Multiple Coordinated Views at Large Displays for Multiple Users:
Empirical Findings on User Behavior, Movements, and Distances

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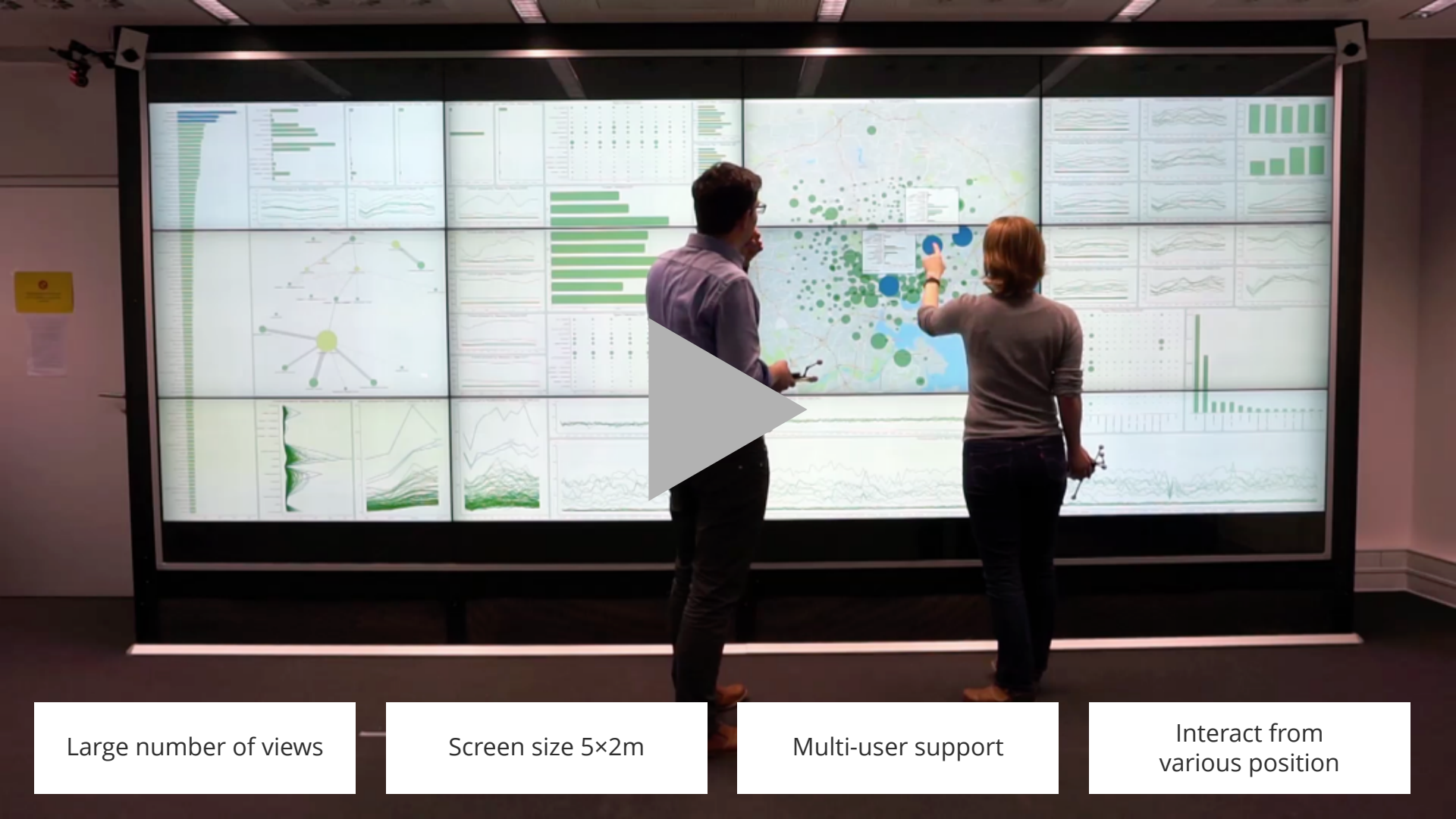


