

- **Final exam will be posted at EOD today**
 - Final examination for 3300 folks
 - Final project for 5100 folks
 - Due date update: 11:59PM on Dec. 13th (no slipdays)
 - Follow instructions carefully and bugtest!
 - Avoid re-using variable names
 - Make sure to include your data files
 - Bare paths. No "", "..", or "/"
- **Do not work in groups** on the take-home exam
(also, do not copy-paste any code from course notes or example homework files – we will be comparing them)
- **Watch ED for errata or clarifications**
(but do not post your own code publicly there)

Wilson's The Grasses of America



Data Physicalization

Process of encoding data into or representing data as physical entities.

What kinds of physical representations exist for data?



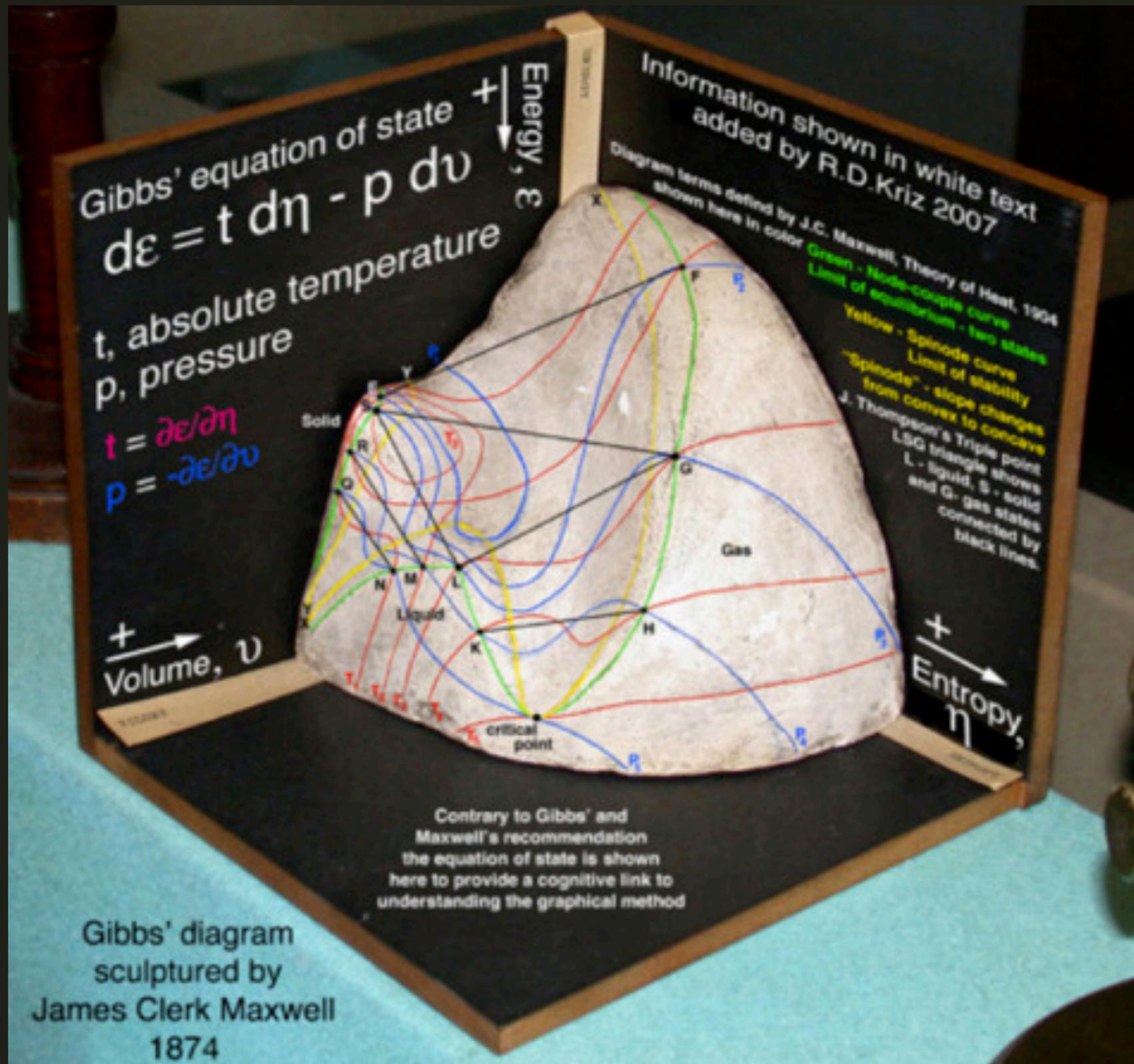
~4000-2000 BCE

Mesopotamian
Tokens



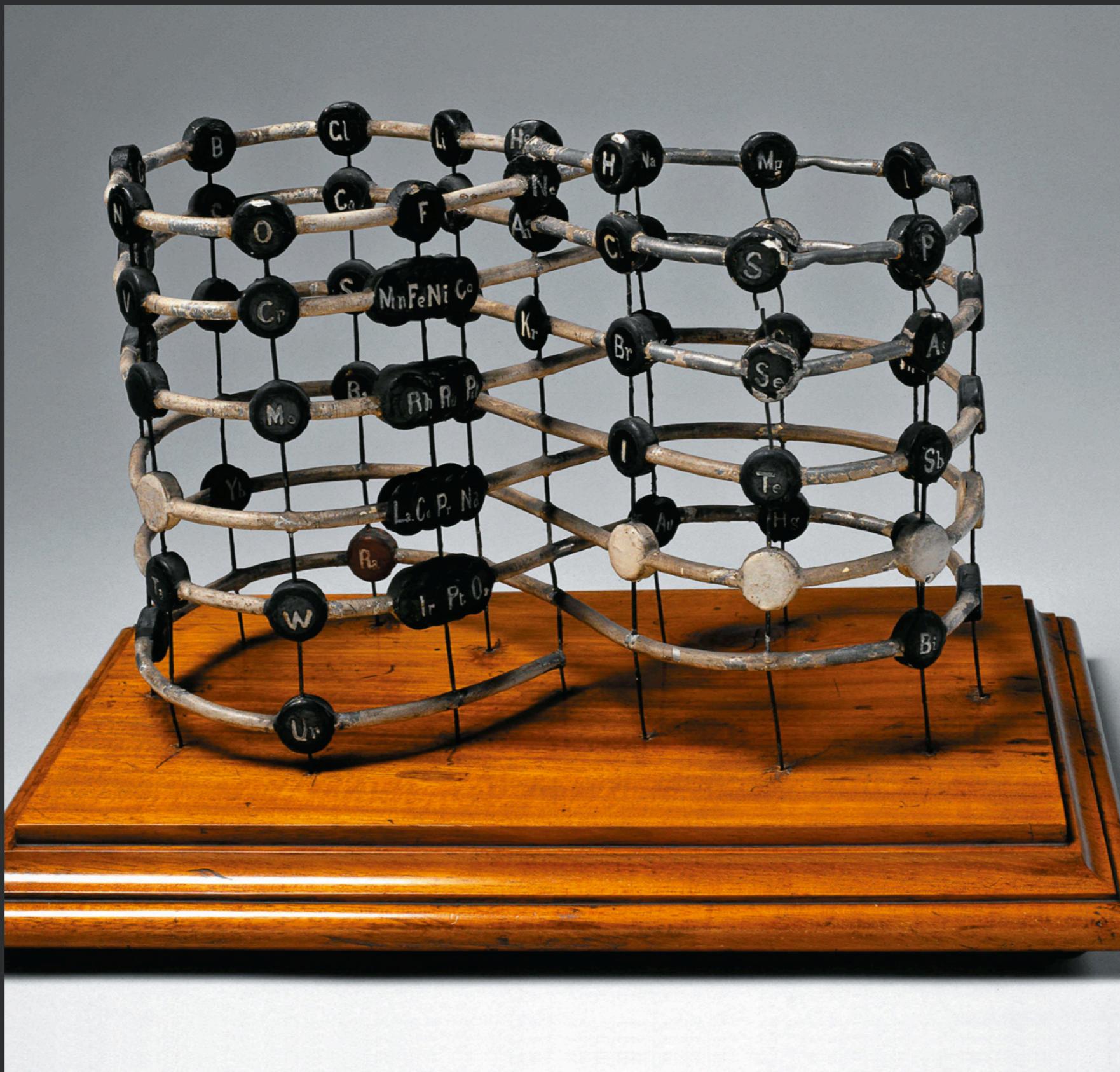
1874 CE

Maxwell



1898 CE

Crookes' "Vis Generatrix"



