Data Physicalization

Exploring the Potential of Physical Visualizations

Simon Stusak

Vorlesung „Advanced Topics in HCI”

Prof. Dr. Florian Alt, SS 2015

Motivation

What are Data Physicalizations?

What are Data Physicalizations?

A *data physicalization* (or simply physicalization) is a physical artifact whose geometry or material properties encode data.

[Jansen et al. 2015]

5500 BC – Mesopotamian Clay Tokens

Source: http://dataphys.org/list / photo by Denise Schmandt-Besserat

2600 BC – Inca Quipus

Source: http://dataphys.org/list / https://courses.cit.cornell.edu/quipu/

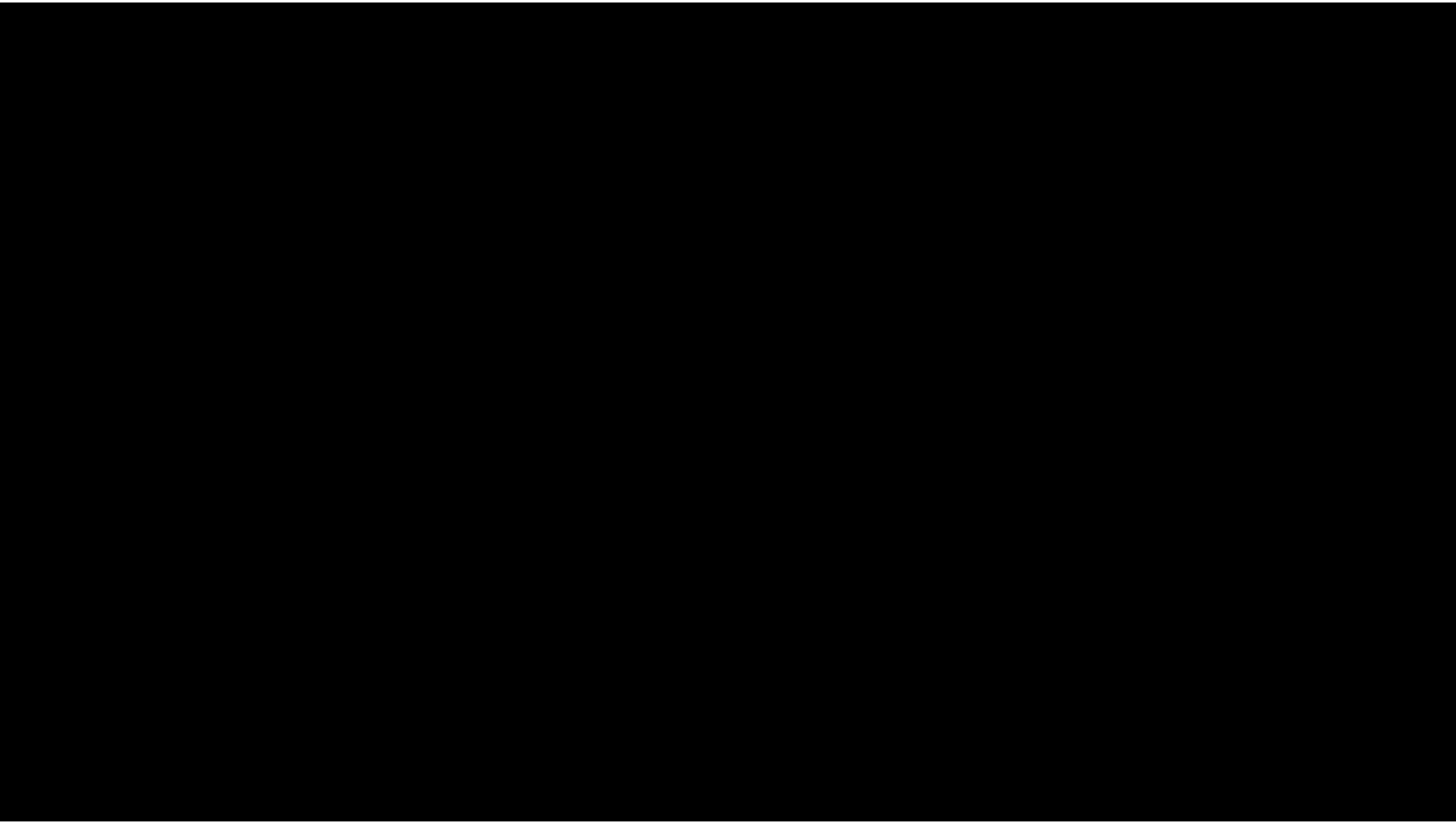
1913 – Frankfurt Streetcar Load

Source: http://dataphys.org/list / Willard Cope Brinton (1914) Graphic Methods for Presenting Facts pp 224-226.

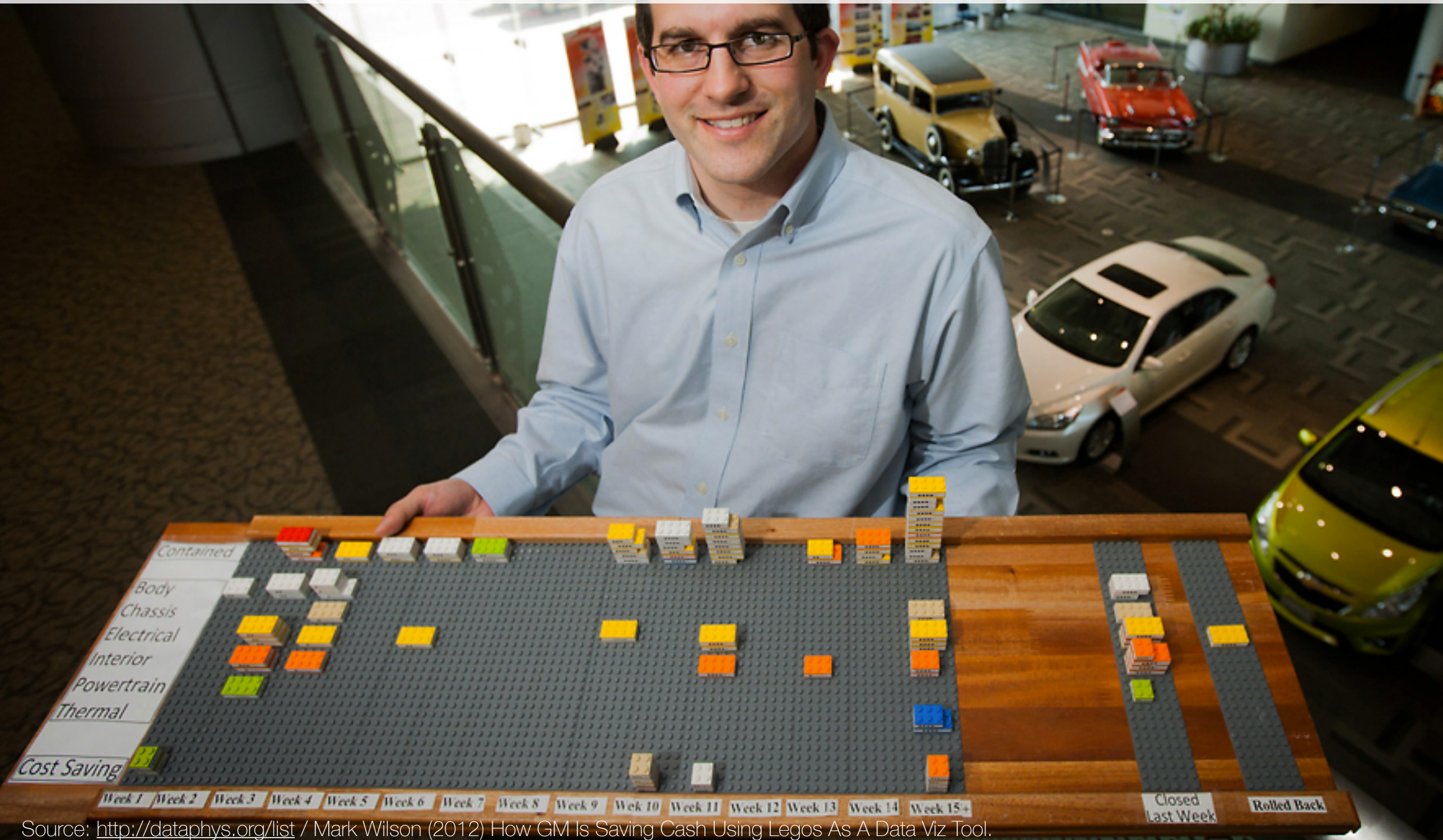
2012 – Emoto: Projection Augmented Heatmaps of Twitter Data

Source: http://dataphys.org/list / Source: Moritz Stefaner, Drew Hemment & Studio NAND. Emoto.

2012 – Emoto: Projection Augmented Heatmaps of Twitter Data



2012 – General Motors' 3D LEGO Visualizations



Source: http://dataphys.org/list / Mark Wilson (2012) How GM Is Saving Cash Using Legos As A Data Viz Tool.

What are their benefits?

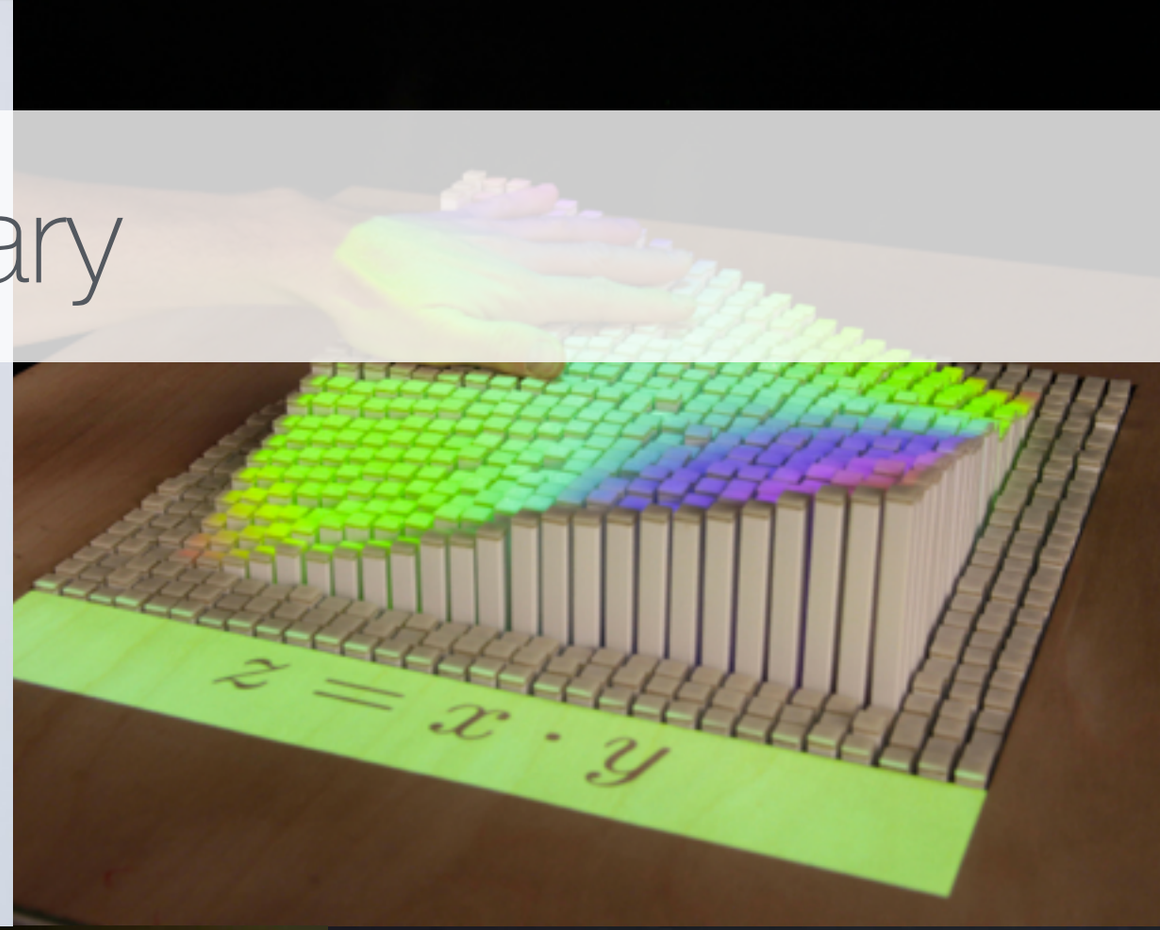
What are their benefits?

Leveraging our Perceptual Exploration Skills

Making Data Accessible

Engaging People

Summary



Source: http://dataphys.org/list / meshu.io / Follmer et al. / Mitchell Whitelaw / Andreas Nicolas Fischer

Introduction

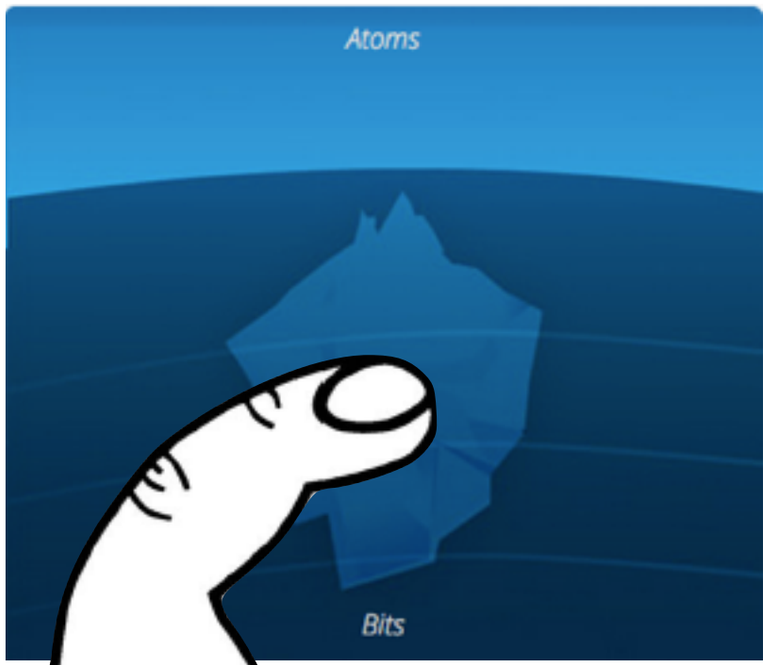
Involved Research Communities

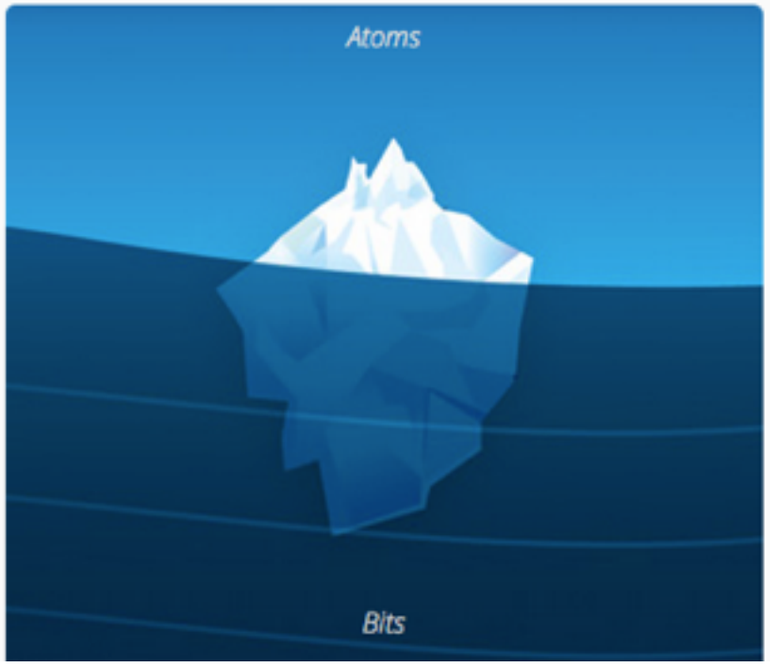
Tangible User Interaction (TUI)

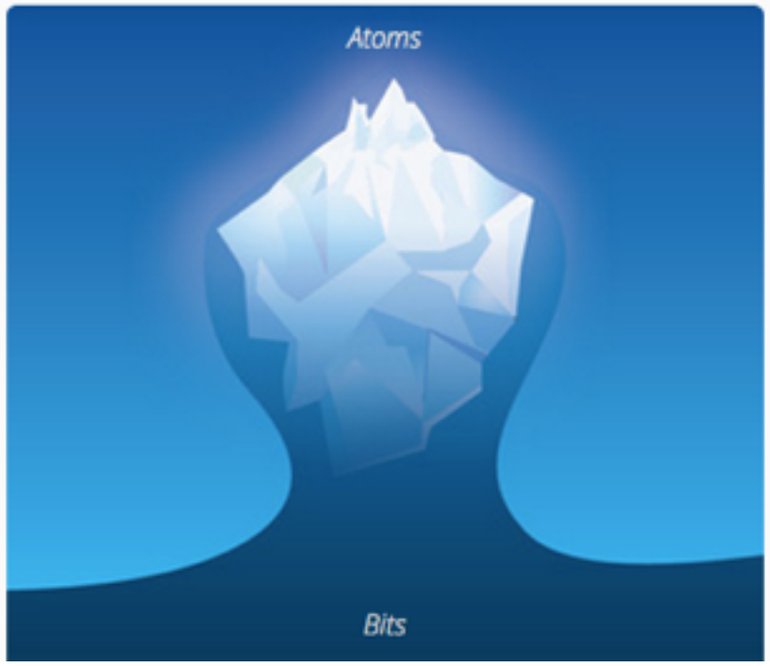
Information Visualization (InfoVis)