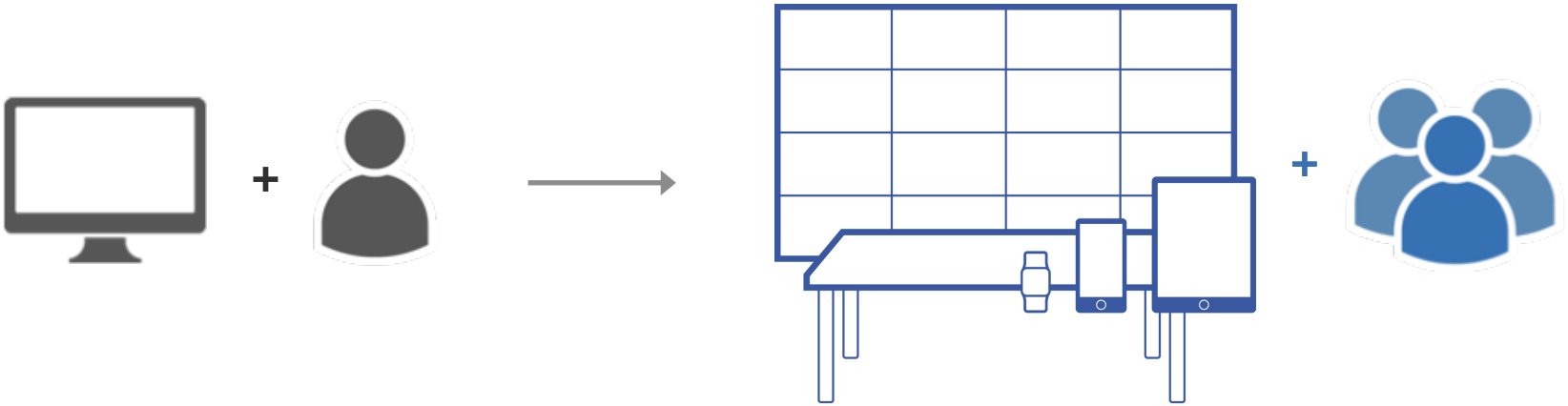
Large number of views

Screen size 5×2m

Multi-user support

Interact from various position

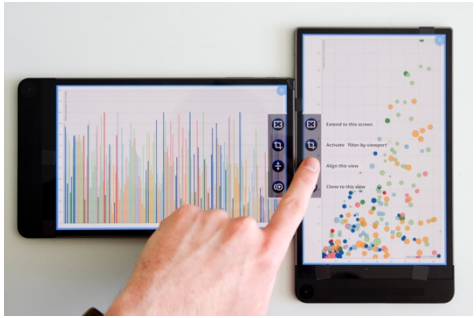
Visualization Workplaces



Visualization Workplaces

VisTiles

[Langner, Horak, and Dachselt, VIS 2017]



David Meets Goliath

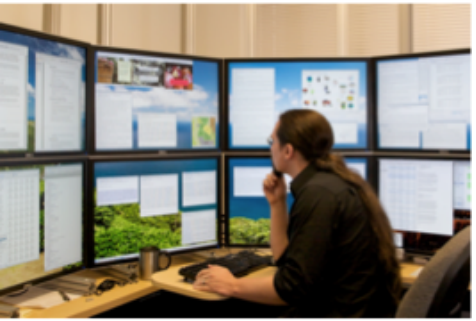
[Horak, Badam, Elmqvist, and Dachselt, CHI 2018]

Now: **Large Wall-sized Displays**

⊕ More data ⊕ More views ⊕ More users

Large Displays for Information Visualization

Previous work showed the potential and positive effect



Sensemaking

Space to Think
[Andrews, Endert, and North, CHI 2010]

Classification Tasks

[Liu, Chapuis, Beaudouin-Lafon, Lecolinet, and Mackay, CHI 2014]

Observation Strategies

[Rajabiyazdi, Walny, Mah, Brosz, and Carpendale, ITS 2015]

Insight Acquisition

[Reda, Johnson, Papka, and Leigh, CHI 2015]

Large Displays for Information Visualization

Interaction beyond mouse and keyboard

Direct Interaction

Touch

[Chegini, Shao, Lehmann, Andrews, and Schreck, FMT 2017]

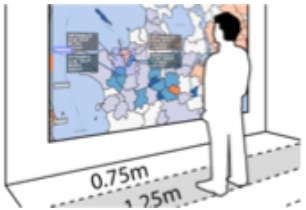
Touch and Pen

[Walny, Lee, Johns, Riche, and Carpendale, TVCG 2012]

Touch and Speech

Orko [Srinivasan and Stasko, InfoVis 2017]

Movement



Proxemics

[Jakobsen, Haile, Knudsen, and Hornbæk, TVCG 2013]

Proxemics and Gestures

[Badam, Amini, Elmqvist, and Irani, VAST 2016]

Body Interactions

BodyLenses [Kister, Reipschläger, Matulic, and Dachselt, ITS 2015]

Additional Devices

Tablets and Device Gestures

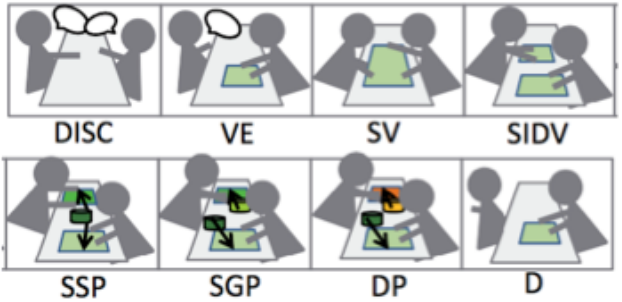
GraSp [Kister, Klamka, Tominski, and Dachselt, EuroVis 2017]

Touch and Smartwatch

David Meets Goliath [Horak, Badam, Elmqvist, and Dachselt, CHI 2018]