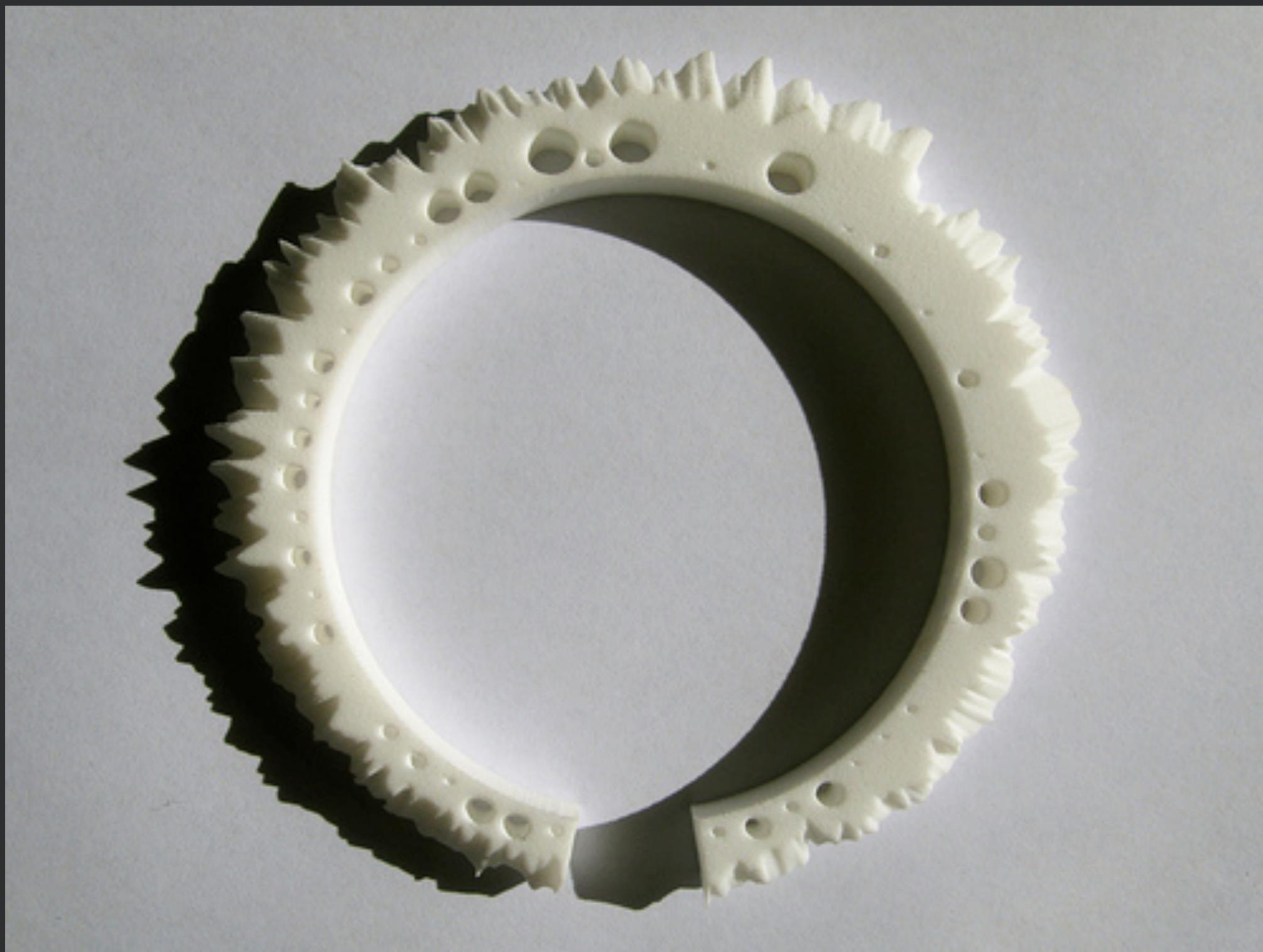
Cline's Temperature Afghan



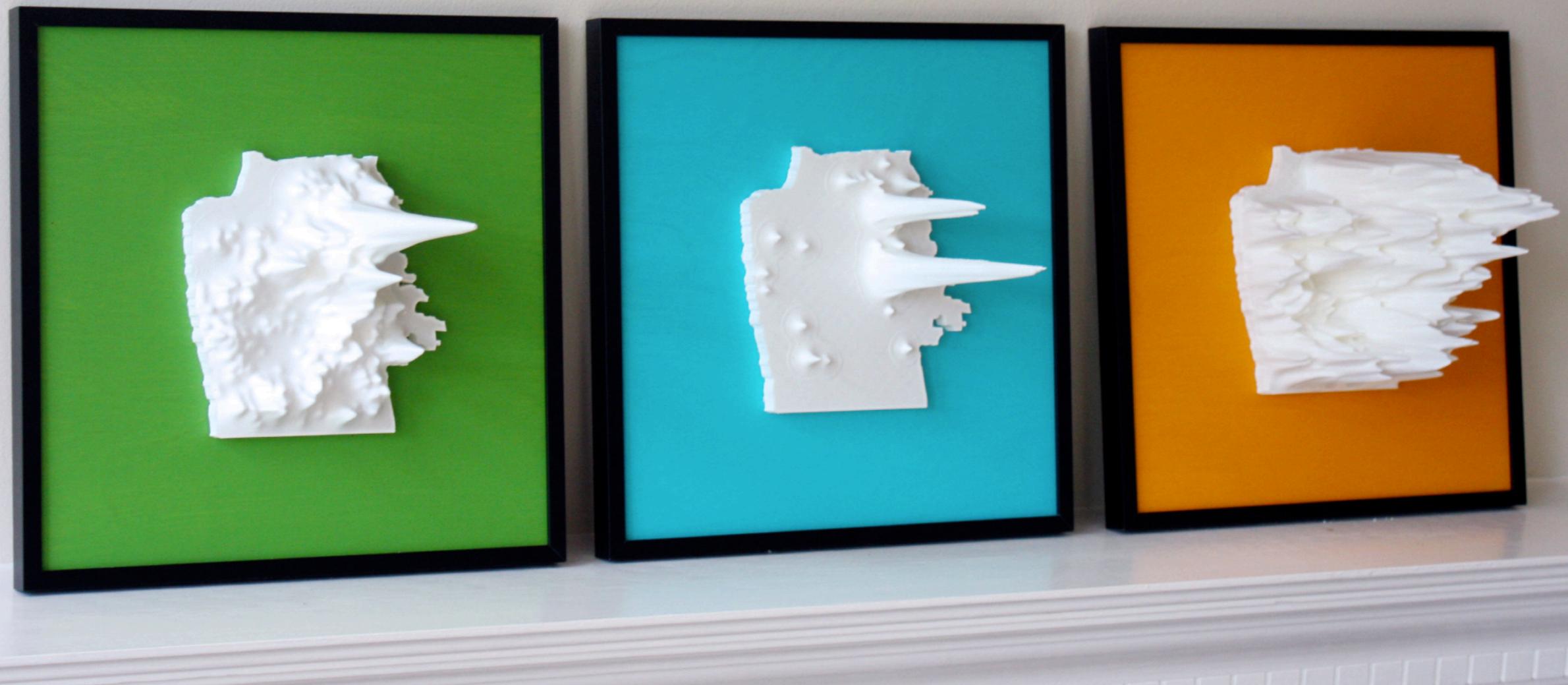
Thudt's Data Pottery