Data Physicalization and TUI

Tangible Bits & Radical Atoms *[Ishii - MIT Media Lab]*

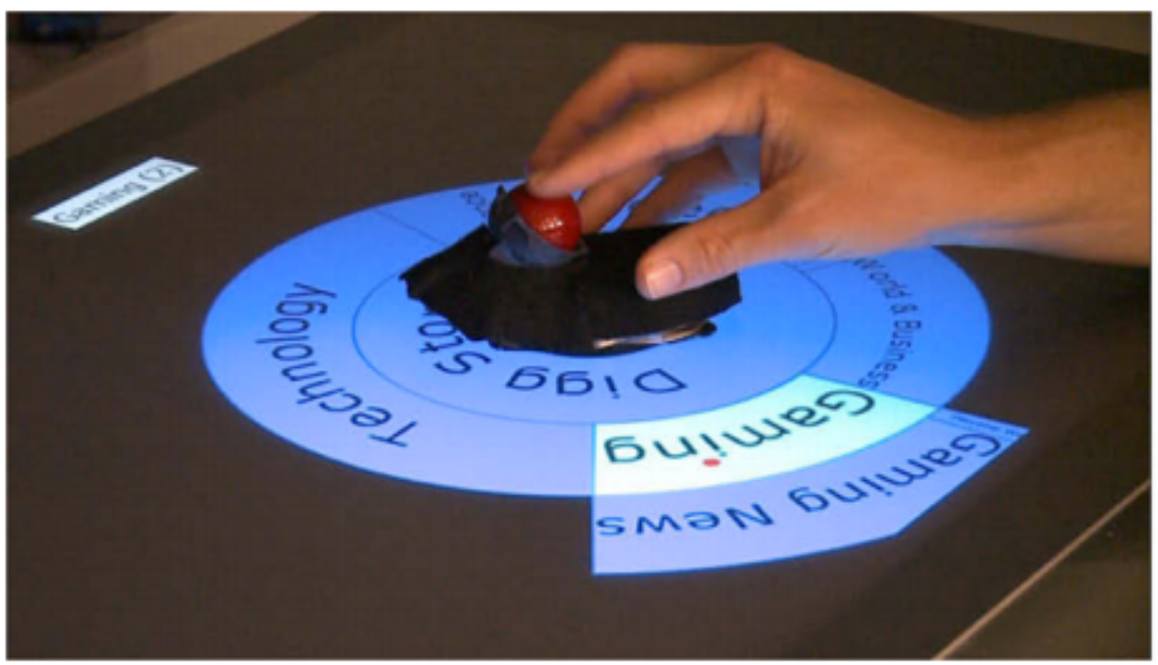


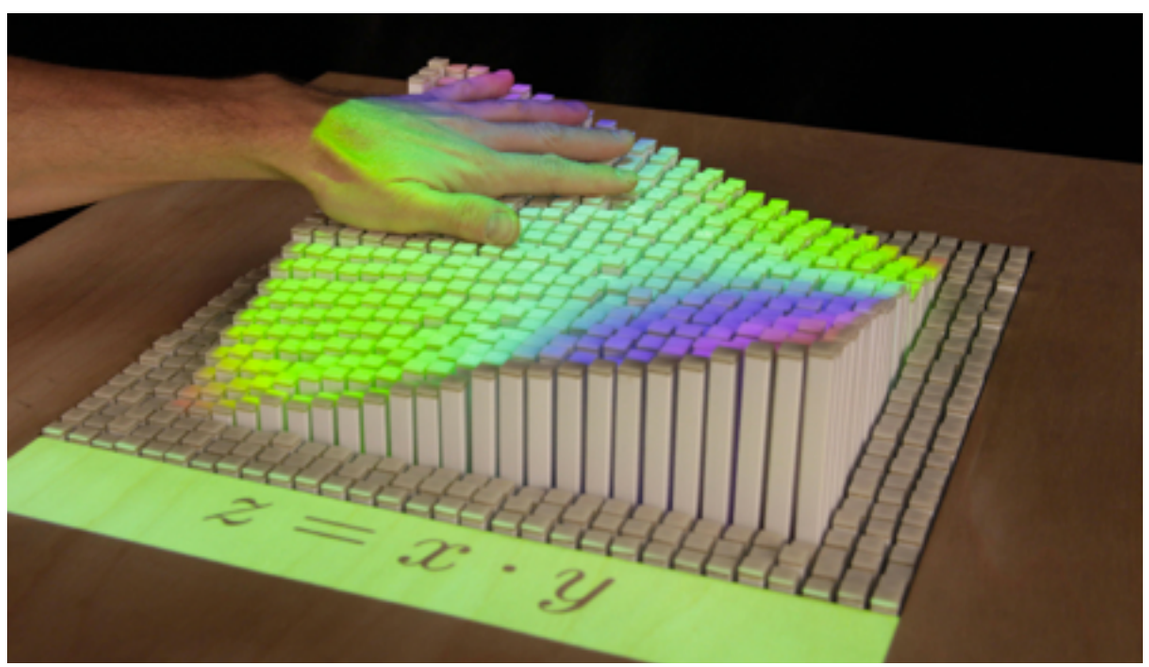




A GUI's mental model of a user
[O'Sullivan and Igoe, 2004; Klemmer et al., 2006]

Tangibles for Visualization Systems

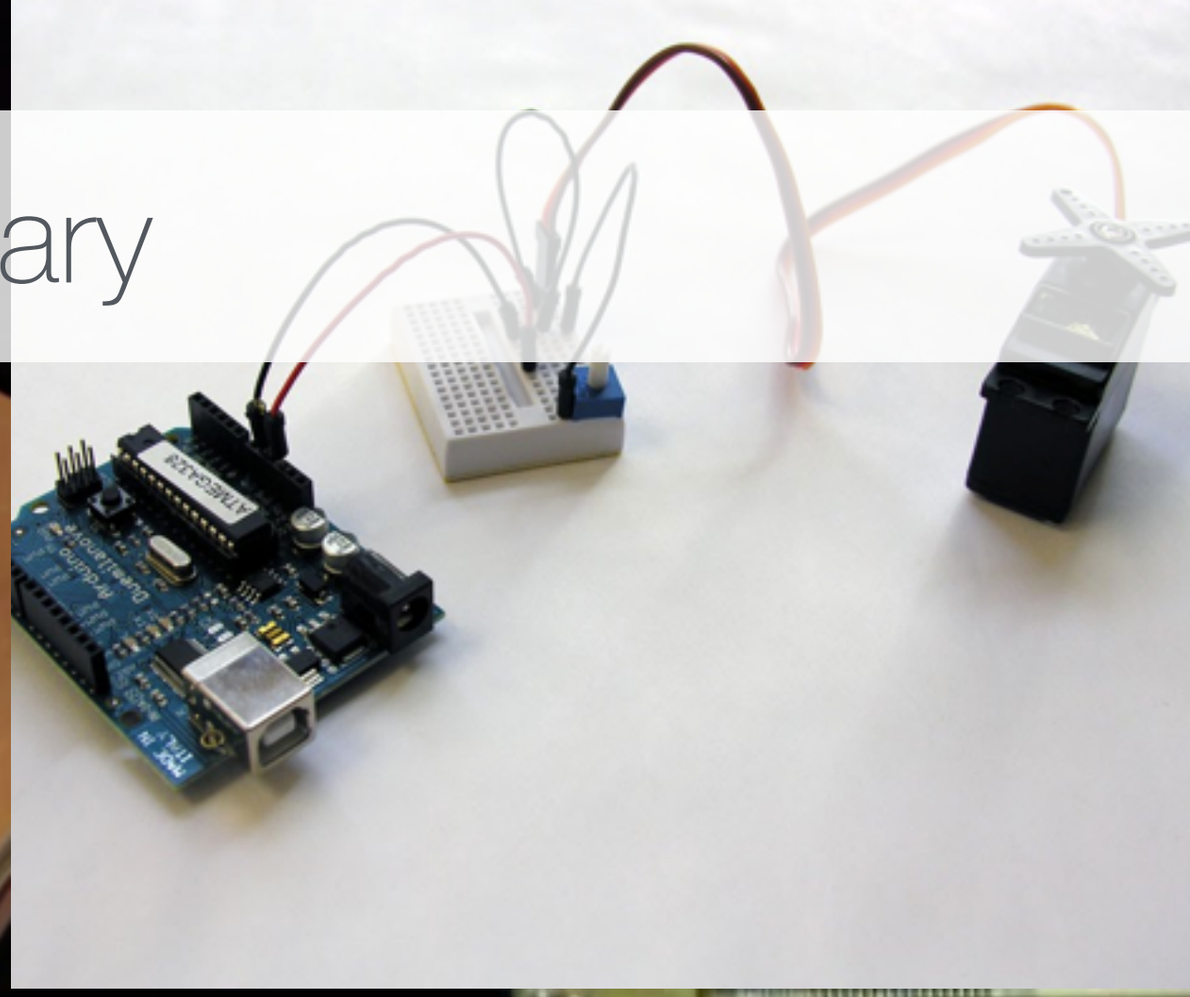


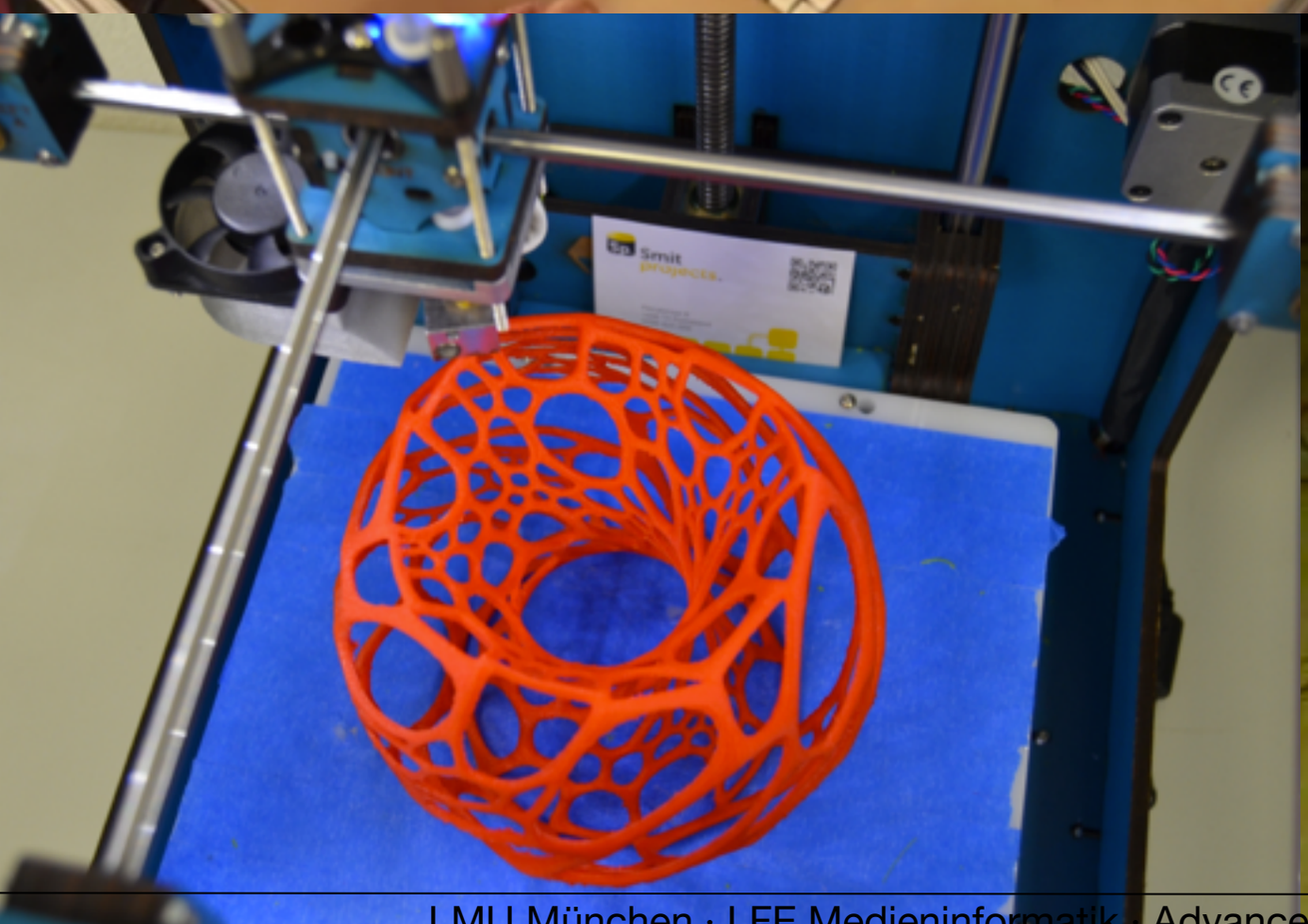


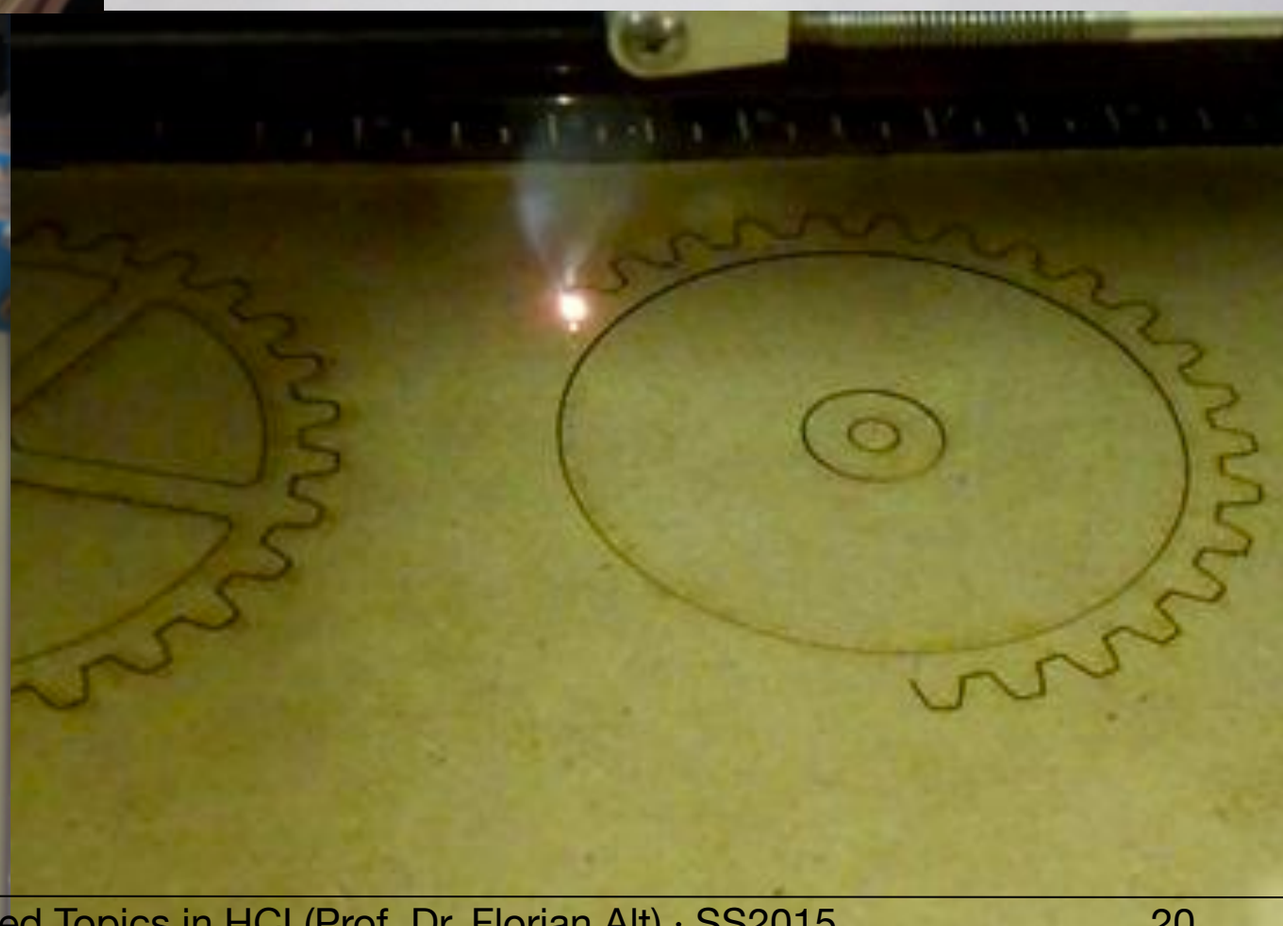
Source: Hancock et al. 2009 / Kruszynski and Liere 2009 / Follmer et al. 2013