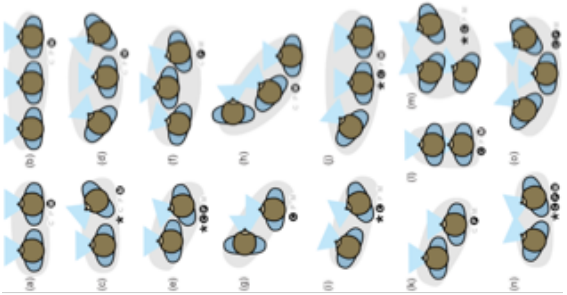
Large Displays for Information Visualization

Different collaboration styles as well as formations and positioning



Collaboration Styles

[Isenberg, Fisher, Morris, Inkpen, Czerwinski, VAST 2010]



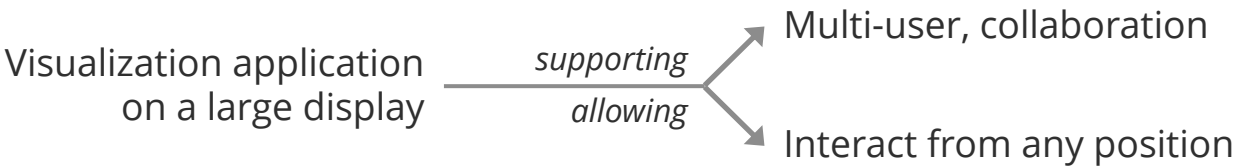
Territoriality and Formations

[Azad, Ruiz, Vogel, Hancock, and Lank, DIS 2012]

Proximity to the display

Up Close and Personal
[Jakobsen and Hornbæk, TOCHI 2014]

Research Focus



- How would users ***behave***, ***move***, and ***vary distances***?
- When or ***from which position*** would they interact?

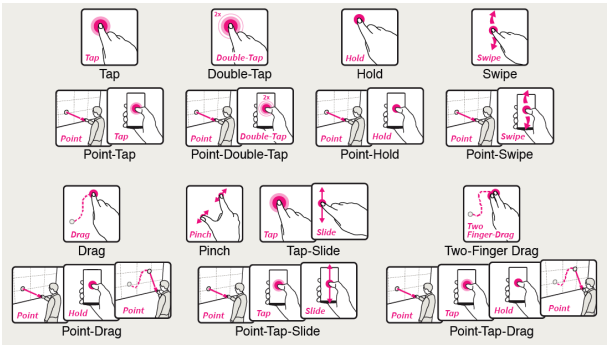
Approach and Contributions

1 - Prototype application

Multiple coordinated views are widely used

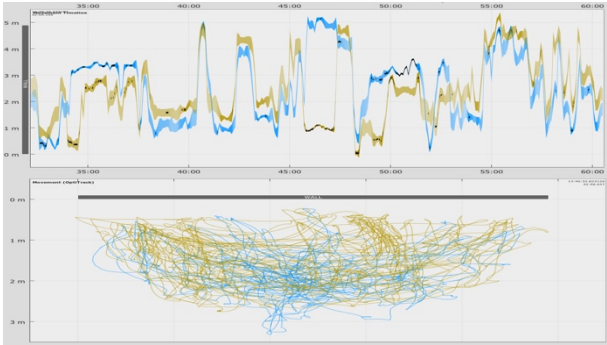
Benefit from large screen

2 - Interaction Concept



Techniques support different distances (to large display)

3 - User Study



Pairs of users explore data together

Behavior, movement, distance, actions, and communication

Prototype Application

Display wall 5×2m,
12x full-HD, 24MP resolution

Pointing approach using **Smartphones**, tracked by a motion capture system

Prototype Application

Display wall 5×2m,
12x full-HD, 24MP resolution

Pointing approach using **Smartphones**, tracked by a motion capture system

Python prototype uses **libavg** [https://libavg.de/]

Open source data set of crime activities, **240k items**, years 2012-2016,
15 attributes

Prototype Application

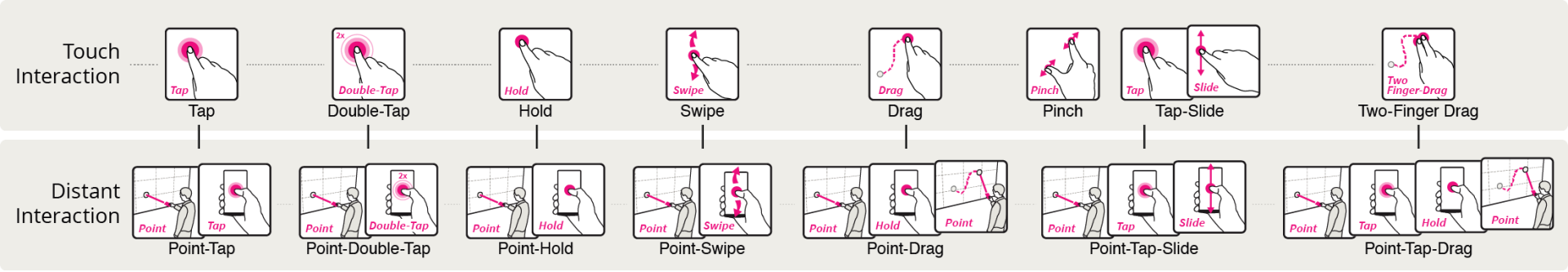
Grid layout with different view positions and view sizes

