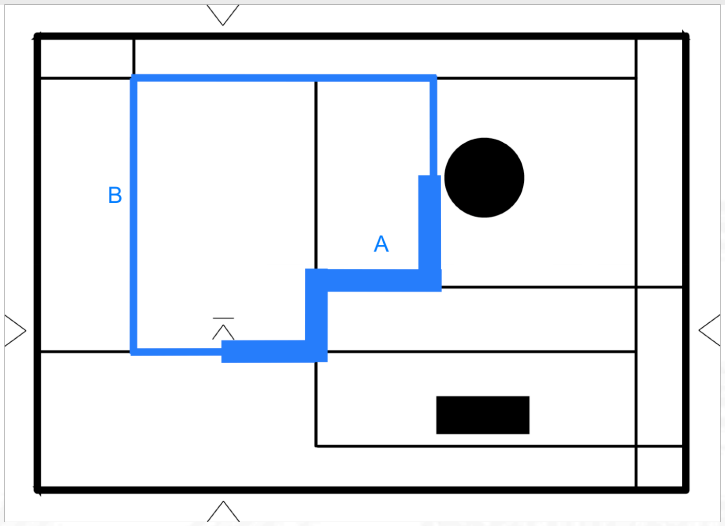
Results from Verbal Descriptions (DescribeRoutes)

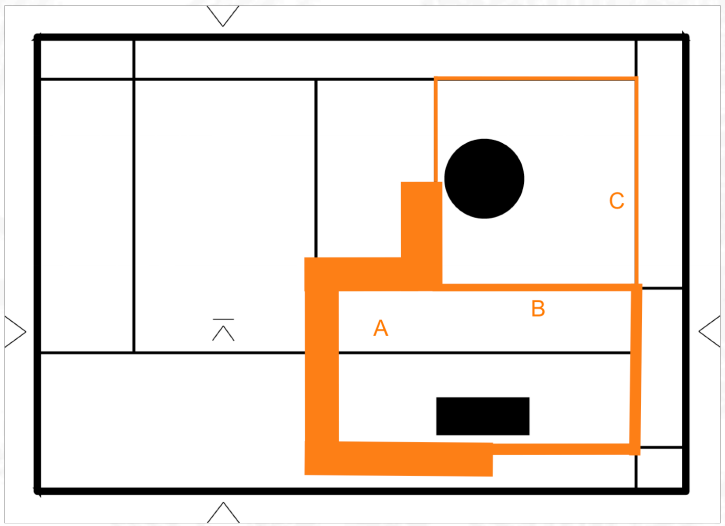
- Only in Grid condition subjects interchanged landmarks
- Directions from the Indicator Line condition rated the best
- Directions from Grid condition rated the worst
- No significant statistical difference in quality between all conditions
- Some test-subjects saw an advantage in remembering long straight segments even if it costs more turns

Visualisation of Route Directions (a selection)









Results from Sketch Maps (DrawMap)

- Sketches from Frame Marks condition rated best
- Sketches from Grid condition rated worst
- Sketches from Frame Marks & Indicator Line condition differ statistically significantly in quality from Grid condition
- Sketches from Frame Marks condition and Indicator Line condition do not differ significantly in quality
- 22% showed characteristics that are usually found in 'route maps' (Tversky 1999, 2002)
- In the Grid condition 62,5% of route maps were produced

Results from Subjective Ratings (RankRefFind & RankRefExplore)

- Frame Marks condition best for finding the YAH point and least hindering in exploration of the map
- Grid condition worst in both subjective ratings

Discussion

Interpretation of Results

- Efficiency in usage:
  - The grid is significantly worse than the indicator line or the frame marks.
  - Results in the frame marks condition do not significantly differ from results in indicator line condition.
- Cognitive Adequacy:
  - The grid has an significant detrimental effect on acquiring a mental representation that stores survey knowledge.
  - The good results in the indicator line condition do not significantly differ from results in the frame marks condition.
  - Subjective ratings appear to support this result.

Expectations Reviewed

- Efficiency in usage:
  - Subjects perform best with Guiding line (✓)
  - Subjects perform worst with Grid ✓
- Cognitive Adequacy:
  - Subjects perform best with Frame marks (✓)
  - Subjects perform worst with Grid ✓

Guiding line & Frame Marks not differ that much.

Recommendation: Use an indicator line or frame marks to indicate the position of an entity in a tactile map, not a grid.

Upcoming Experiments

- Investigations about the complexity threshold for using verbally annotated tactile You-Are-Here maps
  - Usage of ecologically valid maps
  - Check which complexity is manageable with pure tactile maps and which not
  - Goal: Support knowledge acquisition by verbally conveyed content

Thank you for your attention!

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References

Denis, M. (1997). The description of routes: A cognitive approach to the production of spatial discourse. *Cahiers de Psychologie Cognitive*, *16*(4), 409-458.

Tschander, L. B., Schmidtke, H. R., Eschenbach, C., Habel, C., & Kulik, L. (2003). A geometric agent following route instructions. In *Spatial Cognition III*, *Lecture notes in computer science 2685* (pp. 89-111). Berlin / Heidelberg: Springer.

Tversky, B. (2002). What do sketches say about thinking? In *2002 AAAI Spring Symposium, Sketch Understanding Workshop*. Stanford, CA: Stanford University, AAAI Tech. Rep. SS-02-08, Mar. 2002, pp. 148–151.

Tversky, B., & Lee, P. U. (1999). Pictorial and Verbal Tools for Conveying Routes. In *Proceedings of the International Conference on Spatial Information Theory: Cognitive and Computational Foundations of Geographic Information Science*, Lecture Notes in Computer Science (pp. 51-64). Springer-Verlag. doi: 10.1.1.87.8332.