inFORM - Follmer et al. 2013

Summary

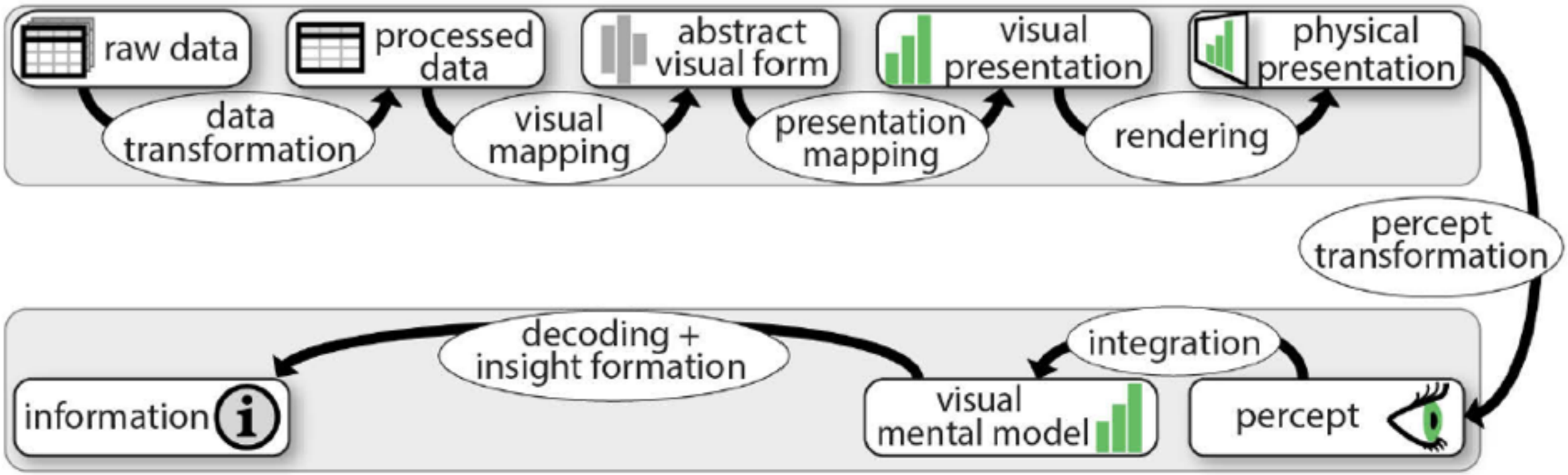






Data Physicalization and InfoVis

Extended InfoVis Pipeline Model *[Jansen et al. 2013]*



Source: Jansen et al. 2013

Extended InfoVis Pipeline Model *[Jansen et al. 2013]*

physical visualization

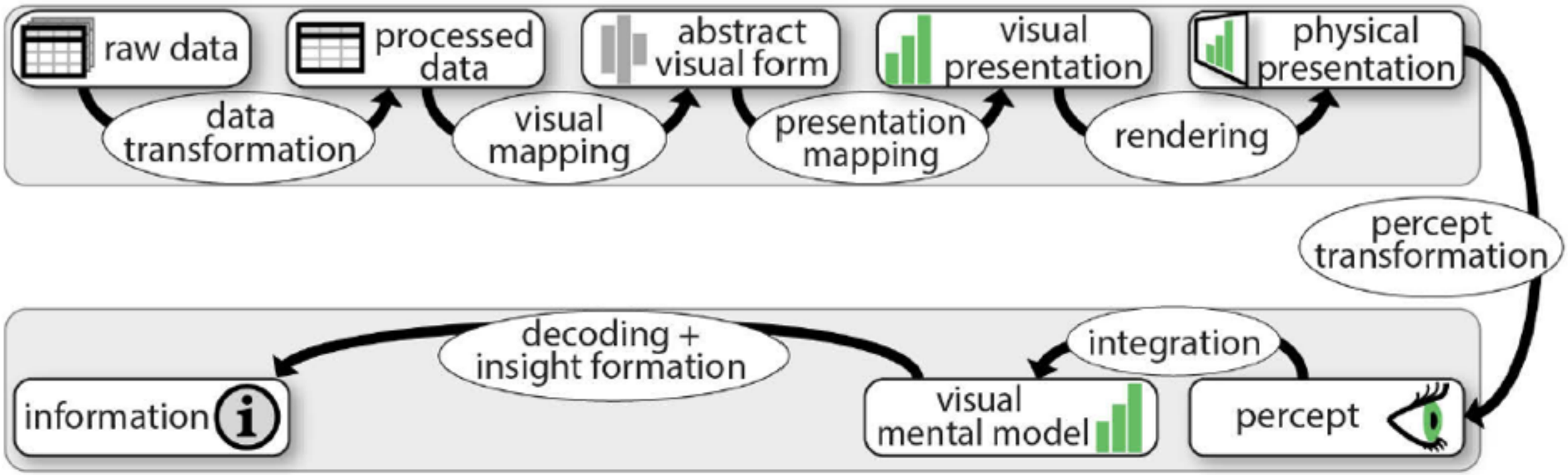
2D screen

stereoscopic screen

3D bar chart

Source: Jansen et al. 2013

Extended InfoVis Pipeline Model *[Jansen et al. 2013]*



Source: Jansen et al. 2013

Research Projects

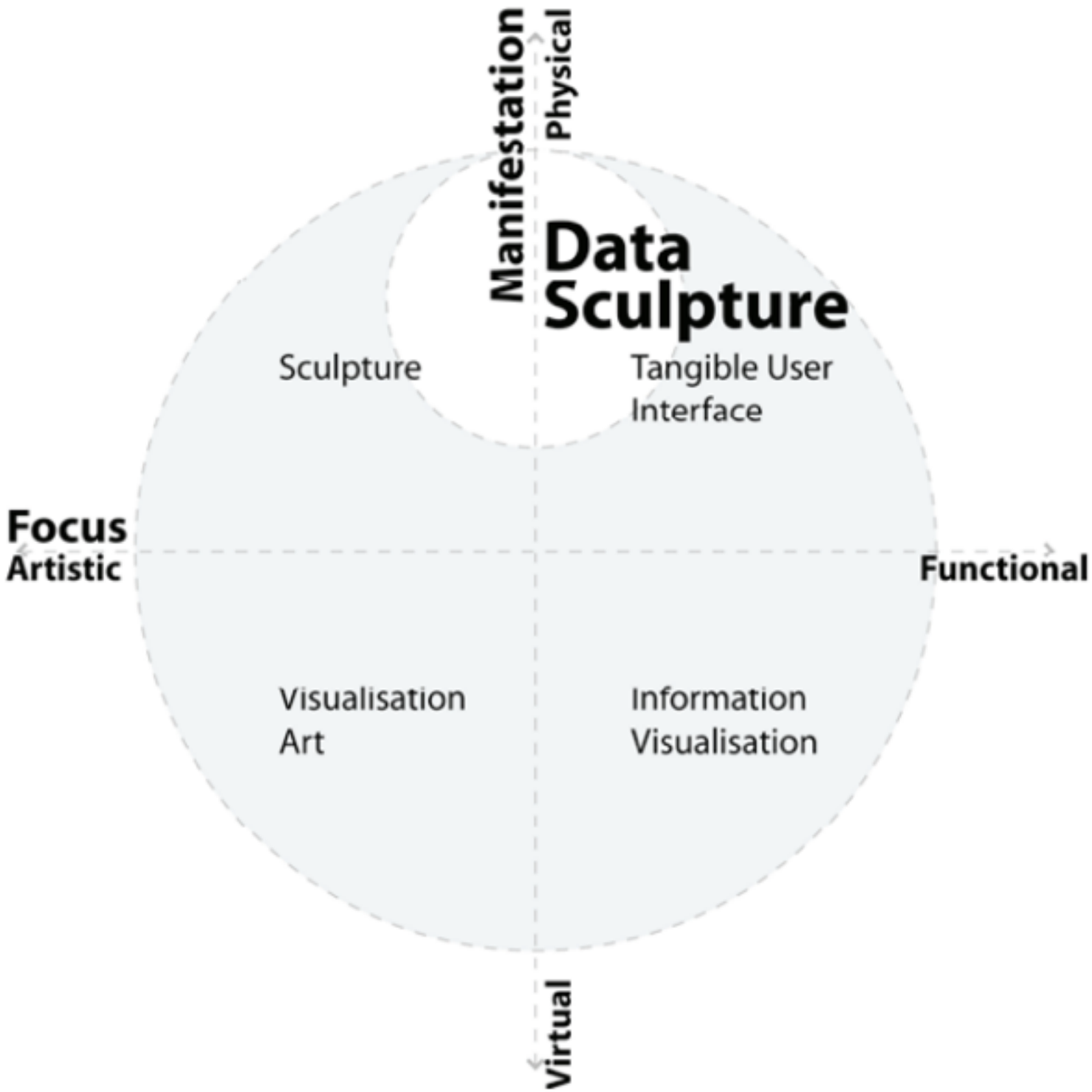
Design & Fabrication

Animation & Interactivity

Evaluation

Projects - Design & Fabrication

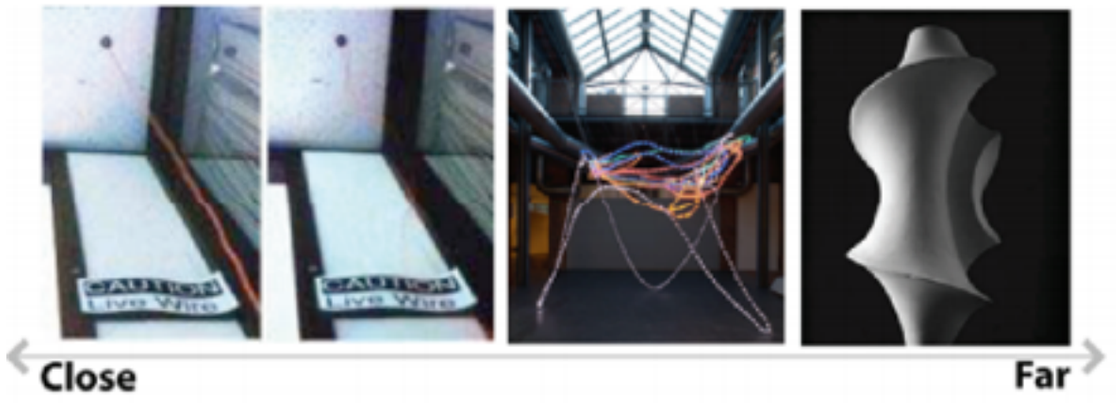
Data Sculptures *[Zhao and Vande Moere 2008]*



Data Sculptures *[Zhao and Vande Moere 2008]*

Data Sculpture	*Metaphor*		*Relationship*	*Distance*
	Data	*Representation*		
Live Wire [38]	Network activity through Ethernet cable	Movement of a cable/string	Indexical	Close
Wable [43]	Web services access patterns	Bar chart	Iconic	Moderate
Nowhere [40]	Search queries	Formation of landscape	Symbolic	Far

Data Sculpture	*Metaphor*		*Satisfied Criteria*	*Distance*
	Data	*Representation*		
Live wire [38]	Network activity	Movement, being 'alive'	Single mental image, affordance, and intuitive	Close
Plastic Trade-Off [41]	Flow of money between stock markets	Pipes, tubes	Affordance, single mental image	Moderate
Mathematical Models [42]	Mathematical concept	Geometric surface	None	Far



Data Sculptures *[Vande Moere and Patel 2009]*

Designing a Data Sculpture

embodiment

metaphorical distance

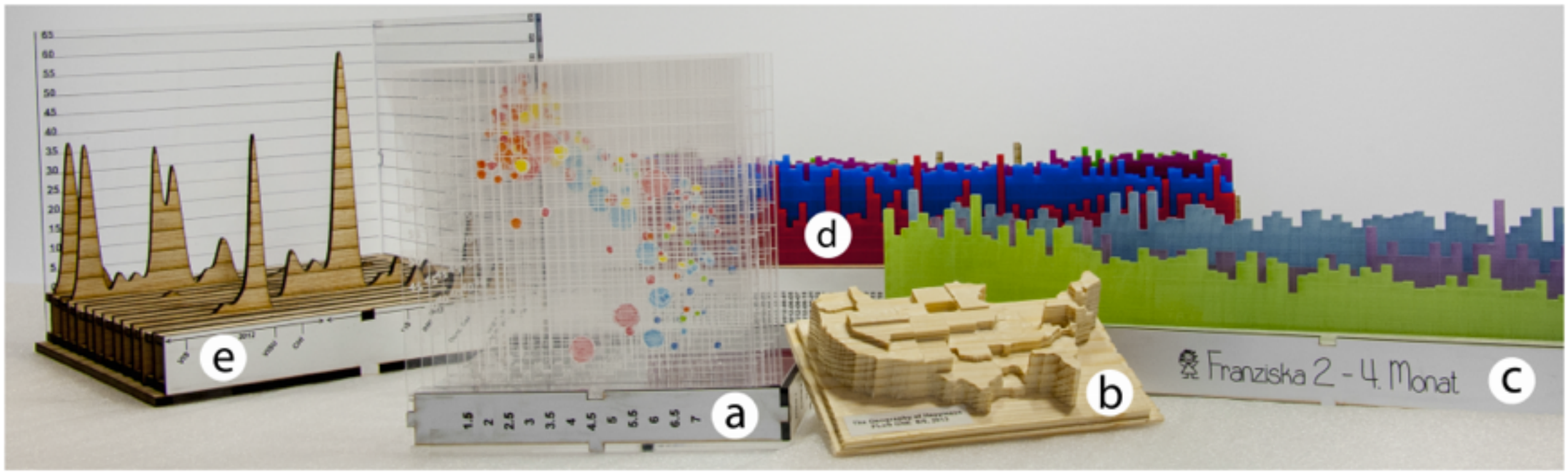
multi-modality

interaction

affordance

physical properties

MakerVis *[Swaminathan et al. 2014]*



MakerVis *[Swaminathan et al. 2014]*

Fabrication Challenges

Manufacturability

Assembly & Fit

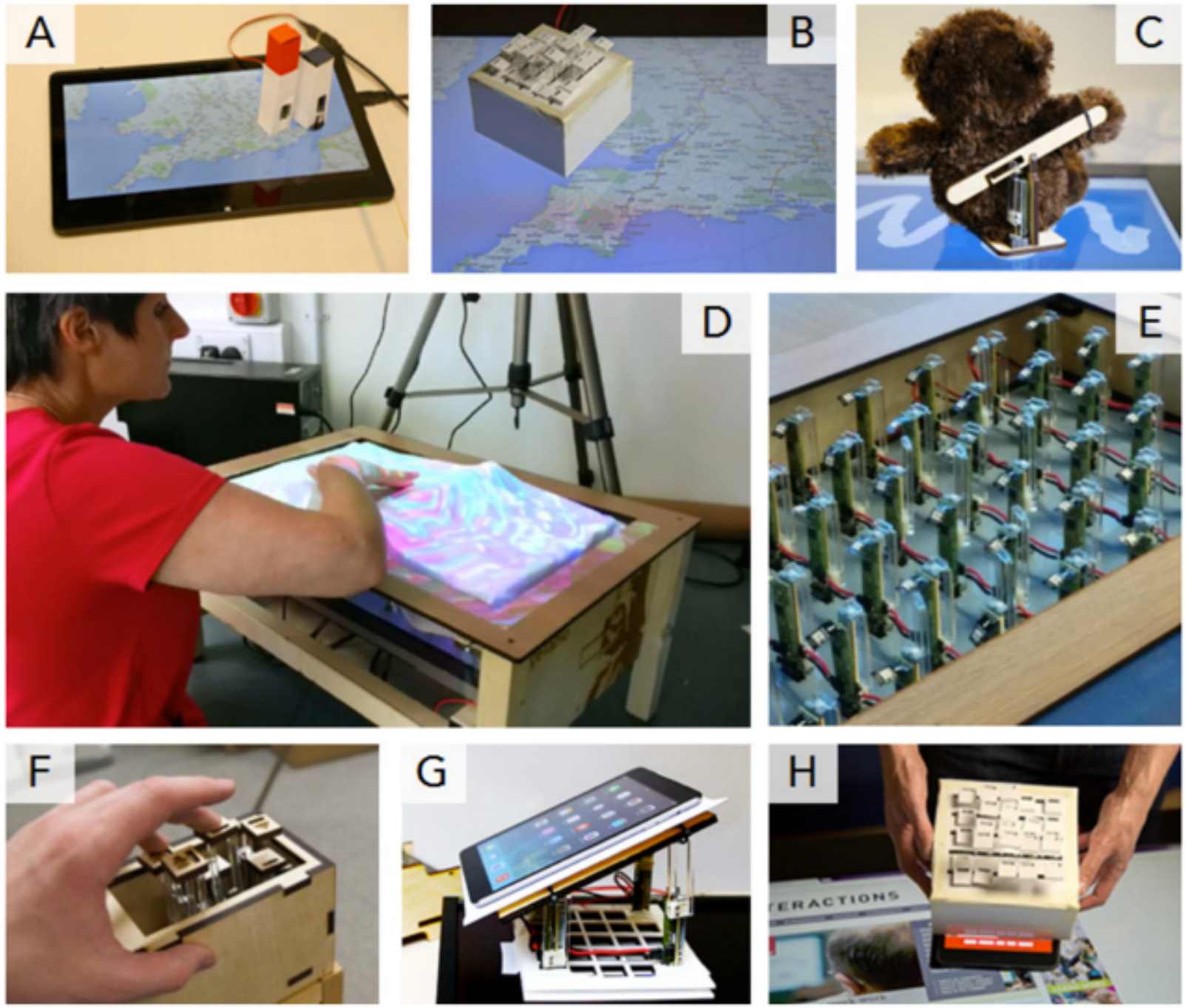
Balance & Stability

Strength

MakerVis *[Swaminathan et al. 2014]*

MakerVis *[Swaminathan et al. 2014]*

ShapeClip *[Hardy et al. 2015]*



ShapeClip *[Hardy et al. 2015]*

Design Challenges *[Jansen et al. 2015]*

Design Challenges *[Jansen et al. 2015]*

Render physical variables (e.g. smell or taste)