47 linked views, arranged by data attribute and visualization type

5 visualization types: bar chart, line chart, scatterplot, map, node-link diagram

Concept for Direct Touch + Distant Interaction

Set of basic interactions …

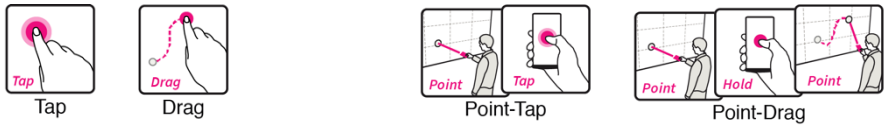


… mapped to common MCV functionality:

- Data item selection
- Details on demand
- Zoom and pan
- Data sorting
- View modification
- Exploration tools (e.g., lenses)
- GUI elements (e.g., menus, slider)

Prototype Application

- Data item selection
- Details on demand
- Tools: Lenses
- Tools: Rulers



Tap Drag Point-Tap Point-Drag

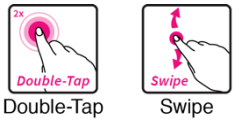
Prototype Application

Data item selection

Details on demand

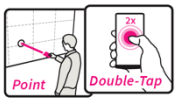
Tools: Lenses

Tools: Rulers

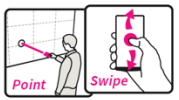


Double-Tap

Swipe



Point-Double-Tap



Point-Swipe

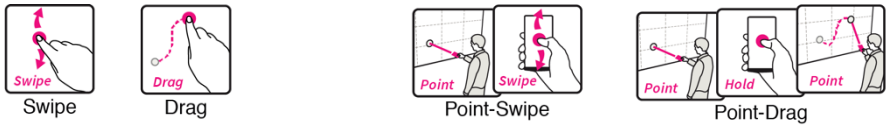
Prototype Application

Data item selection