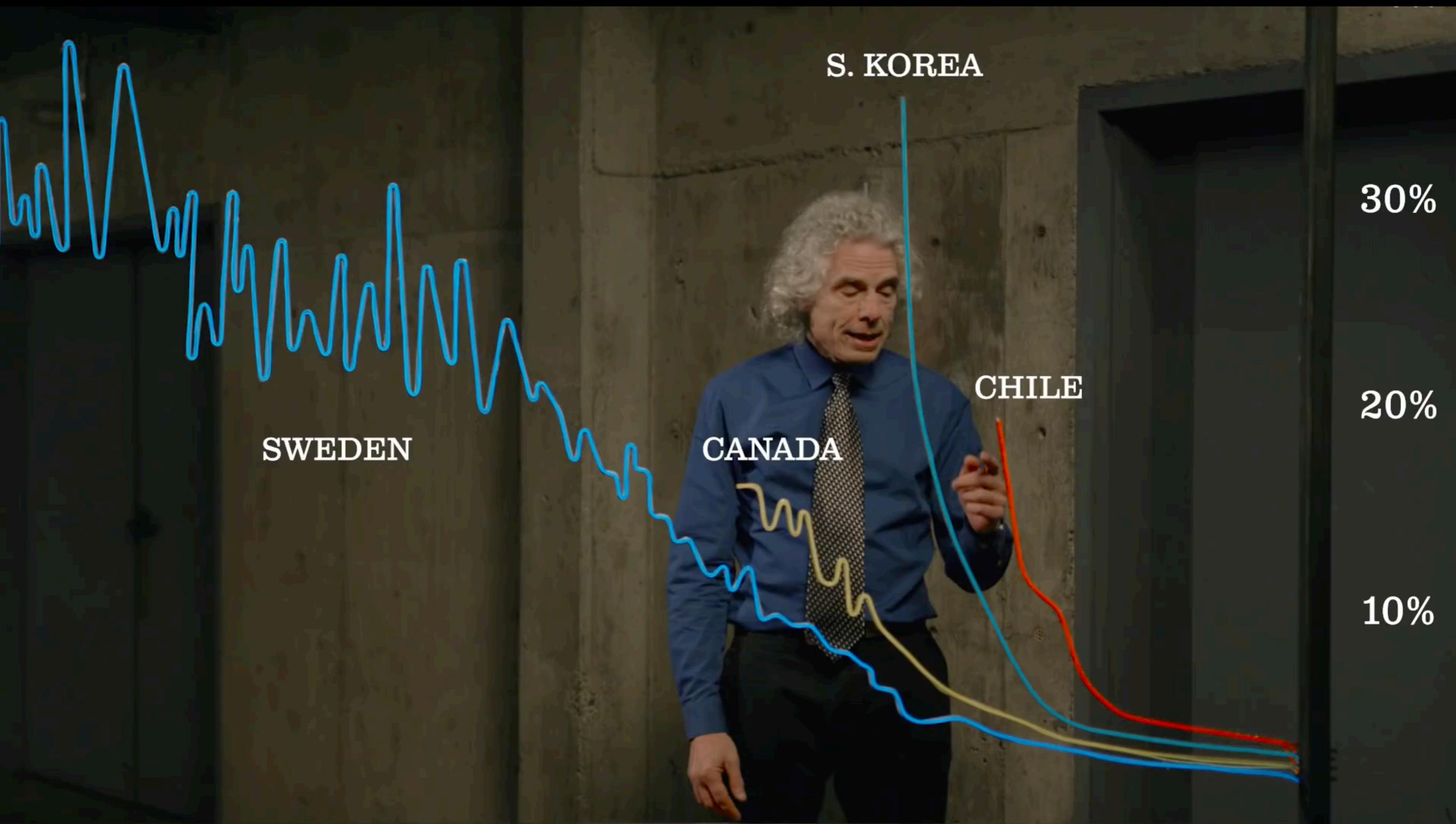


Whitelaw's Canberra Weather Bracelet



McCune's Deviant Cartographs





Physical Visualizations