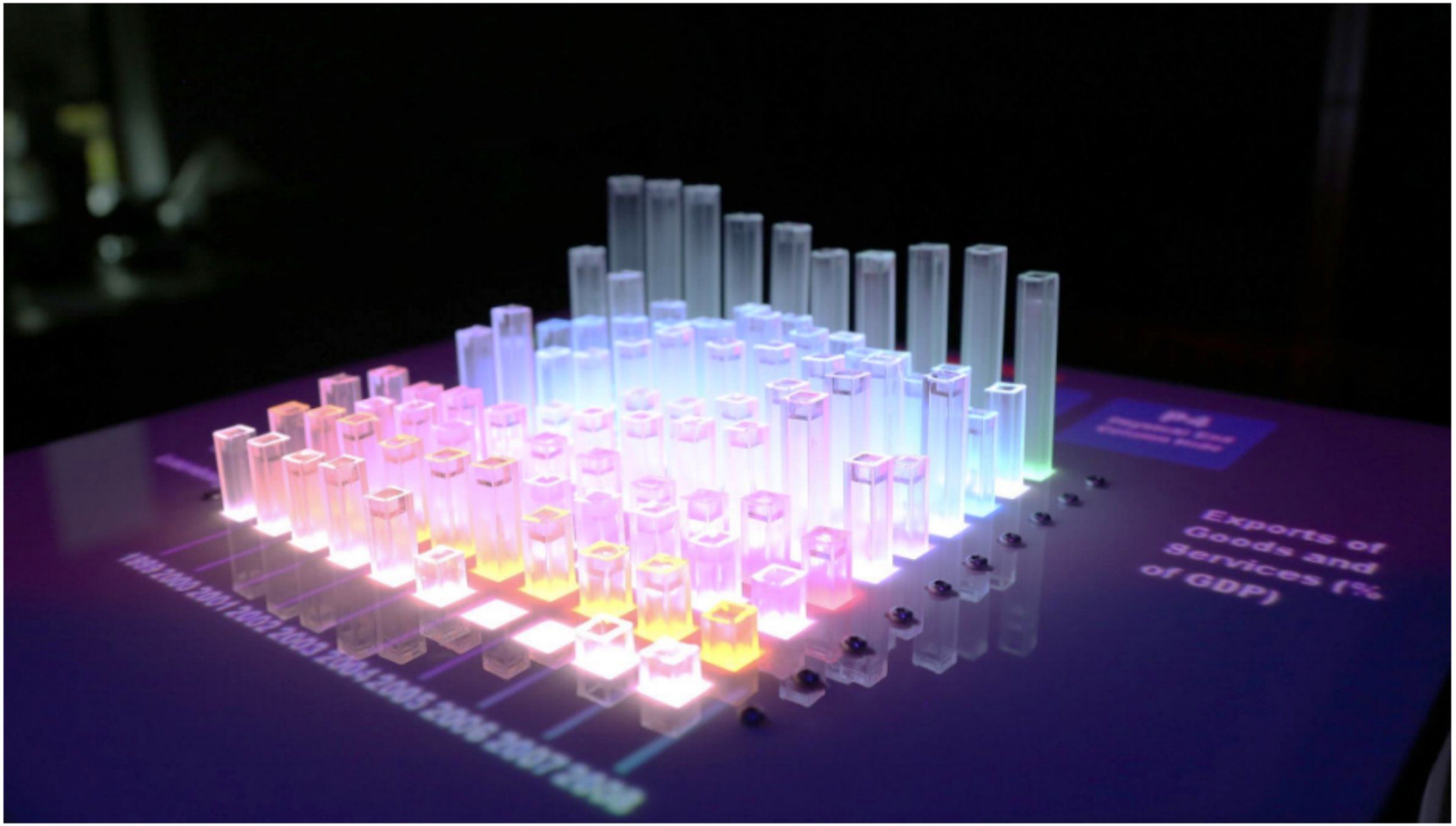
Replication & Accuracy

Time & Costs

Environmental Impact

Projects - Animation & Interactivity

Dynamic Bar Charts *[Taher et al. 2015]*

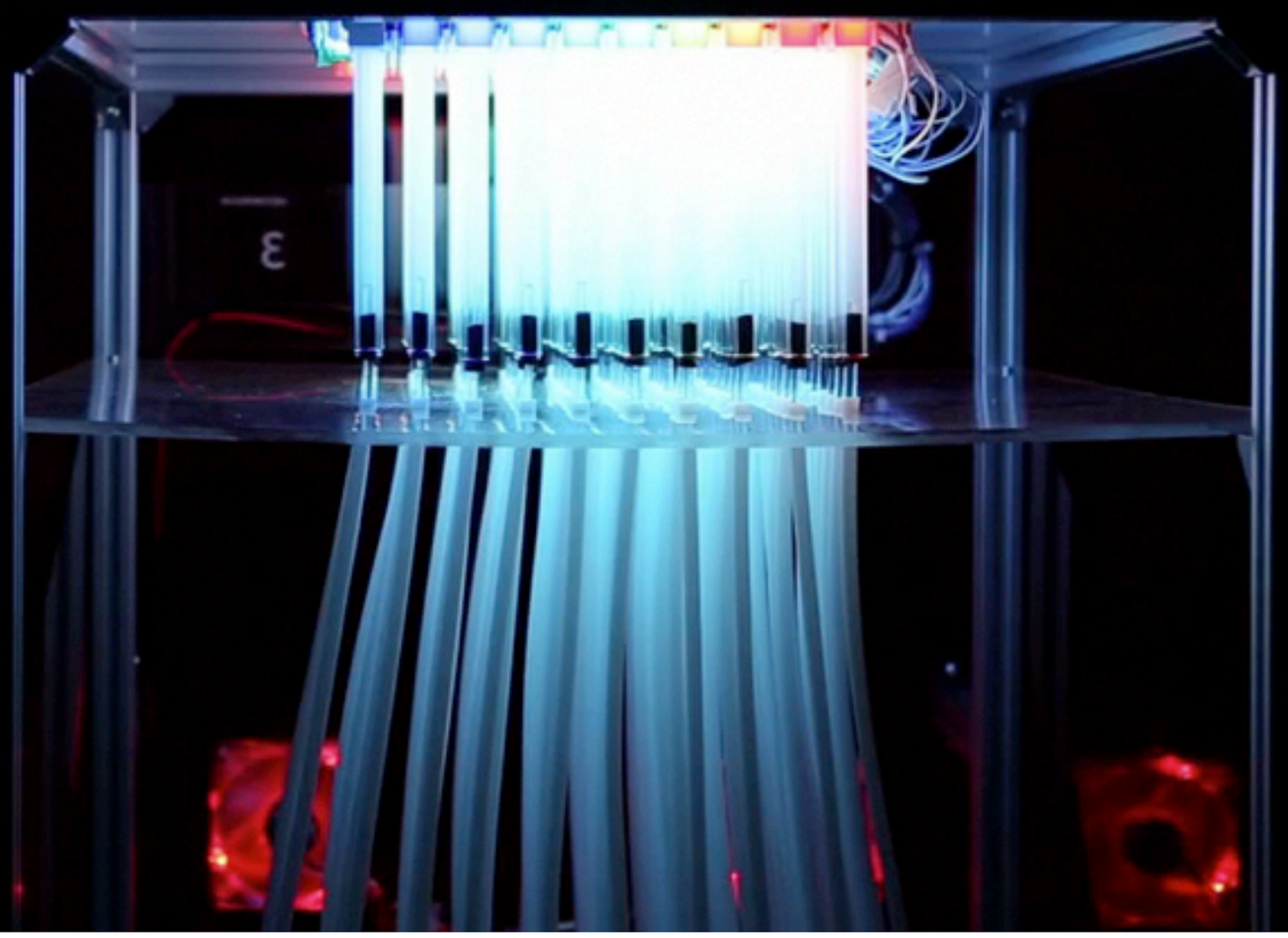


Dynamic Bar Charts *[Taher et al. 2015]*

Exploring Interactions with Physically Dynamic Bar Charts

Faisal Taher [1]
John Hardy [1]
Abhijit Karnik [1]
Christian Weichel [1]
Yvonne Jansen [2]
Kasper Hornbæk [2]
Jason Alexander [1]

[1] Lancaster University, UK
[2] University of Copenhagen, Denmark



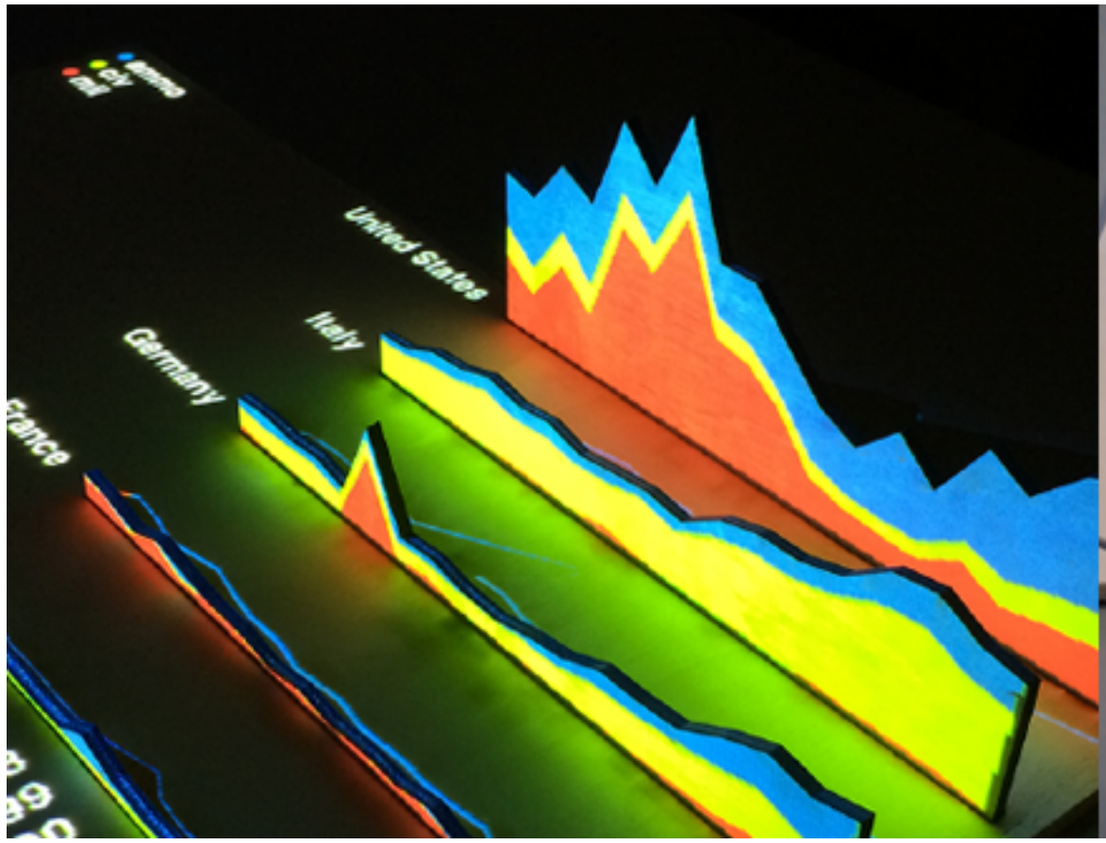
Dynamic Bar Charts *[Taher et al. 2015]*

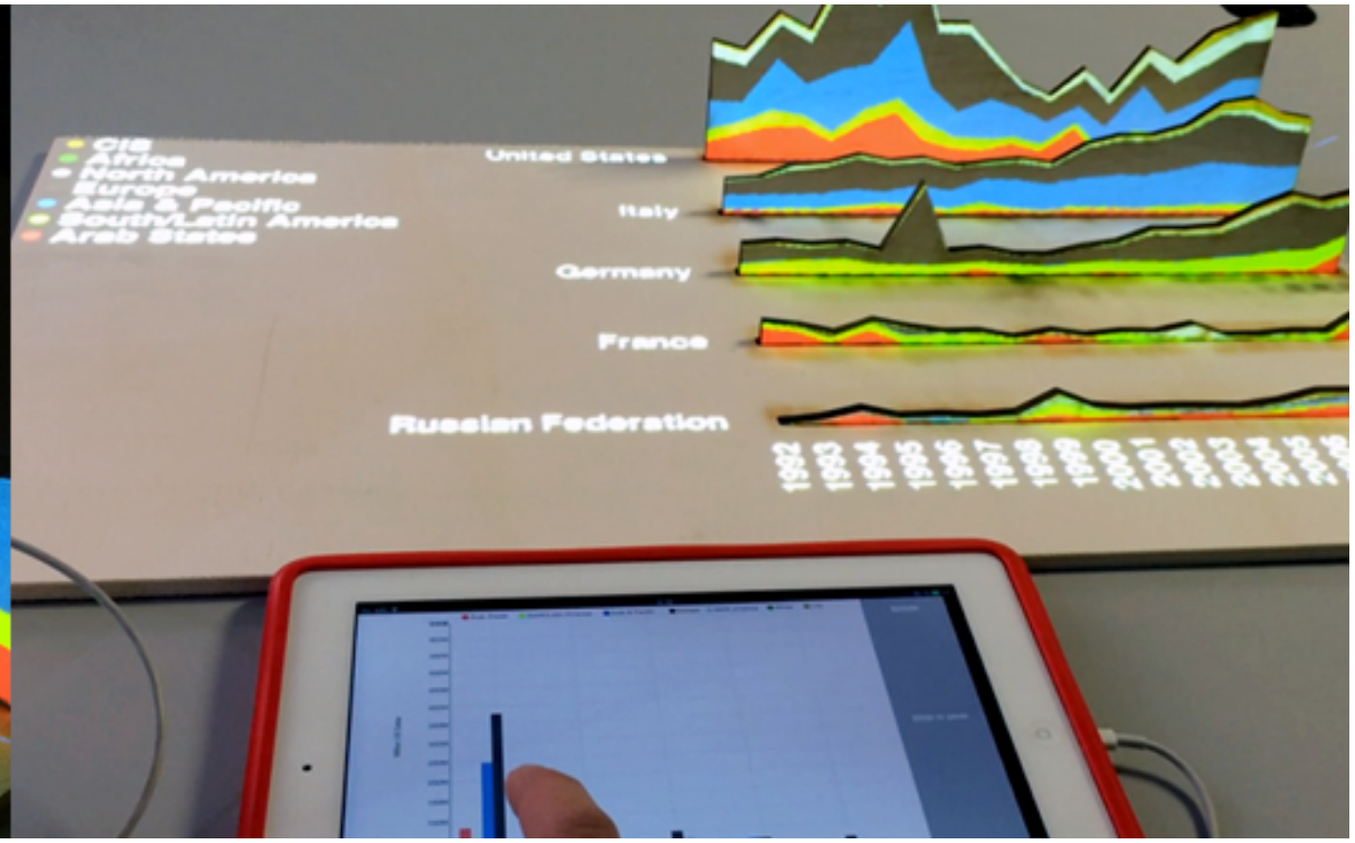
Gestural vs. Physical Interaction

Combining Interaction Modalities

Effect of Preconceptions

Projection Augmentation *[Stusak & Teufel 2014]*





Projection Augmentation *[Stusak & Teufel 2014]*

Projection Augmentation *[Stusak & Teufel 2014]*

Physical Visualization (material, fabrication, size, …)

Projection (position, purpose, …)

Input Modality (touch, remote, …)

Interaction Challenges *[Jansen et al. 2015]*

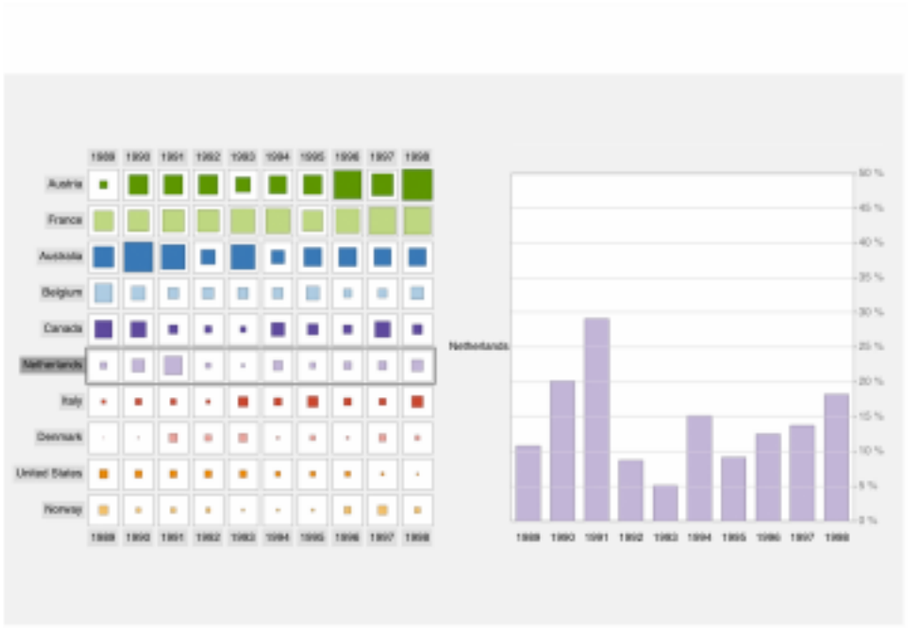
Timing of animated transitions

Design of physical / synthetic interactions

Recognizability and discoverability of interactions

Projects - Evaluation

Efficiency at Information Retrieval *[Jansen et al. 2013]*



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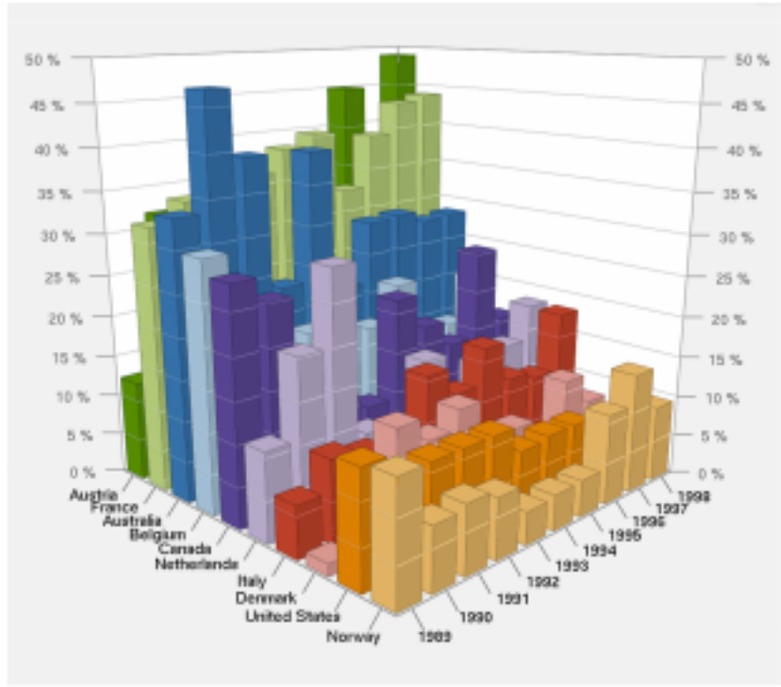