Details on demand

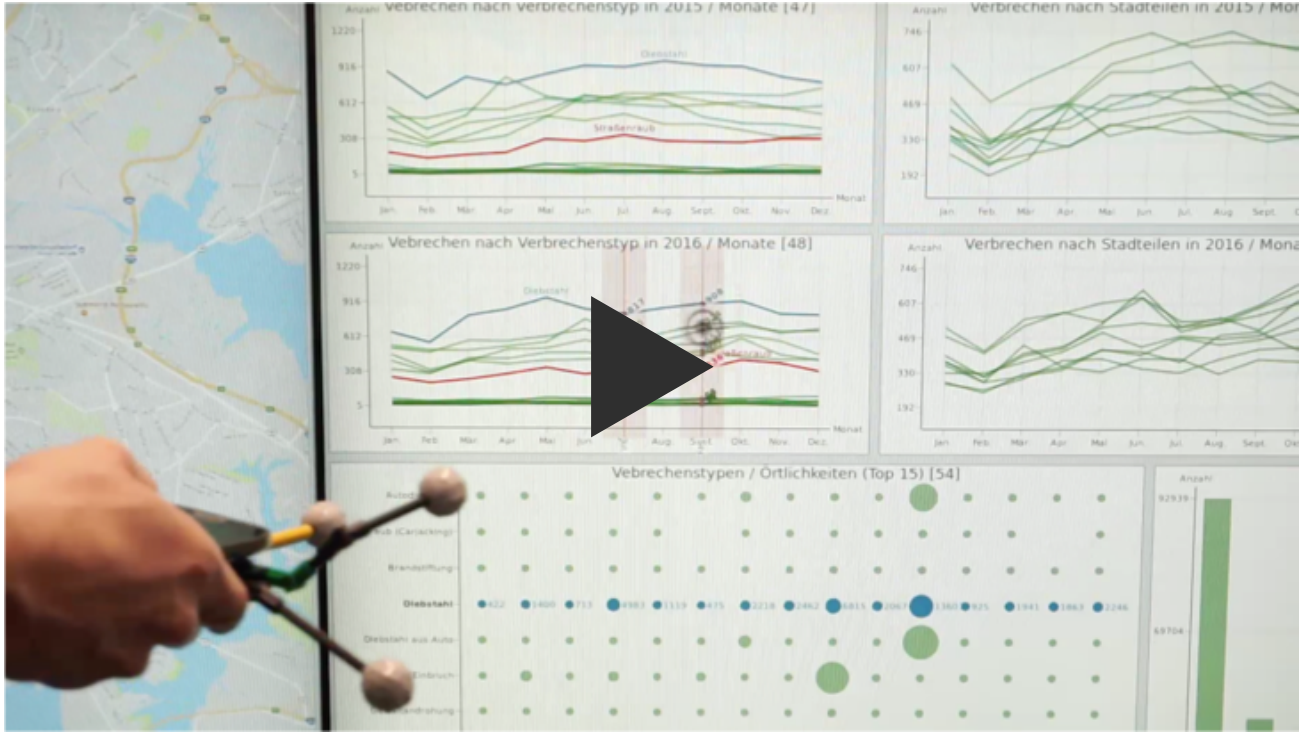
Tools: Lenses

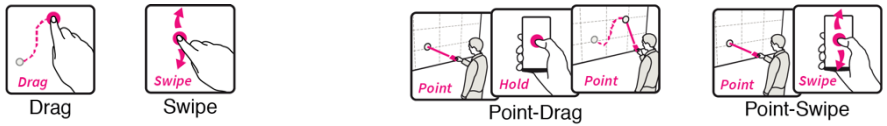
Tools: Rulers



Prototype Application

- Data item selection
- Details on demand
- Tools: Lenses
- Tools: Rulers





User Study

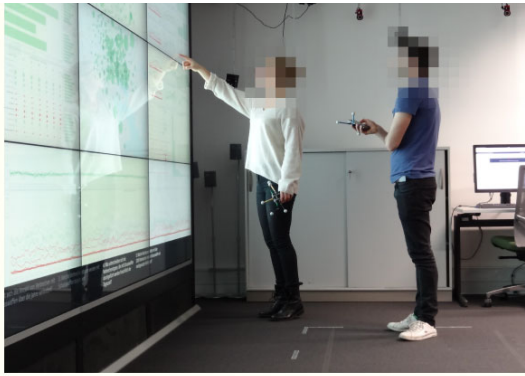
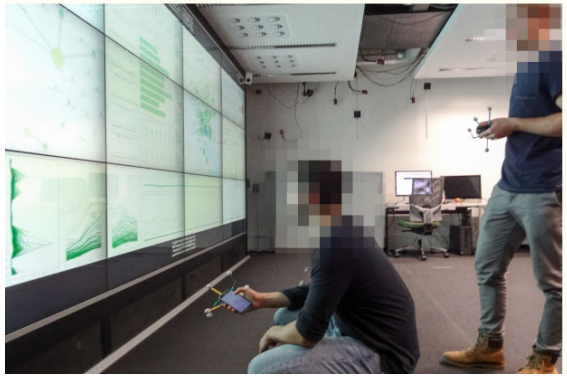
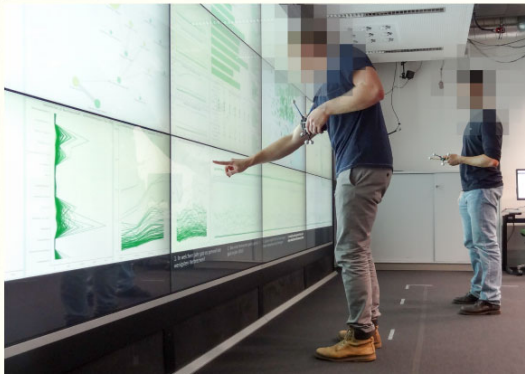
Focus on **user behavior**:
user position and movement, collaboration styles, interaction styles, interaction modality

7 teams = 14 participants
(3 female, 11 male)

Procedure

Total ~85 min

- Introduction
- Training *(~28 min)*
- **Themed exploration** phase *(~27 min)*
- **Open exploration** phase *(~10 min)*
- Final questionnaire

Study Analysis with GIAnT

GIAnT [Zadow and Dachselt, CHI 2017]
→ https://github.com/imldresden/GIAnT

User 1 User 2

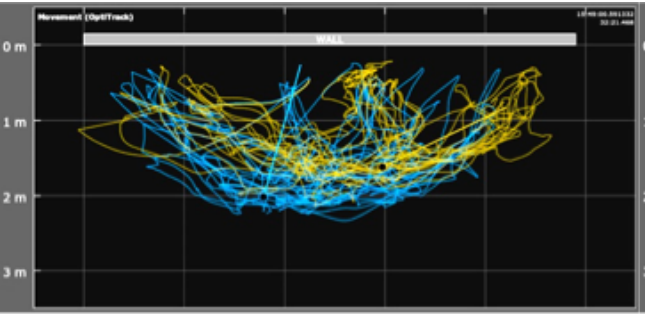
Statistics Application events Left-right movements Videos Interactions on display