What do all of these examples have in common?



Physical Visualizations

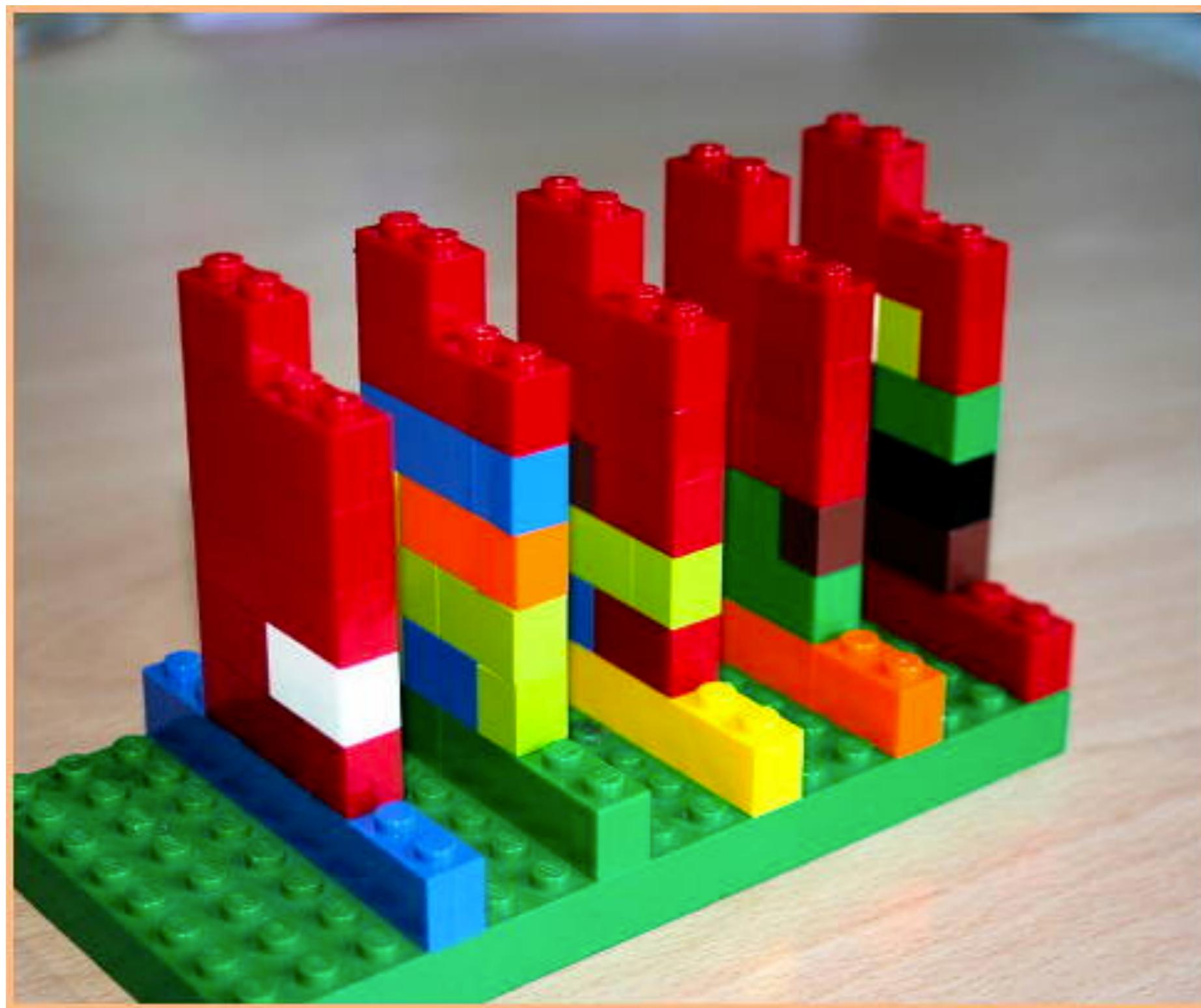
One-off scripts, Processing code, manual construction