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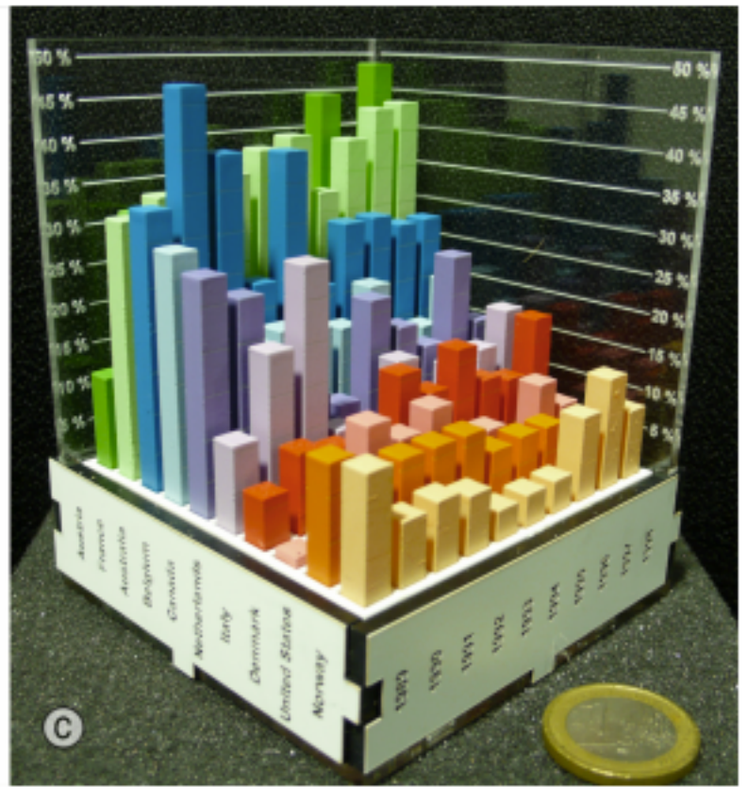

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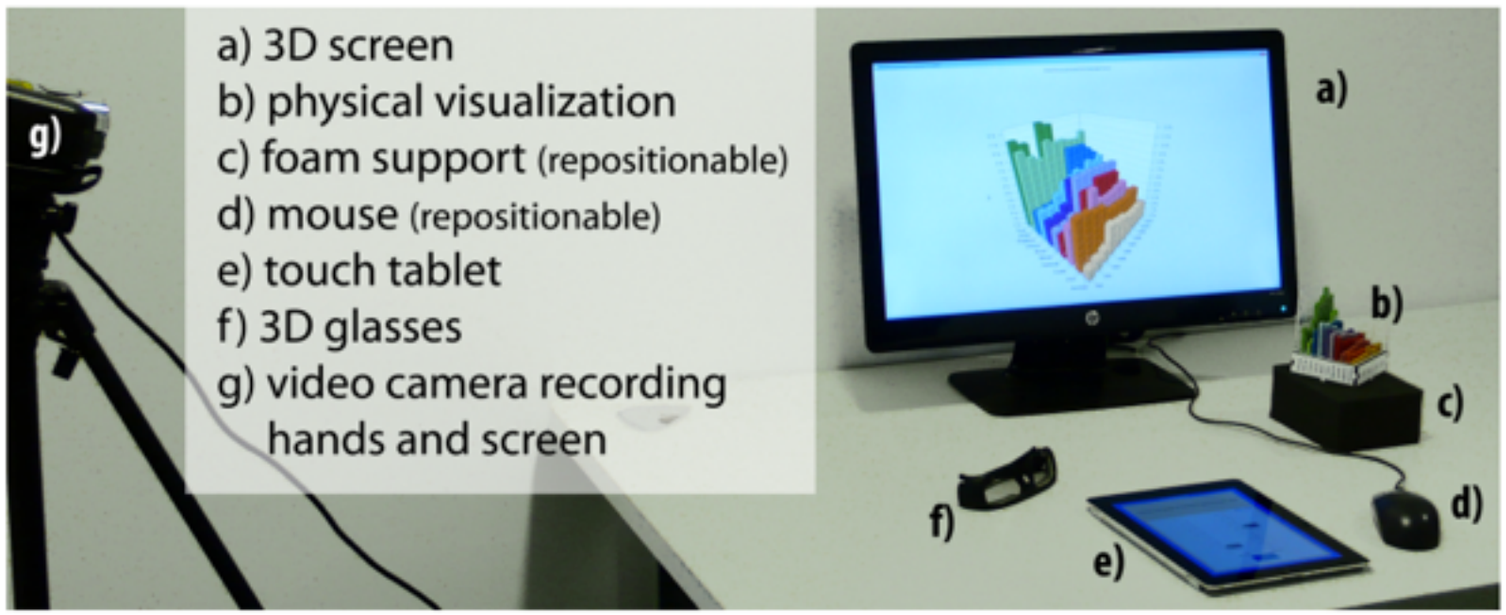


Efficiency at Information Retrieval *[Jansen et al. 2013]*

First Experiment

H1 Task time with physical is about 15–20% lower than with both mono and stereo.

H2 2D outperforms all other techniques by no more than 50% in time.

H3 stereo is slightly faster than mono.

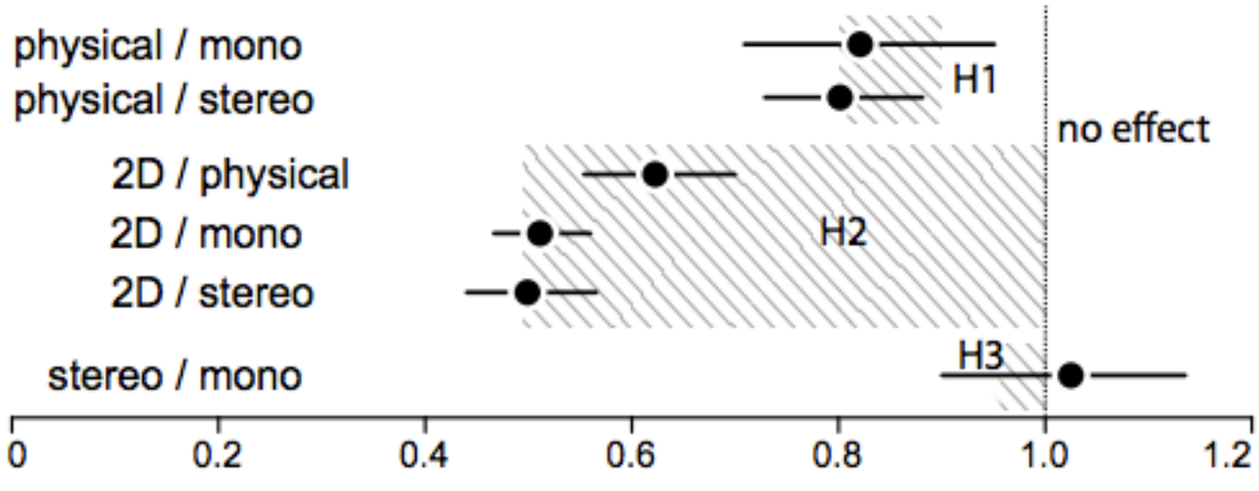


Figure 4. Time ratios between techniques, with 95% CIs. Hatched areas indicate expected effect sizes as expressed in our hypotheses.

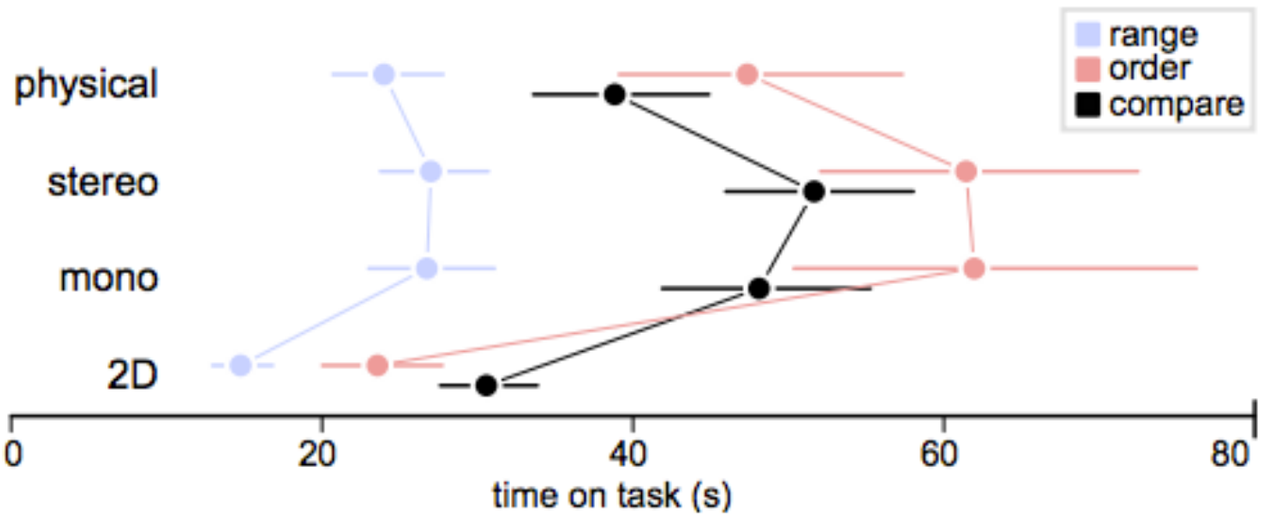


Figure 5. Average time per technique and task, with 95% CIs.

Efficiency at Information Retrieval *[Jansen et al. 2013]*

Second Experiment

H1 touch requires 15-25% less time than no touch.

H2 no touch requires at least 10% less time than prop.

H3 prop and mouse differ by no more than 5%.

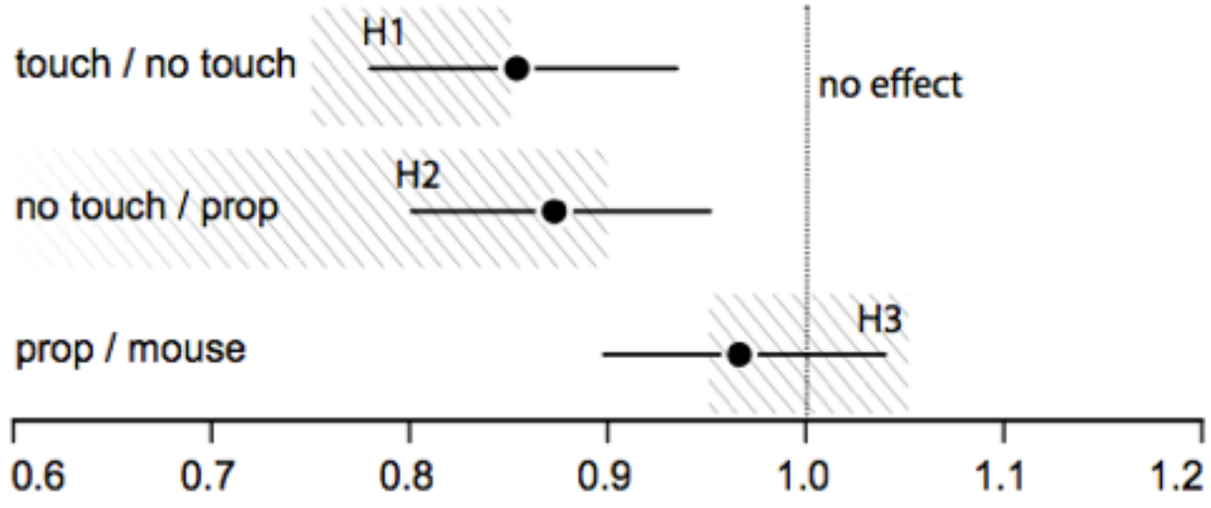


Figure 6. Time ratios between techniques, with 95% CIs. Hatched areas indicate expected effect sizes as expressed in our hypotheses.

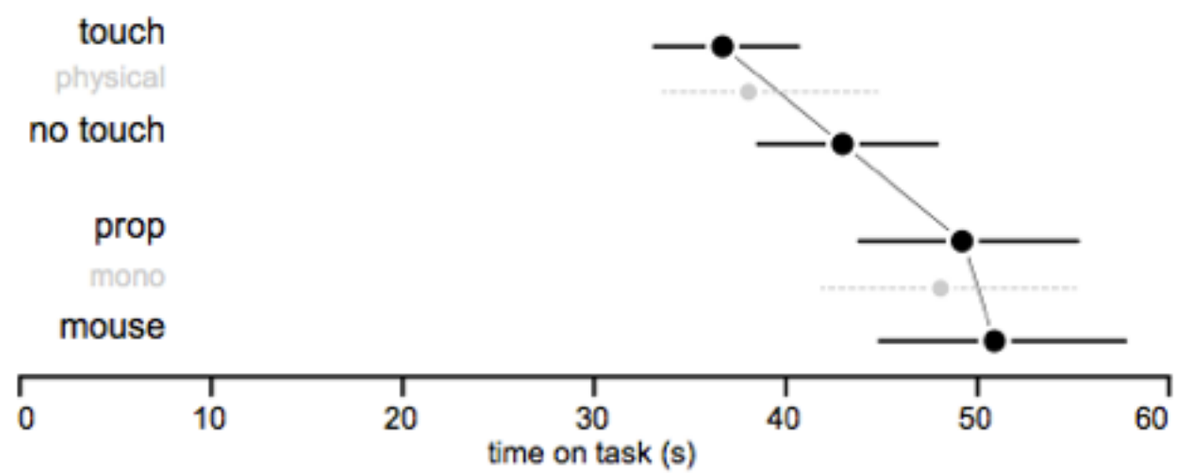


Figure 7. Mean times per technique, with 95% CIs. Results from our first experiment (task *compare*) have been included for reference (gray).

Efficiency at Information Retrieval *[Jansen et al. 2013]*

advantage of the physical bar chart lies in its ability of being ***touched***

the ***action*** of placing fingers to use them as visual or memory aids

degree of ***visual realism***

Memorability *[Stusak et al. 2015]*

Can **physicality** influence the **memorability** of information?

Memorability *[Stusak et al. 2015]*

40 Participants (between-groups) / 17 female / ~23.5 years

Reading Phase

Immediate Recall Phase

2 weeks

Delayed Recall Phase

Memorability *[Stusak et al. 2015]*

extreme values

Which country has the most trust in its government?