Device touches Interactions Distances Movement paths

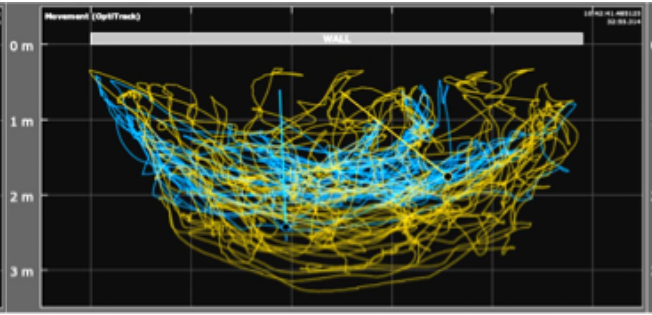
Movement Paths

User 1 User 2

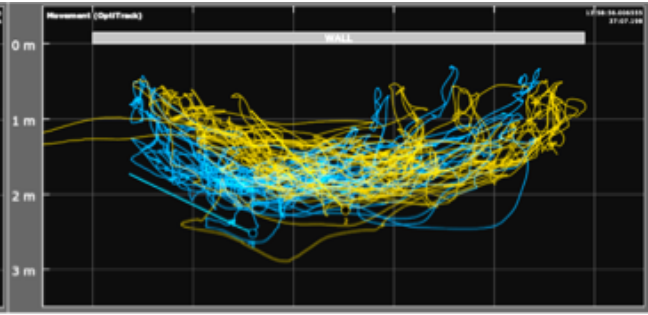
Team 1 (P1, P2)



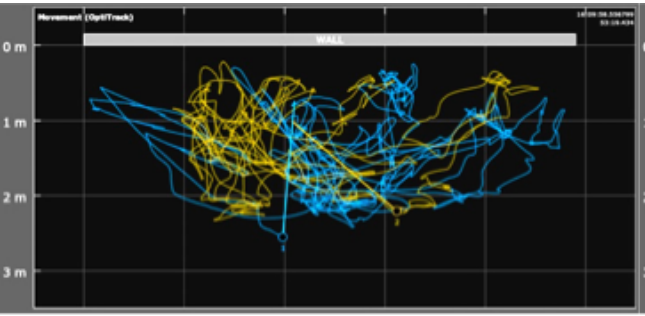
Team 3 (P5, P6)



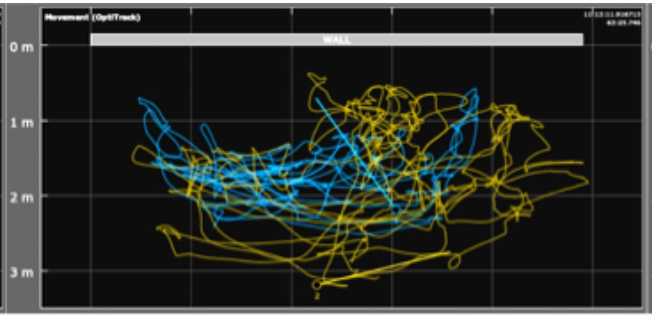
Team 7 (P13, P14)

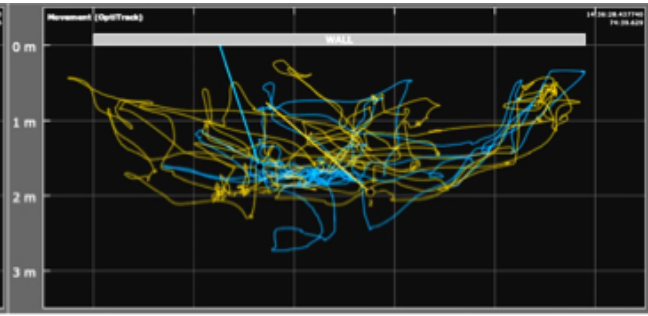


Themed Exploration Phase



Open Exploration Phase





Walking distance and Interactions

Participant	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
***TOUCH** (in %)*	34.3	92.6	93.4	63.9	25.0	66.9	81.2	50.3	80.0	88.2	75.5	60.7	9.4	51.0
***DISTANT** (in %)*	65.7	7.4	6.6	36.1	75.0	33.1	18.8	49.7	20.0	11.8	24.5	39.3	90.6	49.0
# touch downs	70	149	122	108	192	130	117	173	50	170	94	163	234	98
***walked** (in m)*	136	145	188	195	204	287	259	217	208	373	269	257	168	232
Duration	20 min.		21 min.		30 min.		28 min.		25 min.		28 min.		37 min.	

Themed Exploration Phase

Open Exploration Phase

Participant	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
***TOUCH** (in %)*	62.0	83.3	23.5	4.9	10.3	52.4	100.0	79.6	84.8	95.5	94.8	71.4	22.2	85.4
***DISTANT** (in %)*	38.0	16.7	76.5	95.1	89.7	47.6	0.0	20.4	15.2	4.5	5.2	28.6	77.8	14.6
# touch downs	50	48	17	41	29	63	14	54	46	66	58	7	45	48
***walked** (in m)*	89	84	39	38	73	106	70	69	84	139	120	77	50	88
Duration	13 min.		7 min.		12 min.		8 min.		10 min.		11 min.		10 min.	

Summary of Results and Findings

Behavior and Movement

Users often move and vary their distance to the display

— *"moving around was kind of activating to my mind"*

Preference for 'overview distance'

Draw attention by pointing with fingers

Collaboration

Instructions and commands

— *"Go over there and take a look"*

— *"Could you create a ruler"*

Users stand and walk close to each other

Only a few interaction conflicts

Application Usage

Preference for touch input on the large display

Pointing for larger, continuous interactions

Open Research Questions and Outlook

How about the **view layout**?