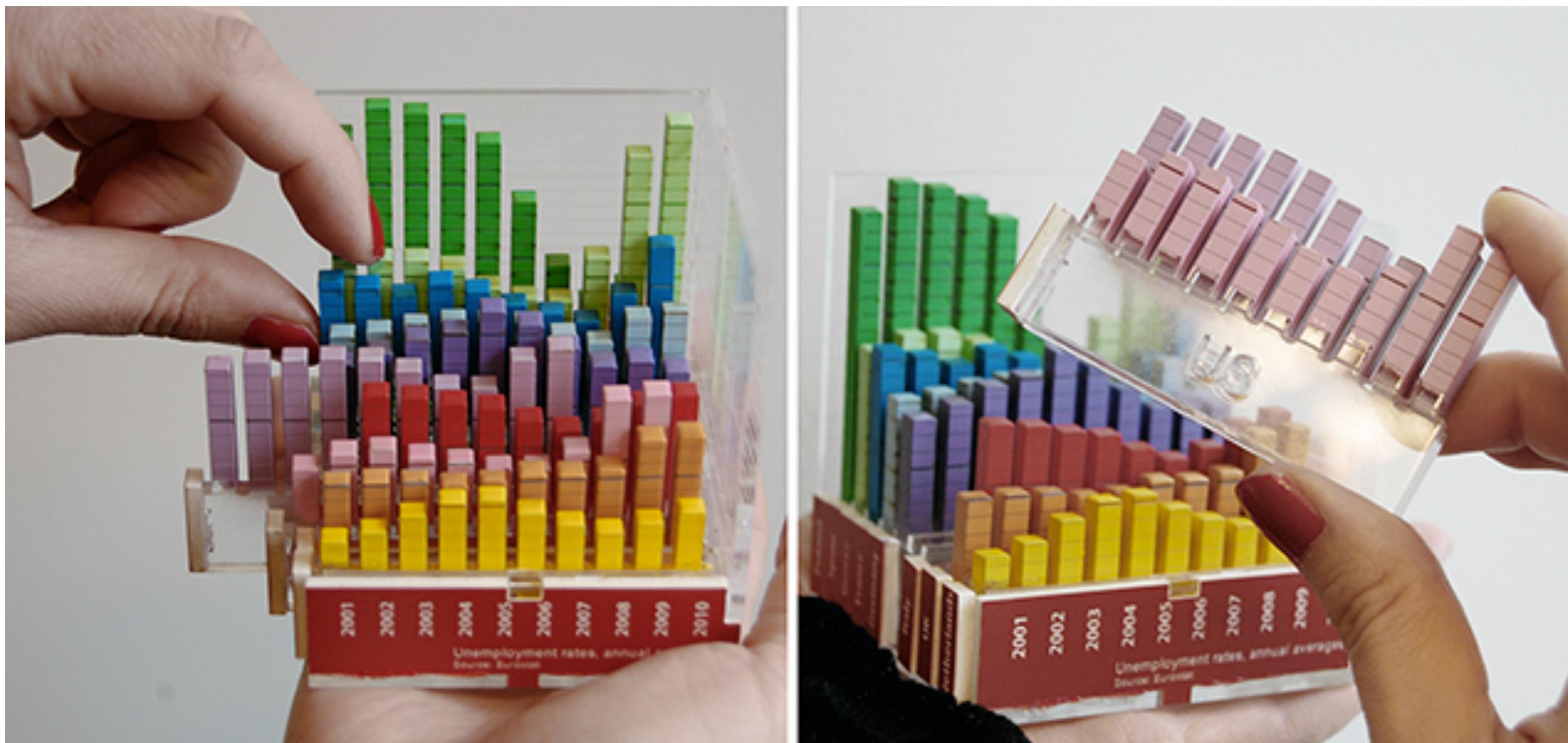
Lots and lots of bespoke creations
...but few ways to generate them

- 1. Can we make automate the process?**
- 2. Is it really worth it?**



Hunger's Lego Time Tracker





Yvonne Jansen, Pierre Dragicevic, and Jean-Daniel Fekete (2013) Evaluating the Efficiency of Physical Visualizations.