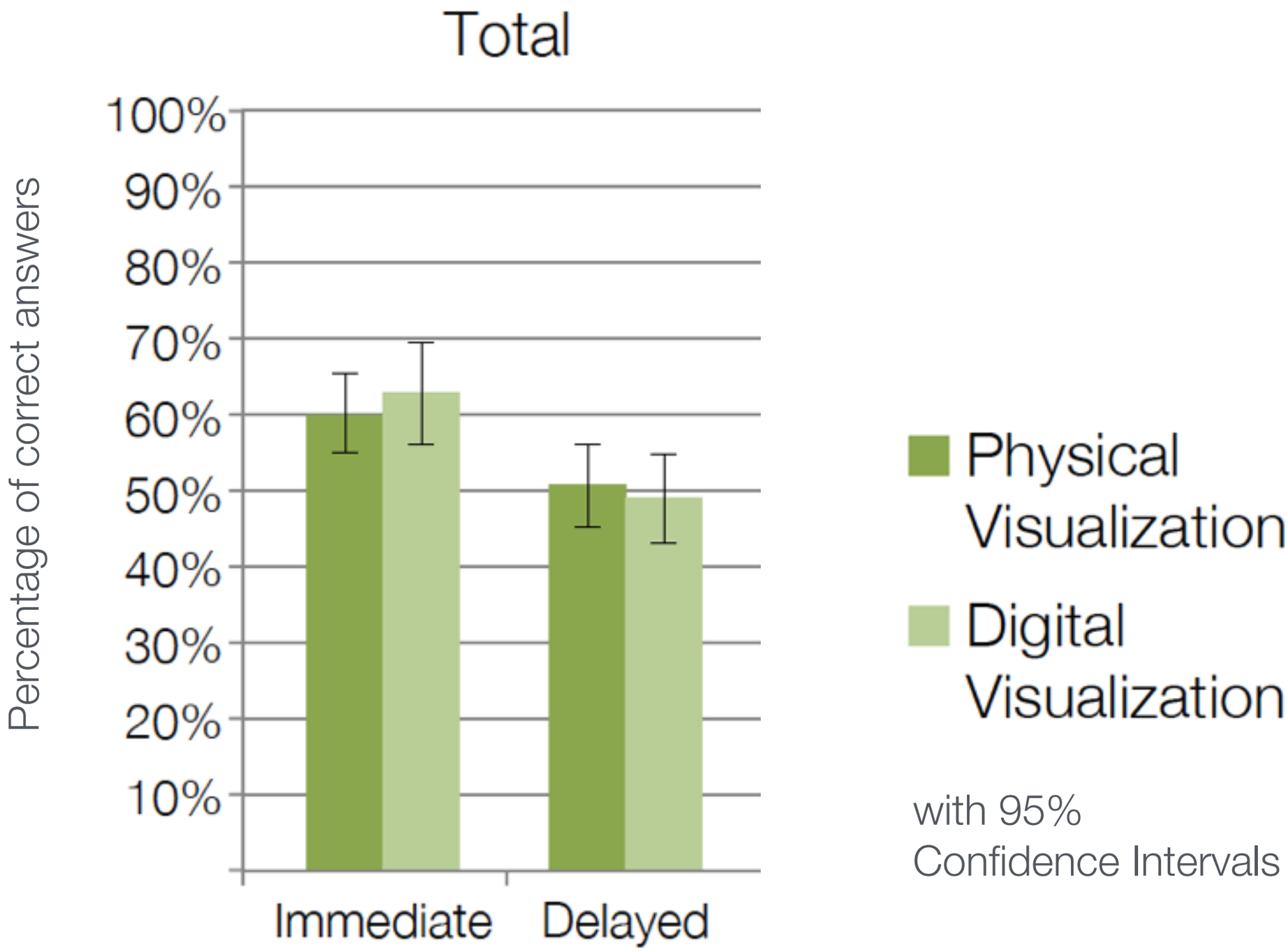
numerics values

In Brazil, only 15% have trust in their government.

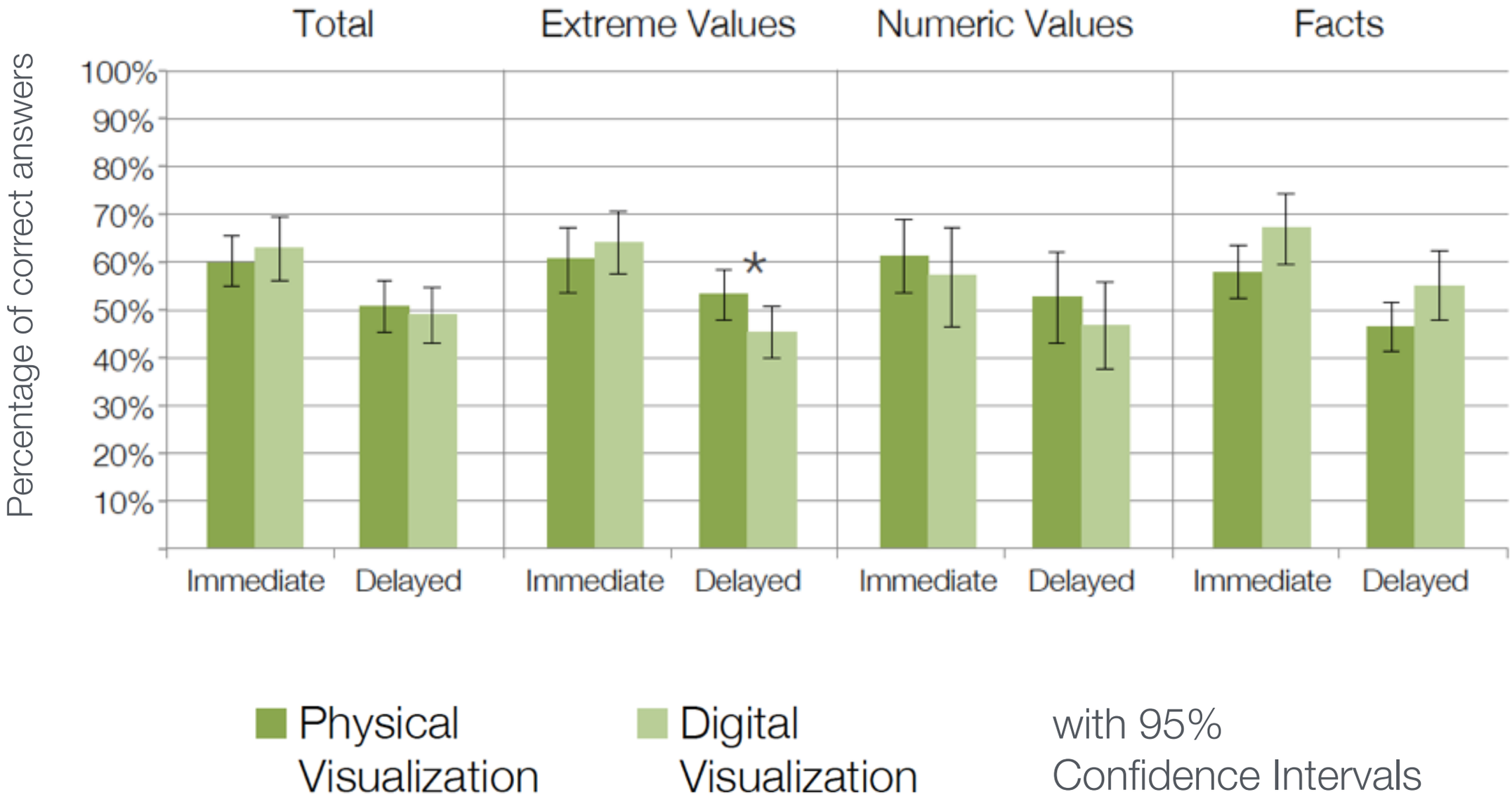
facts

Germany has more trust in its government than Brazil.

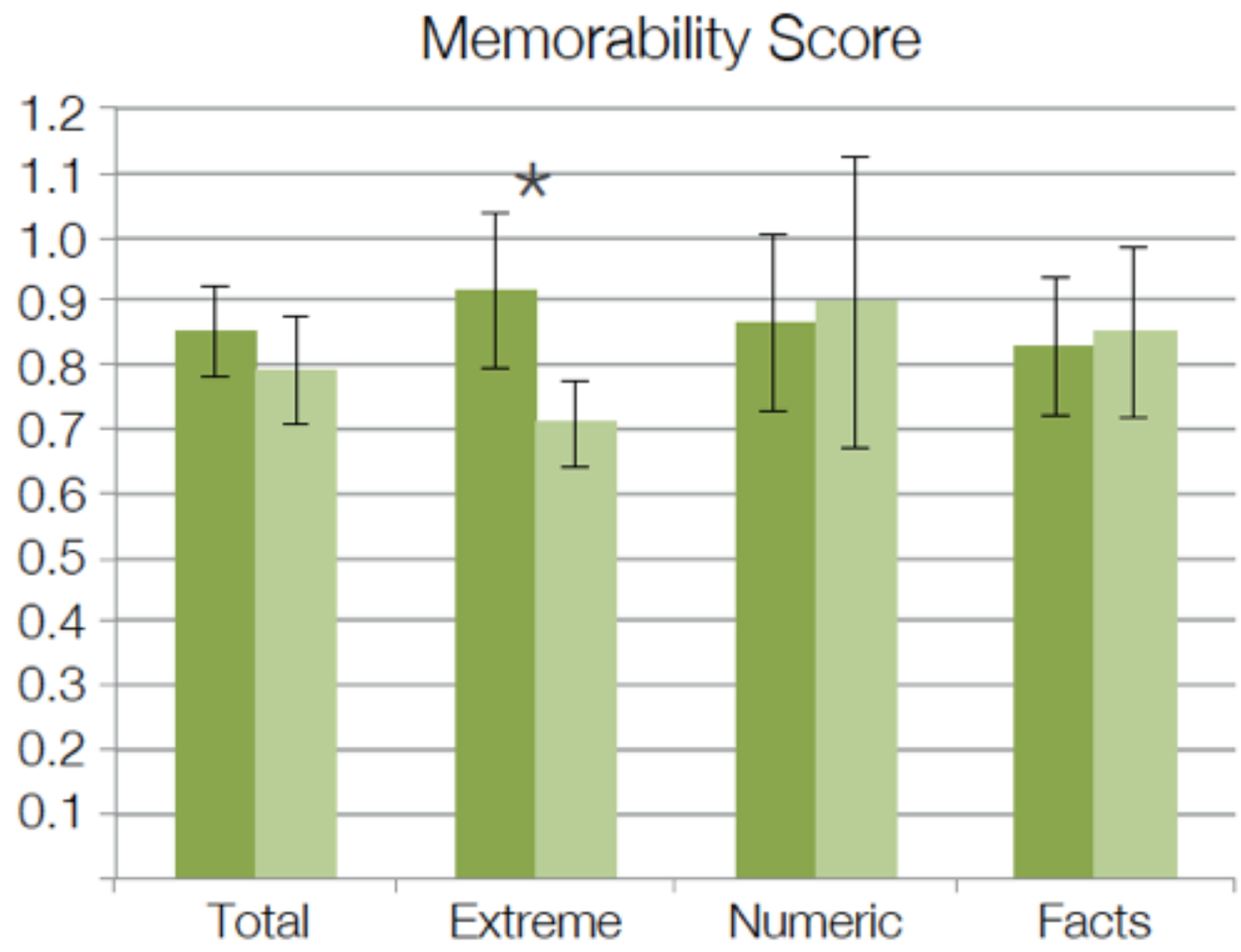
Memorability *[Stusak et al. 2015]*



Memorability *[Stusak et al. 2015]*



Memorability *[Stusak et al. 2015]*



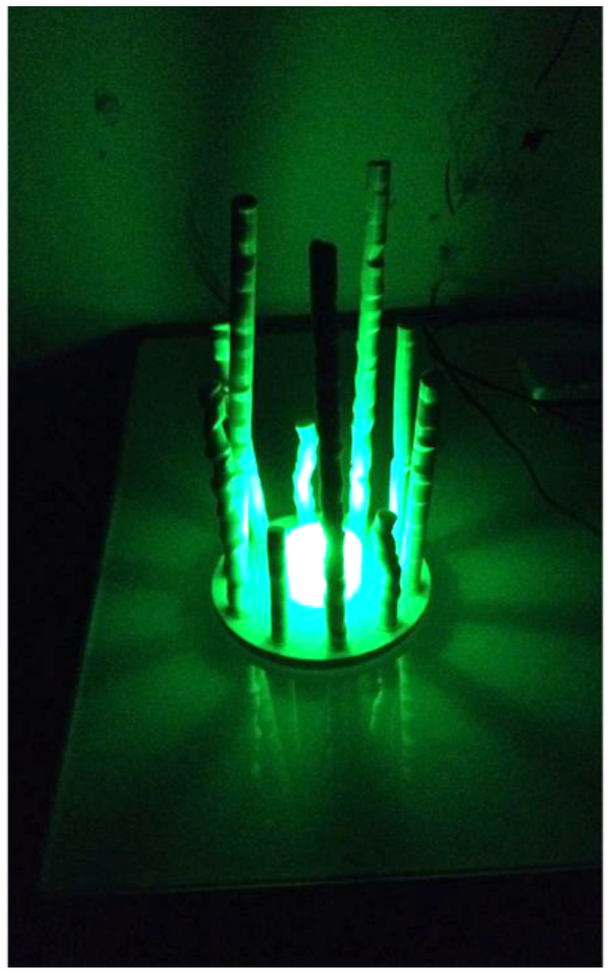
Physical Visualization

Digital Visualization

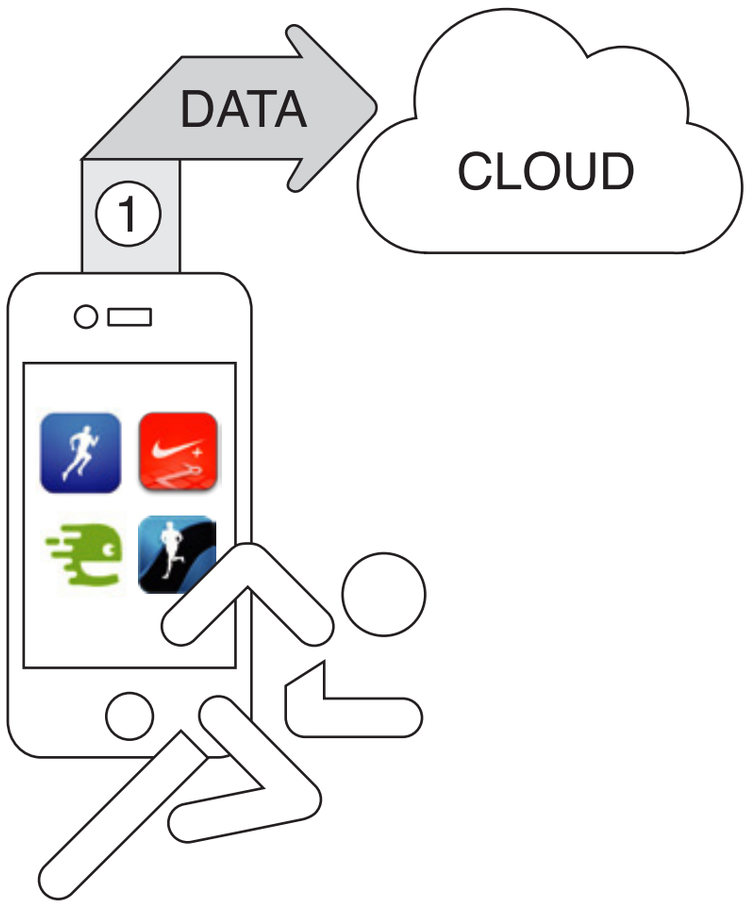
$$\text{Memorability Score} = \frac{\text{delayed recall}}{\text{immediate recall}}$$