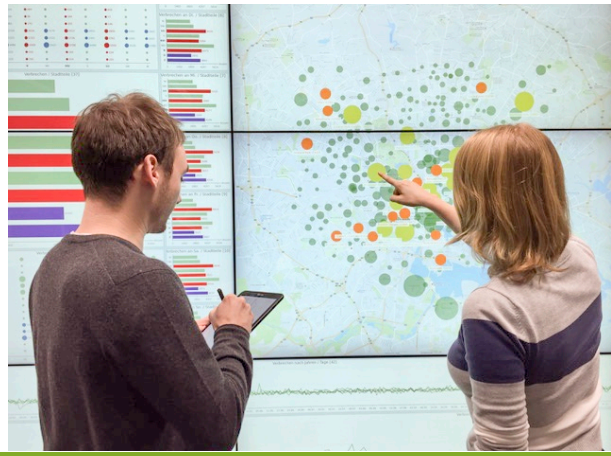
(different view layouts, number and size of views)

What about **different setups**?

(size and resolution of large display)

What about other types of **device usage**?

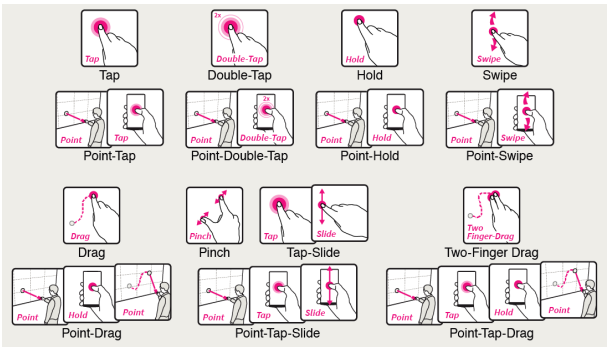
(make use of additional screen, note taking)



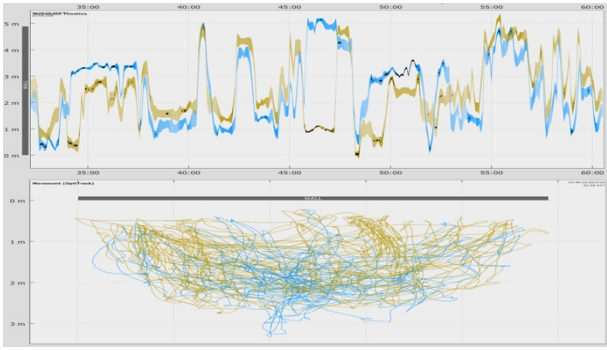
Conclusion

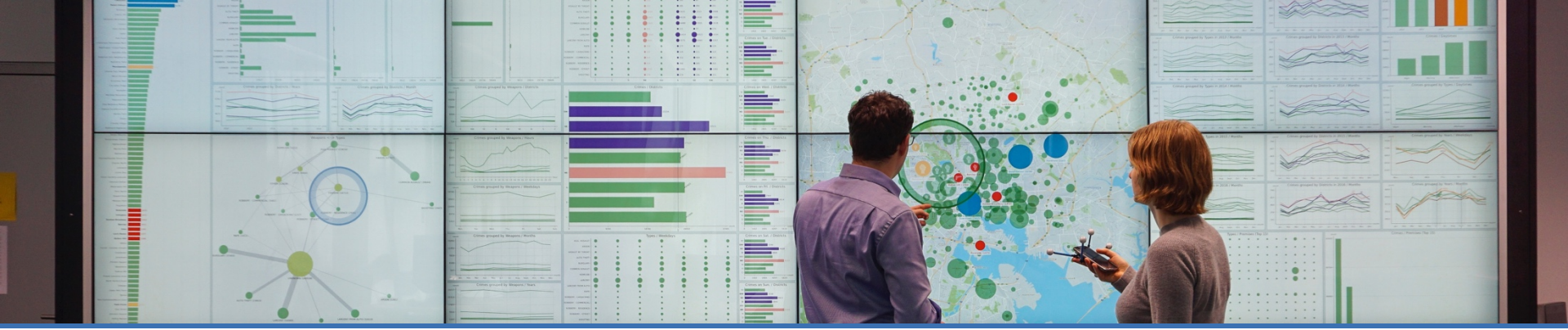
1 - Prototype application

2 - Interaction Concept



3 - User Study





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› **imld.de/mcv-displaywall**
Project website, data, study logs, materials

› **github.com/imldresden**
Prototype + analysis tool

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References

[Andrews, Endert, and North, 2010]
C. Andrews, A. Endert, and C. North, “Space to Think: Large High-resolution Displays for Sensemaking,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Atlanta, Georgia, USA, 2010, pp. 55–64.

[Azad, Ruiz, Vogel, Hancock, and Lank, 2012]
A. Azad, J. Ruiz, D. Vogel, M. Hancock, and E. Lank, “Territoriality and behaviour on and around large vertical publicly-shared displays,” in *Proceedings of the Designing Interactive Systems Conference*, Newcastle Upon Tyne, United Kingdom, 2012, pp. 468–477.