Step 1: Choose your data:

Electricity.csv

[Upload new CSV data](#)

Step 2: Select your visualization:

Bar Chart

Step 3: Map your data dimensions:

[Import](#)

Physical Mapping:

Slices	X-axis	Y-axis
Country		
<input checked="" type="checkbox"/> Norway		
<input checked="" type="checkbox"/> Iceland		
<input checked="" type="checkbox"/> Canada		
<input checked="" type="checkbox"/> Sweden		
<input checked="" type="checkbox"/> Finland		
	Year	
	<input checked="" type="checkbox"/> 1971	
	<input checked="" type="checkbox"/> 1974	
	<input checked="" type="checkbox"/> 1977	
	<input checked="" type="checkbox"/> 1980	
	<input checked="" type="checkbox"/> 1983	
		Consumption
		<input checked="" type="checkbox"/> 13850.93236
		<input checked="" type="checkbox"/> 16071.86461
		<input checked="" type="checkbox"/> 16217.28318
		<input checked="" type="checkbox"/> 18316.55117
		<input checked="" type="checkbox"/> 20062.55793

Step 4: Adjust the parameters:

Slice Spacing(mm)	<input type="range"/>	2
Bar Spacing(mm)	<input type="range"/>	2
Bar Width(mm)	<input type="range"/>	3.2
Max Bar Height(mm)	<input type="range"/>	38
Slice Base Height(mm)	<input type="range"/>	15
Ticks Number	<input type="range"/>	10
Global Scale	<input type="checkbox"/> true	
Slice Label Size	<input type="range"/>	10
X Label Size	<input type="range"/>	10
Y Label Size	<input type="range"/>	10

Step 5: Set the fabrication settings:

Laser Cutter

Fabrication parameters:

defaultMaterial	<input type="text"/> cardboard-3mm
Max Width(mm)	<input type="range"/>
Max Length(mm)	<input type="range"/>
Max Height(mm)	<input type="range"/>

Step 6: Cut and Assemble Slices

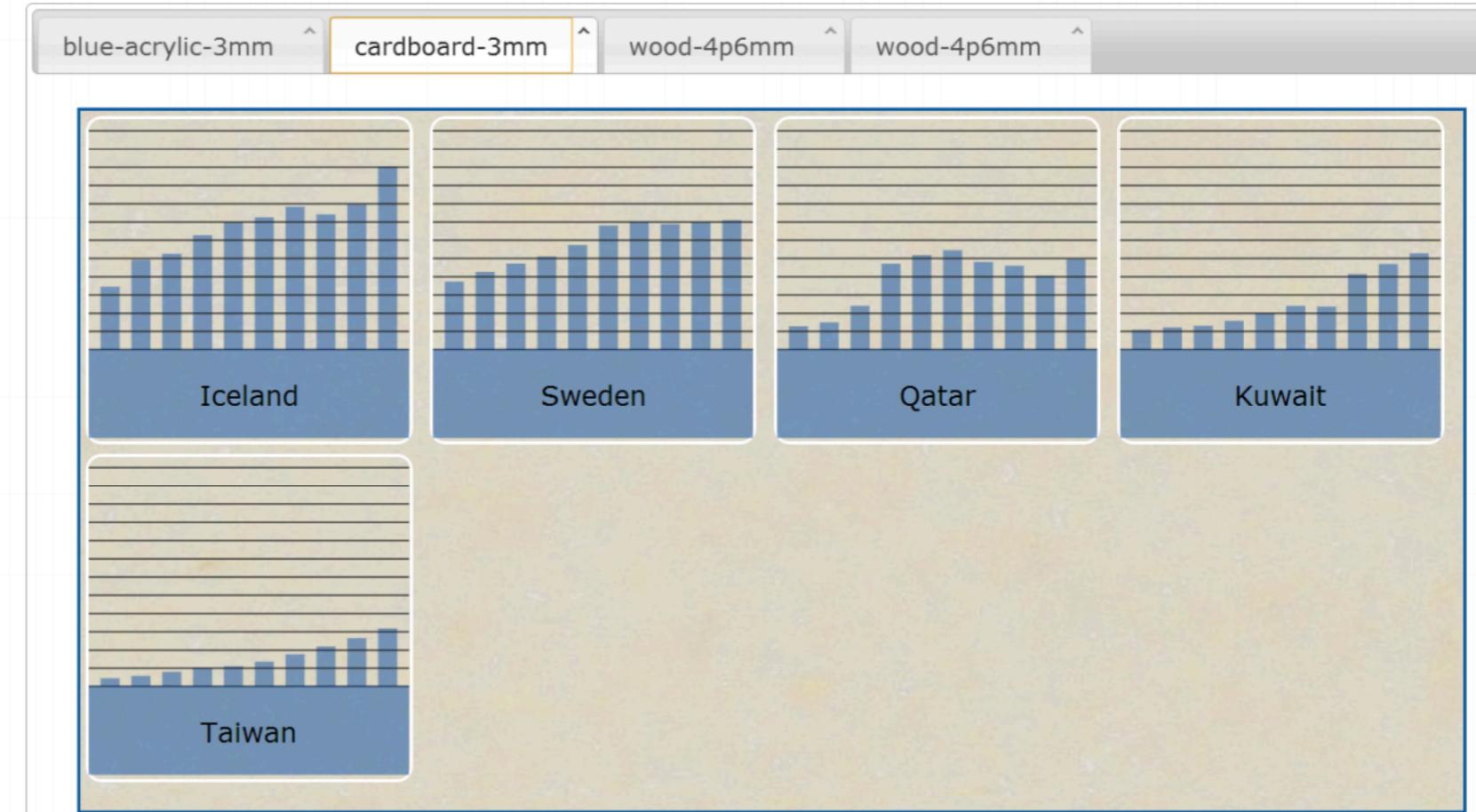
[Instructions](#)