Activity Sculptures *[Stusak et al. 2014]*

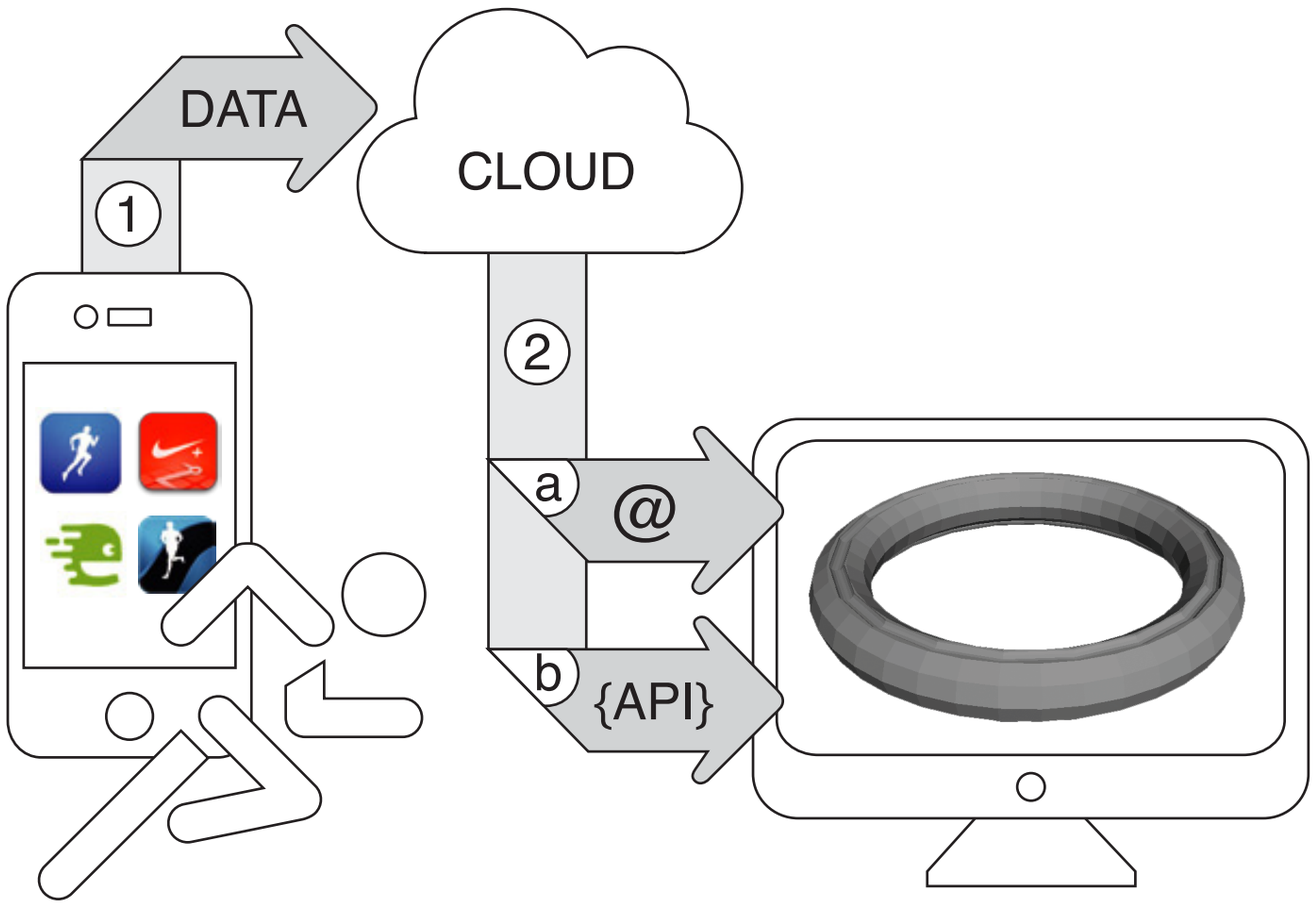
Data Sculptures of running activity

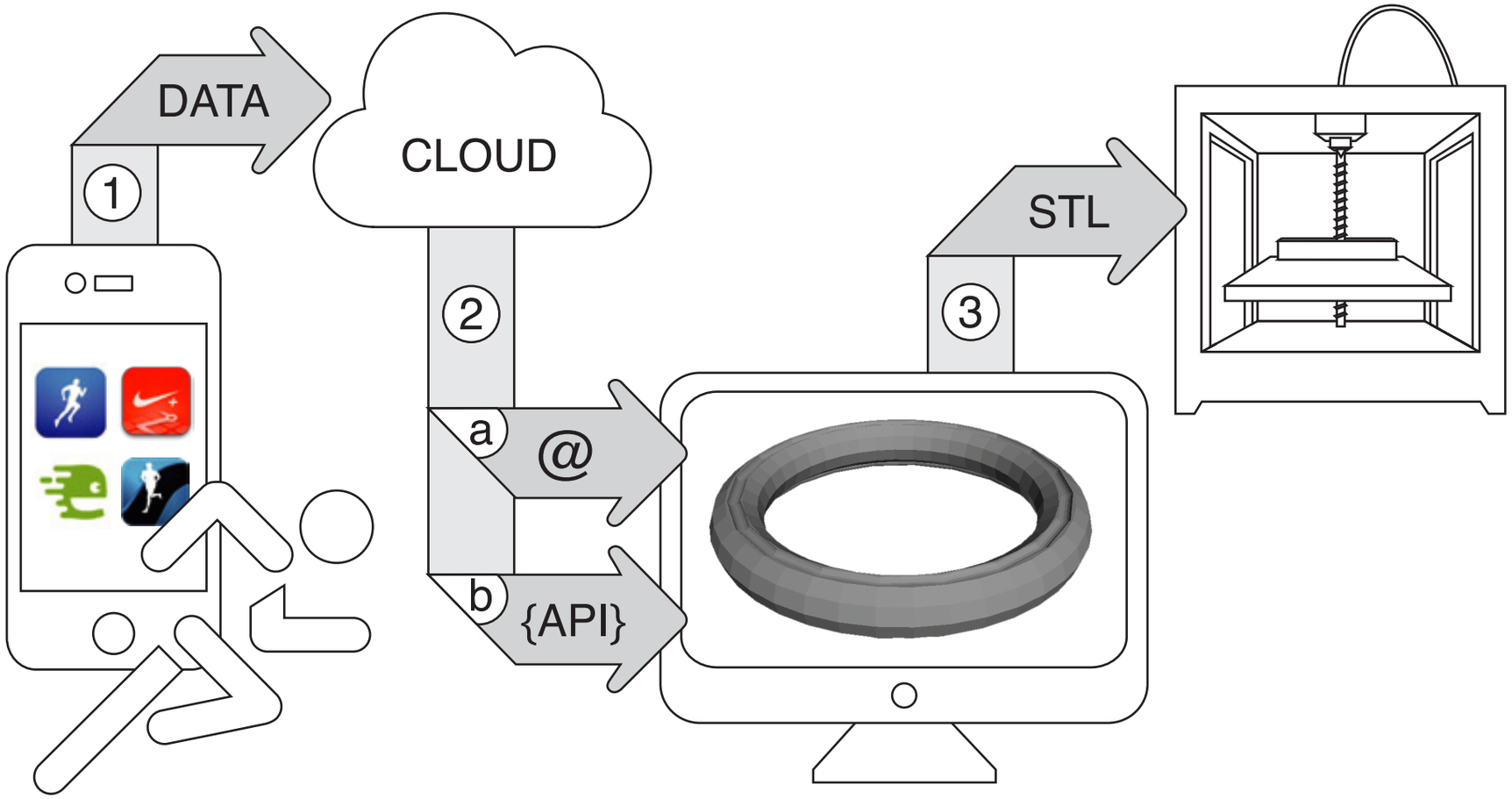

Activity Sculptures *[Stusak et al. 2014]*



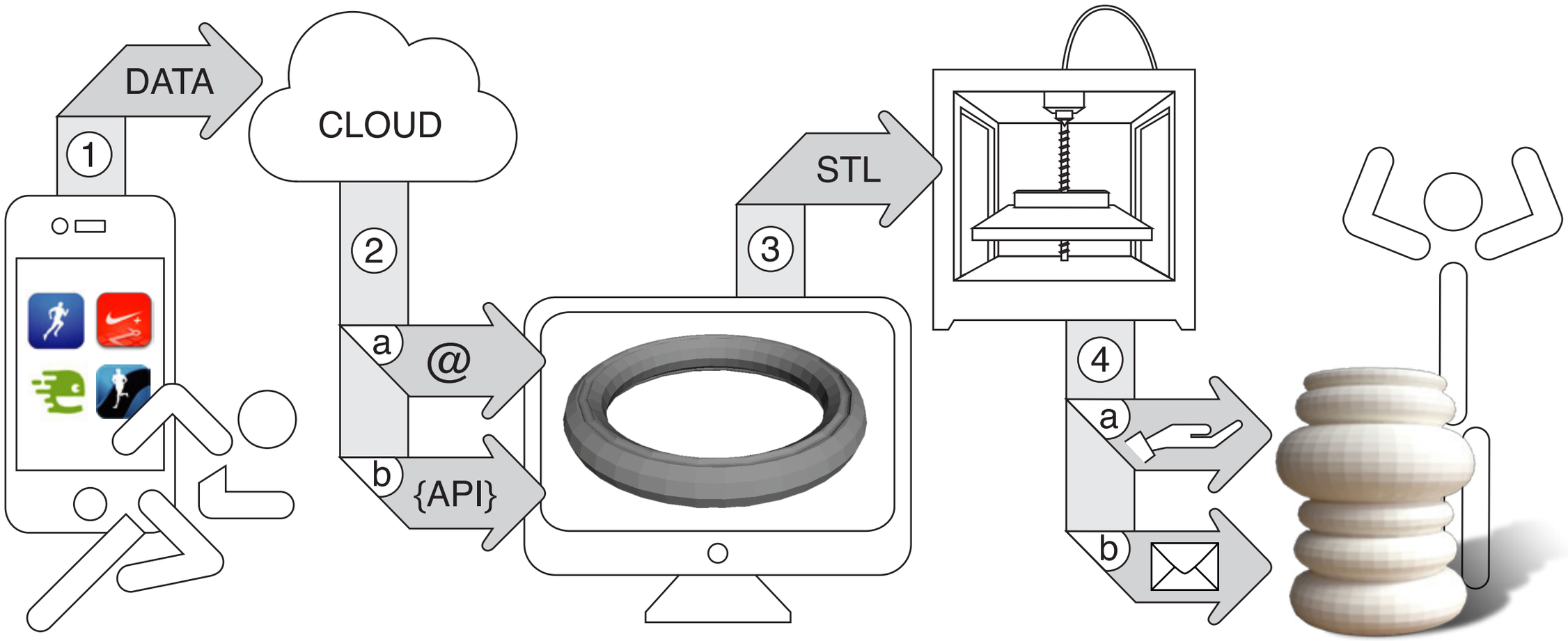
Activity Sculptures *[Stusak et al. 2014]*



Activity Sculptures *[Stusak et al. 2014]*



Activity Sculptures *[Stusak et al. 2014]*



Activity Sculptures *[Stusak et al. 2014]*

Field Study: 3 weeks / 14 participants

71 runs in total (between 1 and 9 runs)

semi-structured interviews

Activity Sculptures *[Stusak et al. 2014]*

sculptures were embedded in everyday life

potential for motivation and self-reflection was rated good

suitability for self-expression less positively after study

Activity Sculptures *[Stusak et al. 2014]*

difficulties in understanding the data-mapping

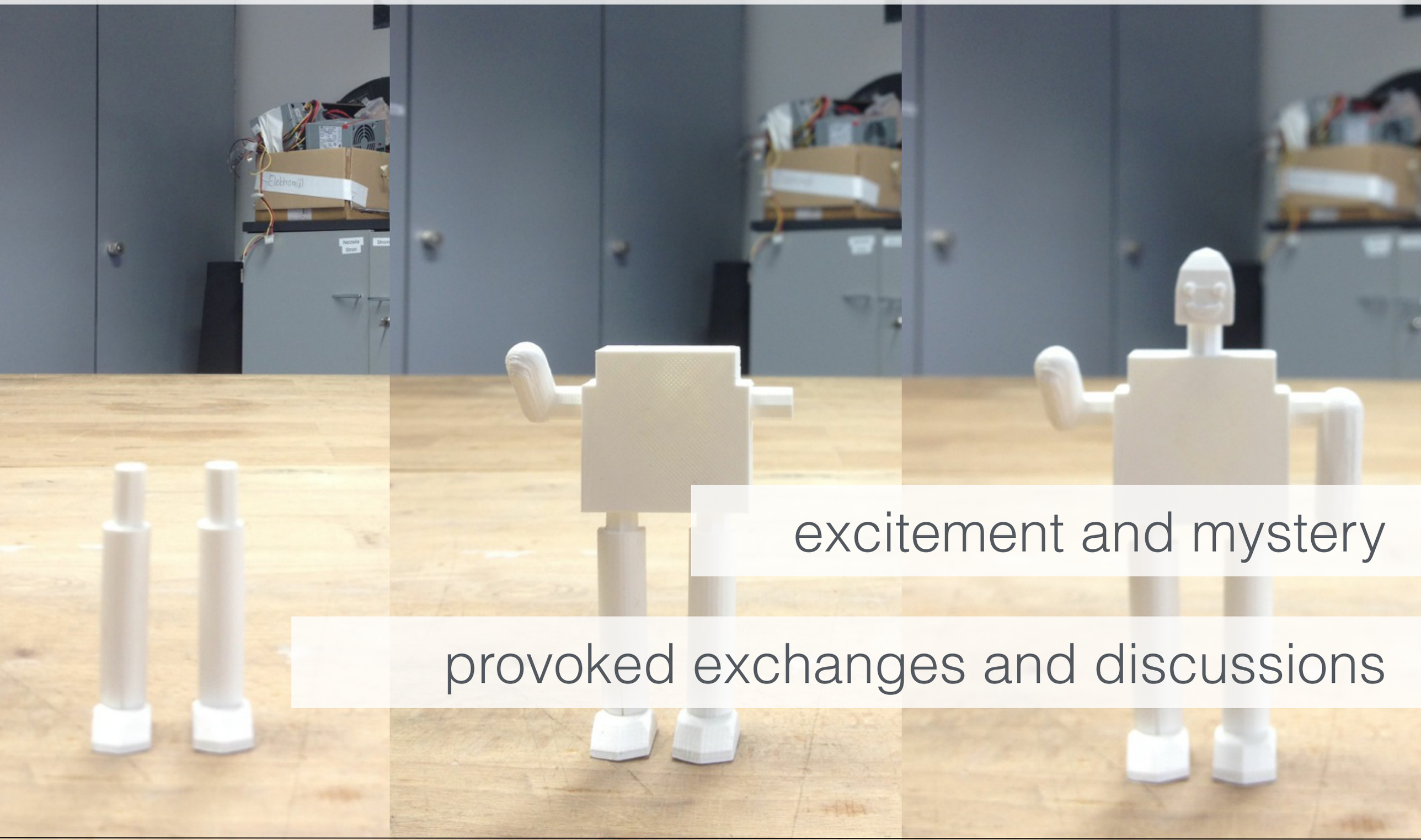
learned how to read the visualization

Activity Sculptures *[Stusak et al. 2014]*

curiosity and playfulness influenced running habits

„pearl of shame“

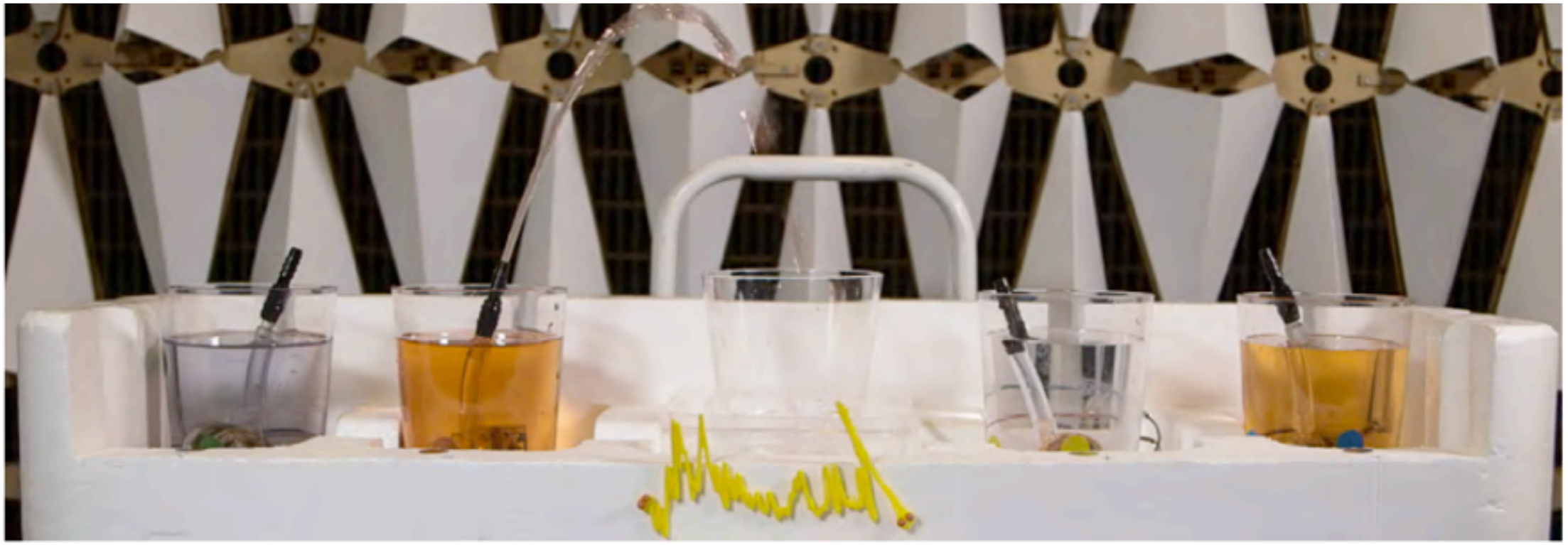
Activity Sculptures *[Stusak et al. 2014]*



excitement and mystery

provoked exchanges and discussions

Tasty Beats *[Khot et al. 2015]*



Tasty Beats *[Khot et al. 2015]*

Tasty Beats *[Khot et al. 2015]*

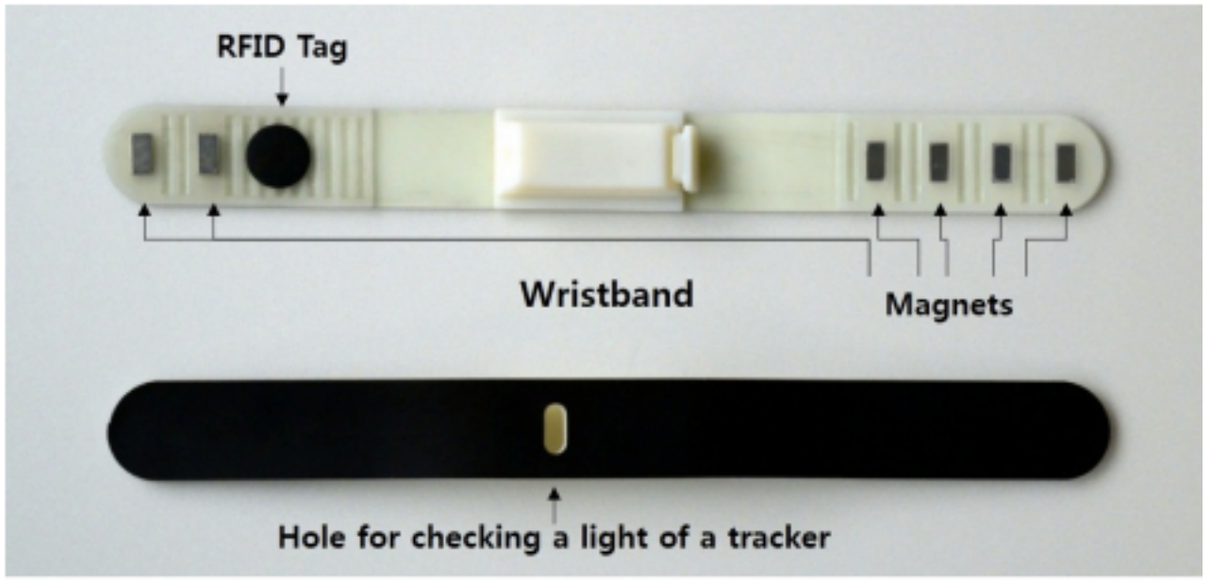
Experiences (surprise, satisfaction, joy)