[Badam, Amini, Elmqvist, and Irani, 2016]
S. K. Badam, F. Amini, N. Elmqvist, and P. Irani, “Supporting visual exploration for multiple users in large display environments,” in *2016 IEEE Conference on Visual Analytics Science and Technology (VAST)*, 2016, pp. 1–10.

[Chegini, Shao, Lehmann, Andrews, and Schreck, 2017]
M. Chegini, L. Shao, D. J. Lehmann, K. Andrews, and T. Schreck, “Interaction Concepts for Collaborative Visual Analysis of Scatterplots on Large Vertically-Mounted High-Resolution Multi-Touch Displays,” in *Proc. Forum Media Technology & All Around Audio Symposium*, St. Pölten, Austria, 2017, pp. 90–96.

[Horak, Badam, Elmqvist, and Dachselt, 2018]
T. Horak, S. K. Badam, N. Elmqvist, and R. Dachselt, “When David Meets Goliath: Combining Smartwatches with a Large Vertical Display for Visual Data Exploration,” in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, Montreal QC, Canada, 2018, pp. 19:1–19:13.

[Isenberg, Fisher, Morris, Inkpen, Czerwinski, 2010]
P. Isenberg, D. Fisher, M. R. Morris, K. Inkpen, and M. Czerwinski, “An exploratory study of co-located collaborative visual analytics around a tabletop display,” in *2010 IEEE Symposium on Visual Analytics Science and Technology*, 2010, pp. 179–186.

References

[Jakobsen, Haile, Knudsen, and Hornbæk, 2013]
M. R. Jakobsen, Y. S. Haile, S. Knudsen, and K. Hornbaek, “Information Visualization and Proxemics: Design Opportunities and Empirical Findings,” *Visualization and Computer Graphics, IEEE Transactions on*, vol. 19, no. 12, pp. 2386–2395, 2013.

[Jakobsen and Hornbæk, 2014]
M. R. Jakobsen and K. Hornbæk, “Up Close and Personal: Collaborative Work on a High-resolution Multitouch Wall Display,” *ACM Transactions on Computer-Human Interaction (TOCHI)*, vol. 21, no. 2, pp. 11:1–11:34, Feb. 2014.

[Kister, Klamka, Tominski, and Dachselt, 2017]
U. Kister, K. Klamka, C. Tominski, and R. Dachselt, “GraSp: Combining Spatially-aware Mobile Devices and a Display Wall for Graph Visualization and Interaction,” *Computer Graphics Forum*, vol. 36, no. 3, pp. 503–514, 2017.

[Kister, Reipschläger, Matulic, and Dachselt, 2015]
U. Kister, P. Reipschläger, F. Matulic, and R. Dachselt, “BodyLenses: Embodied Magic Lenses and Personal Territories for Wall Displays,” in *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces*, Madeira, Portugal, 2015, pp. 117–126.

[Langner, Horak, and Dachselt, 2018]
R. Langner, T. Horak, and R. Dachselt, “VisTiles: Coordinating and Combining Co-located Mobile Devices for Visual Data Exploration,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 1, pp. 626–636, Jan. 2018.

[Liu, Chapuis, Beaudouin-Lafon, Lecolinet, and Mackay, 2014]
C. Liu, O. Chapuis, M. Beaudouin-Lafon, E. Lecolinet, and W. E. Mackay, “Effects of Display Size and Navigation Type on a Classification Task,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Toronto, Ontario, Canada, 2014, pp. 4147–4156.

[Rajabiyazdi, Walny, Mah, Brosz, and Carpendale, 2015]
F. Rajabiyazdi, J. Walny, C. Mah, J. Brosz, and S. Carpendale, “Understanding Researchers’ Use of a Large, High-Resolution Display Across Disciplines,” in *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces*, Madeira, Portugal, 2015, pp. 107–116.

References

[Reda, Johnson, Papka, and Leigh, 2015]
K. Reda, A. E. Johnson, M. E. Papka, and J. Leigh, “Effects of Display Size and Resolution on User Behavior and Insight Acquisition in Visual Exploration,” in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, Seoul, Republic of Korea, 2015, pp. 2759–2768.

[Srinivasan and Stasko, 2017]
A. Srinivasan and J. Stasko, “Orko: Facilitating Multimodal Interaction for Visual Exploration and Analysis of Networks,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 1, pp. 511–521, Jan. 2018.

[Zadow and Dachselt, 2017]
U. von Zadow and R. Dachselt, “GIAnT: Visualizing Group Interaction at Large Wall Displays,” in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI ’17*, Denver, Colorado, USA, 2017, pp. 2639–2647.

[Walny, Lee, Johns, Riche, and Carpendale, 2012]
J. Walny, B. Lee, P. Johns, N. Henry Riche, and S. Carpendale, “Understanding Pen and Touch Interaction for Data Exploration on Interactive Whiteboards,” *IEEE Transactions on Visualization and Computer Graphics*, vol. 18, no. 12, pp. 2779–2788, Dec. 2012.