[Download Laser Stencils](#)

3D Preview:

[Refresh](#)

Laser Stencils:



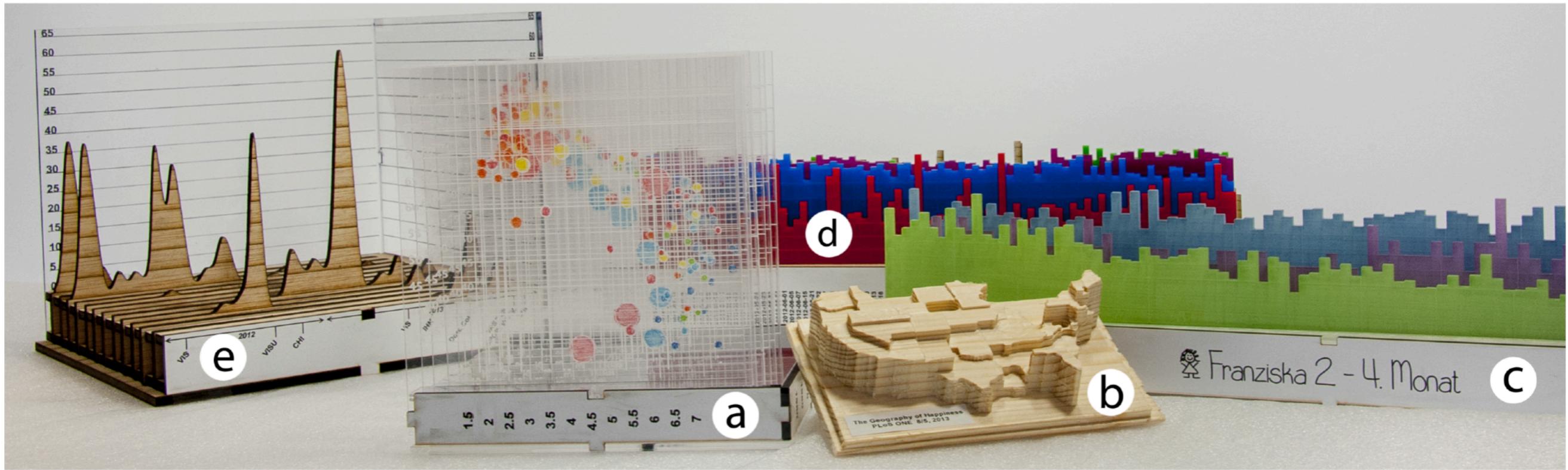


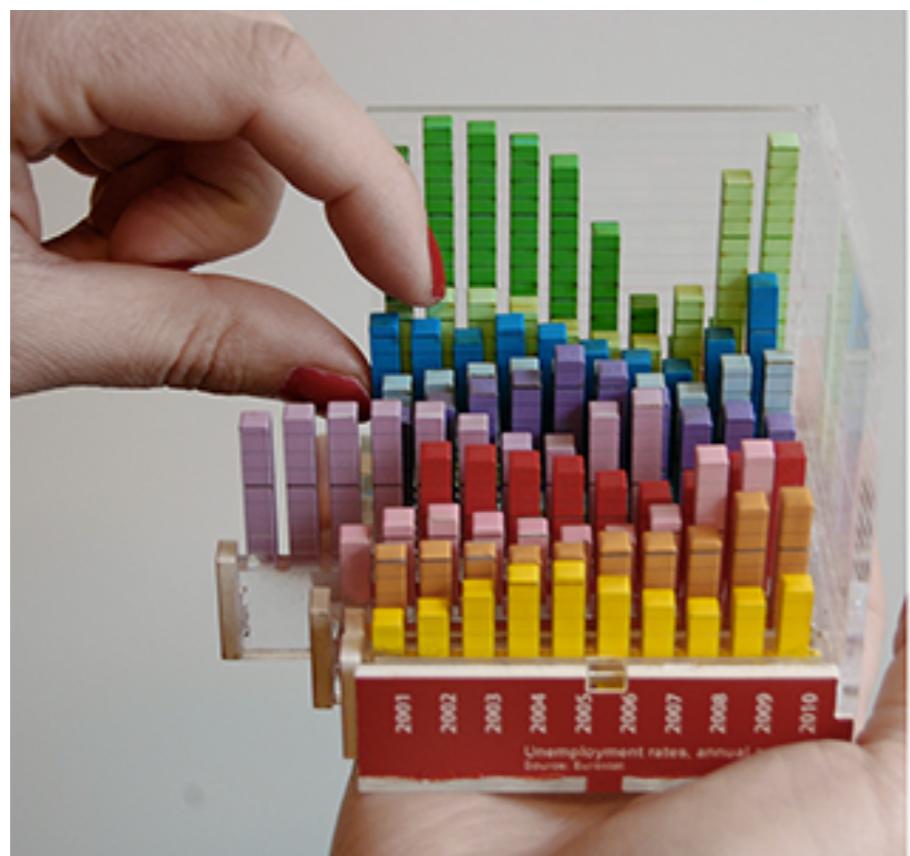
Figure 1. Physical visualizations created with our fabrication tool, MakerVis: a) a layered scatterplot modeled after Rosling ; b) a prism map showing relative happiness in US states computed from Twitter sentiments; c), d), e) layered bar charts and line charts crafted by end users.