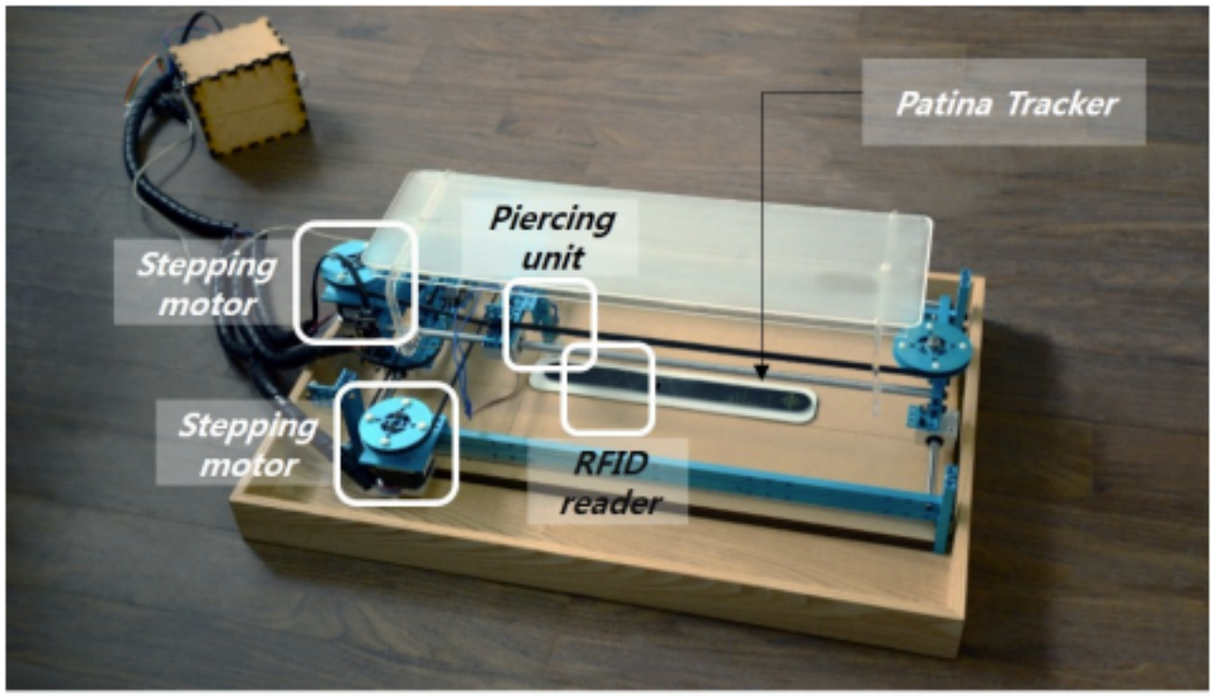
Relation to Physical Activity

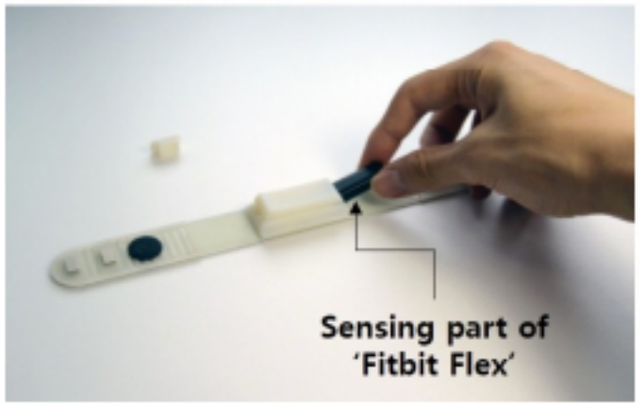
Social Dynamics

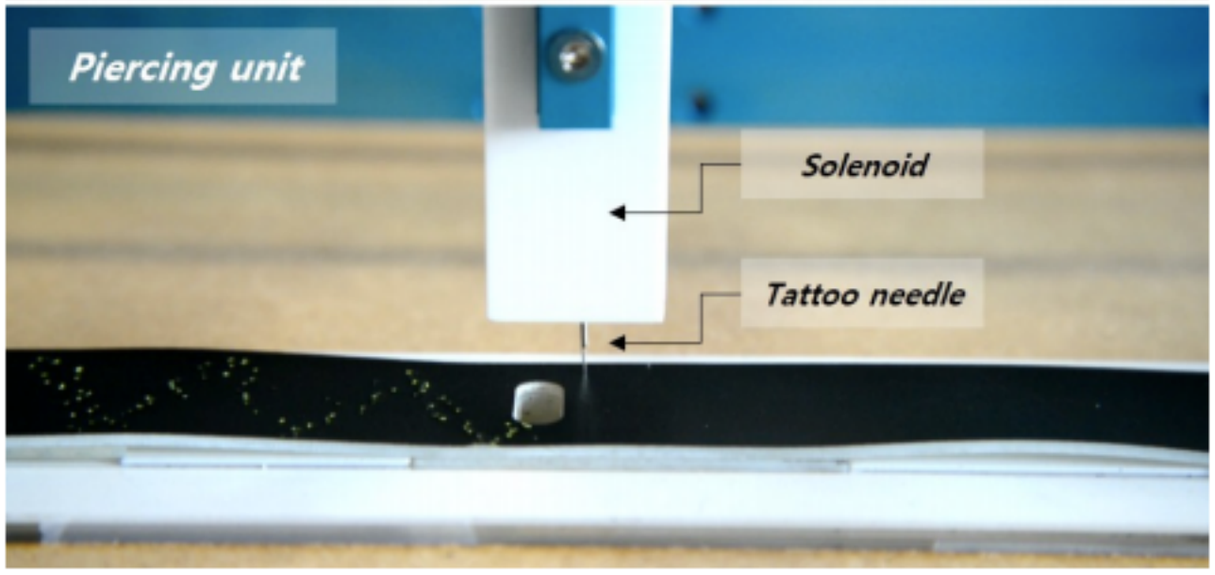
Rewarding Aspects

Patina Engraver *[Lee et al. 2015]*

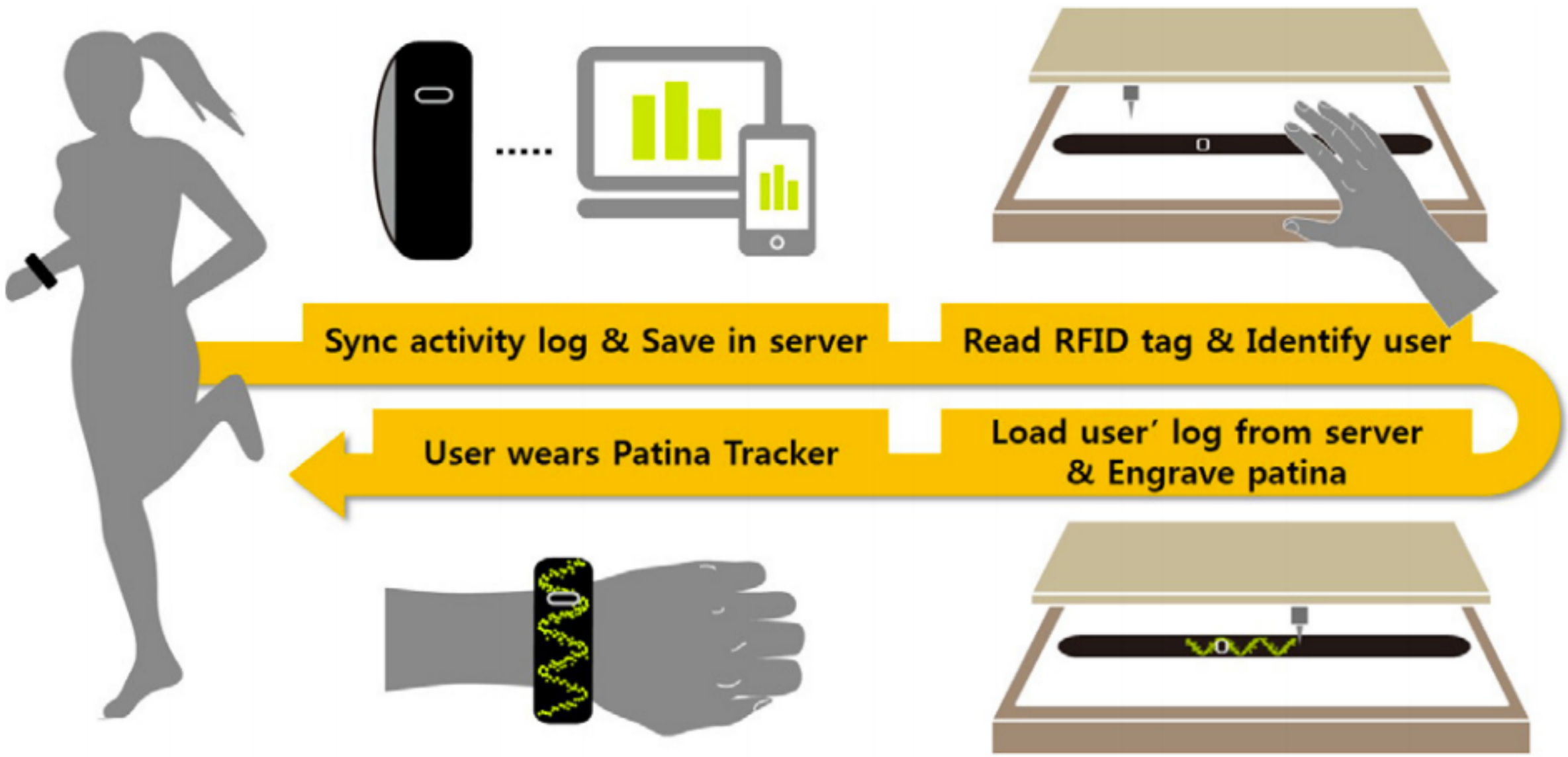




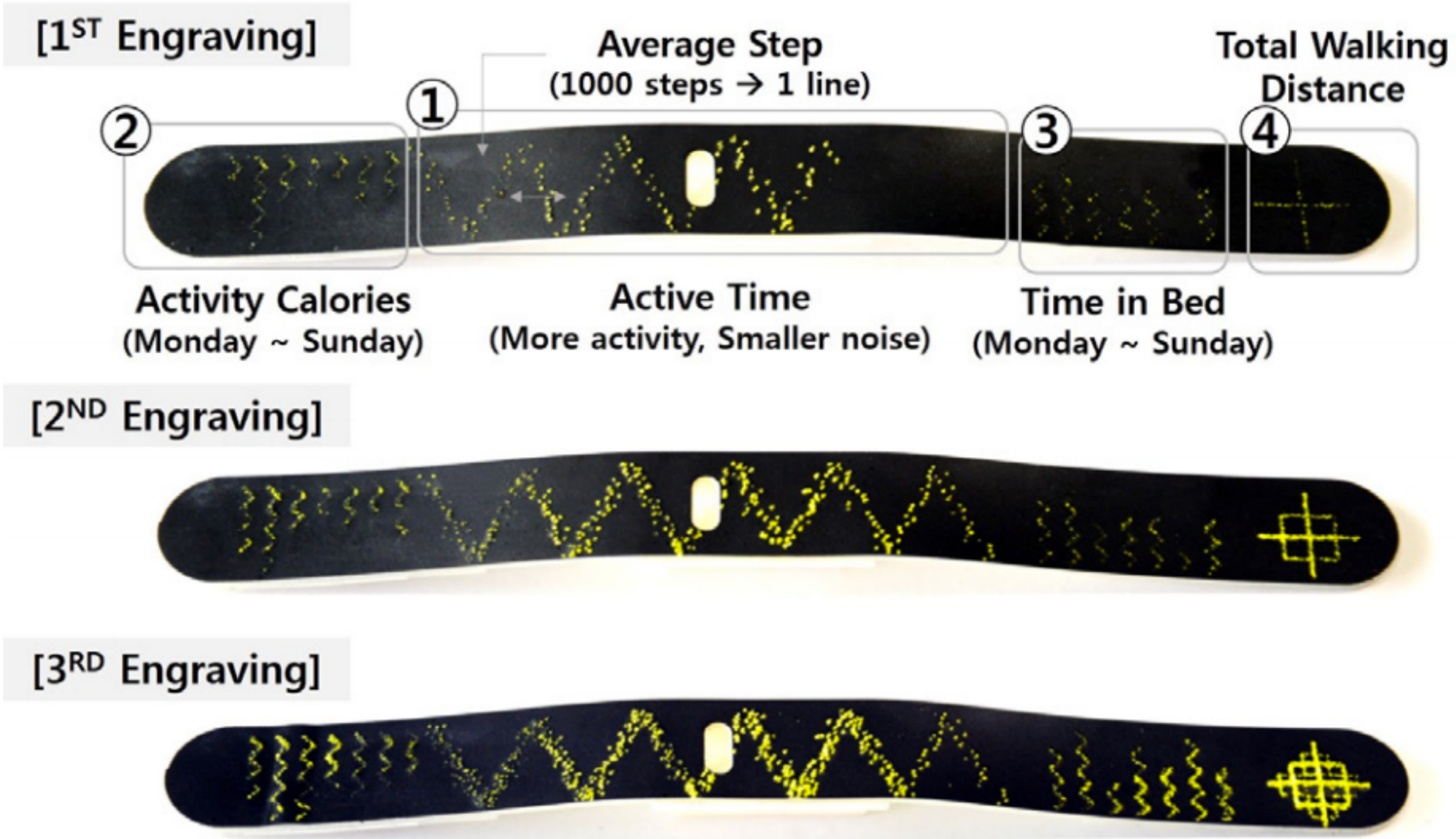




Patina Engraver *[Lee et al. 2015]*



Patina Engraver *[Lee et al. 2015]*



Patina Engraver *[Lee et al. 2015]*

Wondering about What Patina Means

Feeling Pressure for Engraving Aesthetic Patina

Evaluation Challenges *[Jansen et al. 2015]*

Evaluation Challenges *[Jansen et al. 2015]*

Evaluation beyond time and error

Comparative evaluation - fair alternative

Focus on presentation modality - avoid experimental bias

Benefits and Research Agenda

The Benefits of Data Physicalizations I *[Jansen et al. 2015]*

Leveraging our Perceptual Exploration Skills

Active Perception

Depth Perception

Non-visual Senses

Intermodal Perception

The Benefits of Data Physicalizations II *[Jansen et al. 2015]*

Making Data Accessible

Cognitive Benefits

Bringing Data into the Real World

Engaging People

Research Agenda *[Jansen et al. 2015]*

Designing Physical Data Representations

Supporting Animation and Interactivity

Evaluation-Specific Challenges

References

Dragicevic, P., and Jansen, Y. List of physical visualizations. dataphys.org/list, 2012.

Follmer, S., Leithinger, D., Olwal, A., Hogge, A., and Ishii, H. inFORM: Dynamic physical affordances and constraints through shape and object actuation. In Proc. UIST (2013), 417–426.

Hardy, John and Weichel, Christian and Taher, Faisal and Vidler, John and Alexander, Jason. 2015. ShapeClip: Towards Rapid Prototyping with Shape-Changing Displays for Designers. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 19-28.

Ishii, H., Lakatos, D., Bonanni, L., and Labrune, J.-B. Radical Atoms: Beyond Tangible Bits, toward transformable materials. Interactions 19, 1 (2012), 38–51.

Ishii, H., and Ullmer, B. Tangible Bits: towards seamless interfaces between people, bits and atoms. In Proc. CHI, ACM (1997), 234–241.

Jansen, Y. Physical and Tangible Information Visualization. PhD thesis, Universite Paris-Sud XI, 2014

Jansen, Y., and Dragicevic, P. An interaction model for visualizations beyond the desktop. TVCG 19, 12 (2013), 2396–2405.

Jansen, Y., Dragicevic, P., and Fekete, J.-D. Evaluating the efficiency of physical visualizations. In Proc. CHI (2013), 2593–2602.

Lee, Moon-Hwan and Cha, Seijin and Nam, Tek-Jin. Patina Engraver: Visualizing Activity Logs as Patina in Fashionable Trackers. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 1173-1182.

Khot, Rohit Ashok and Lee, Jeewon and Aggarwal, Deepti and Hjorth, Larissa and Mueller, Florian ‚Floyd'. TastyBeats: Designing Palatable Representations of Physical Activity. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 2933-2942.

References

Stusak, S., Tabard, A., Sauka, F., Khot, R., and Butz, A. Activity sculptures: Exploring the impact of physical visualizations on running activity. TVCG 20, 12 (2014), 2201–2210.

Stusak, Simon and Teufel, Markus. Projection augmented physical visualizations. In Proceedings of the 2nd ACM symposium on Spatial user interaction (SUI '14). ACM, New York, NY, USA, 145-145.

Stusak, Simon and Schwarz, Jeannette and Butz, Andrea. Evaluating the Memorability of Physical Visualizations. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 3247-3250.

Swaminathan, S., Shi, C., Jansen, Y., Dragicevic, P., Oehlberg, L., and Fekete, J.-D. Supporting the design and fabrication of physical visualizations. In Proc. CHI (2014), 3845–3854.

Taher, Faisal and Hardy, John and Karnik, Abhijit and Weichel, Christian and Jansen, Yvonne and Hornb{\ae}k, Kasper and Alexander, Jason. 2015. Exploring Interactions with Physically Dynamic Bar Charts. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 3237-3246.

Underkoffler, J., and Ishii, H. Urp: A luminous-tangible workbench for urban planning and design. In Proc. CHI (1999), 386–393.

Vande Moere, A., and Patel, S. The Physical Visualization of Information: Designing Data Sculptures in an Educational Context. In Visual Information Communication. Springer, 2010, pp. 1–23.

Zhao, J., and Vande Moere, A. Embodiment in data sculpture: A model of the physical visualization of information. In Proc. DIMEA (2008), 343–350.