Physicalization Toolkits

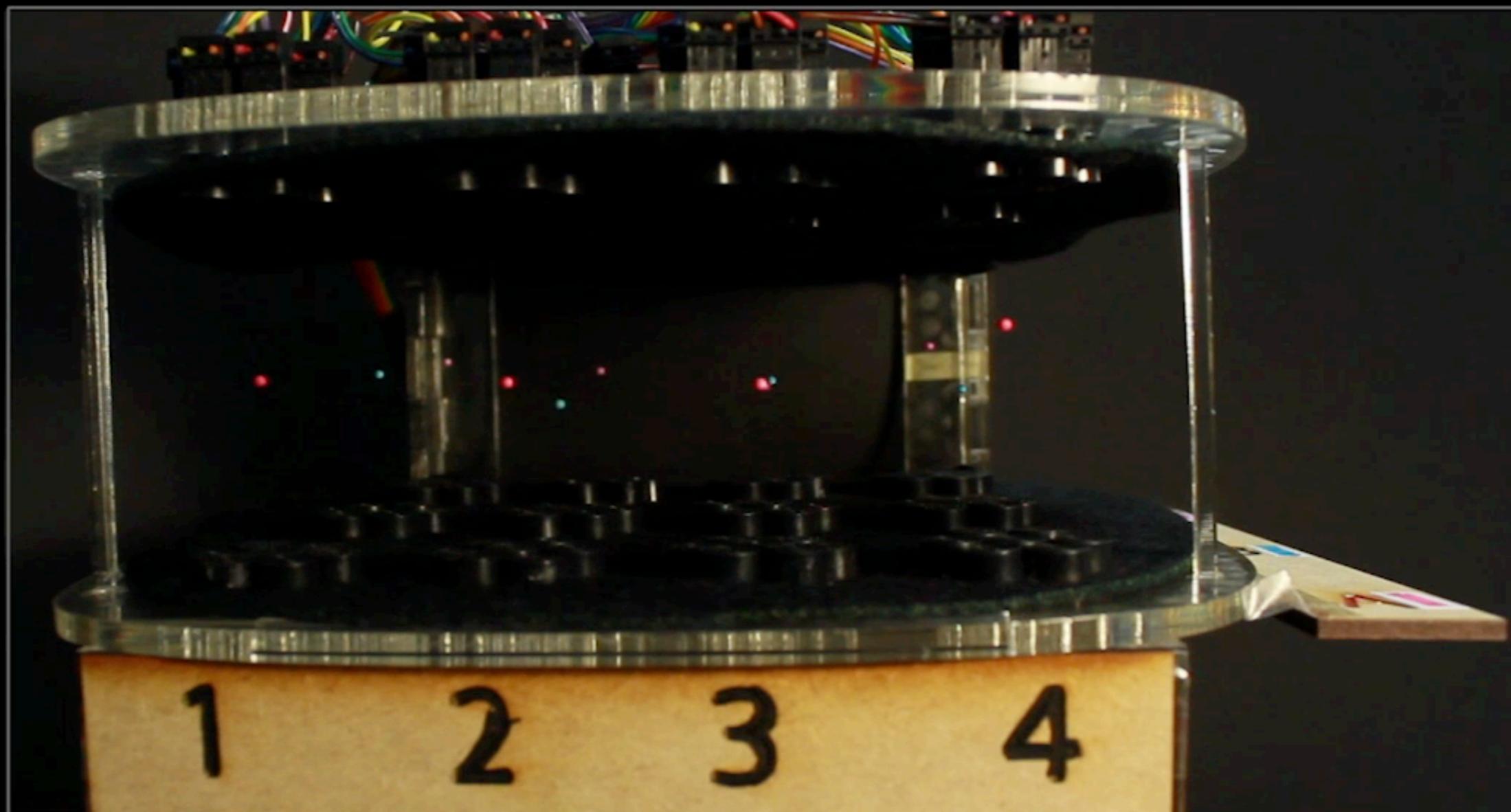
Work great... but falling back on traditional metaphors

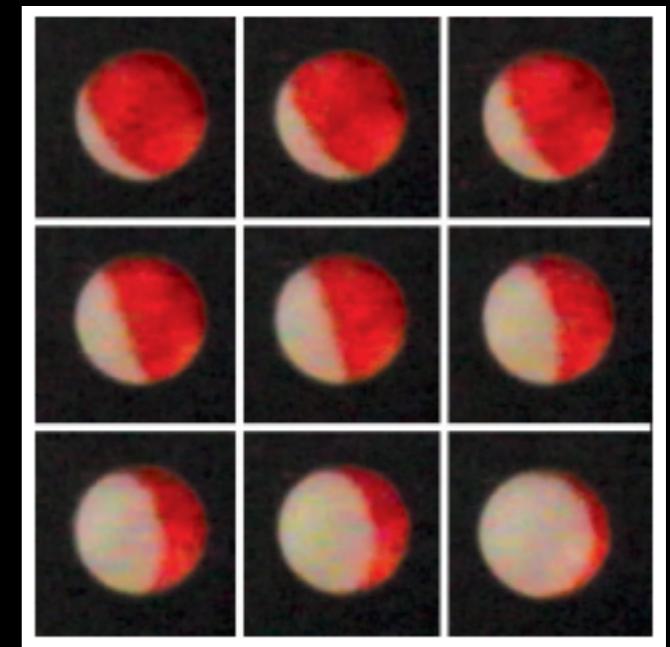
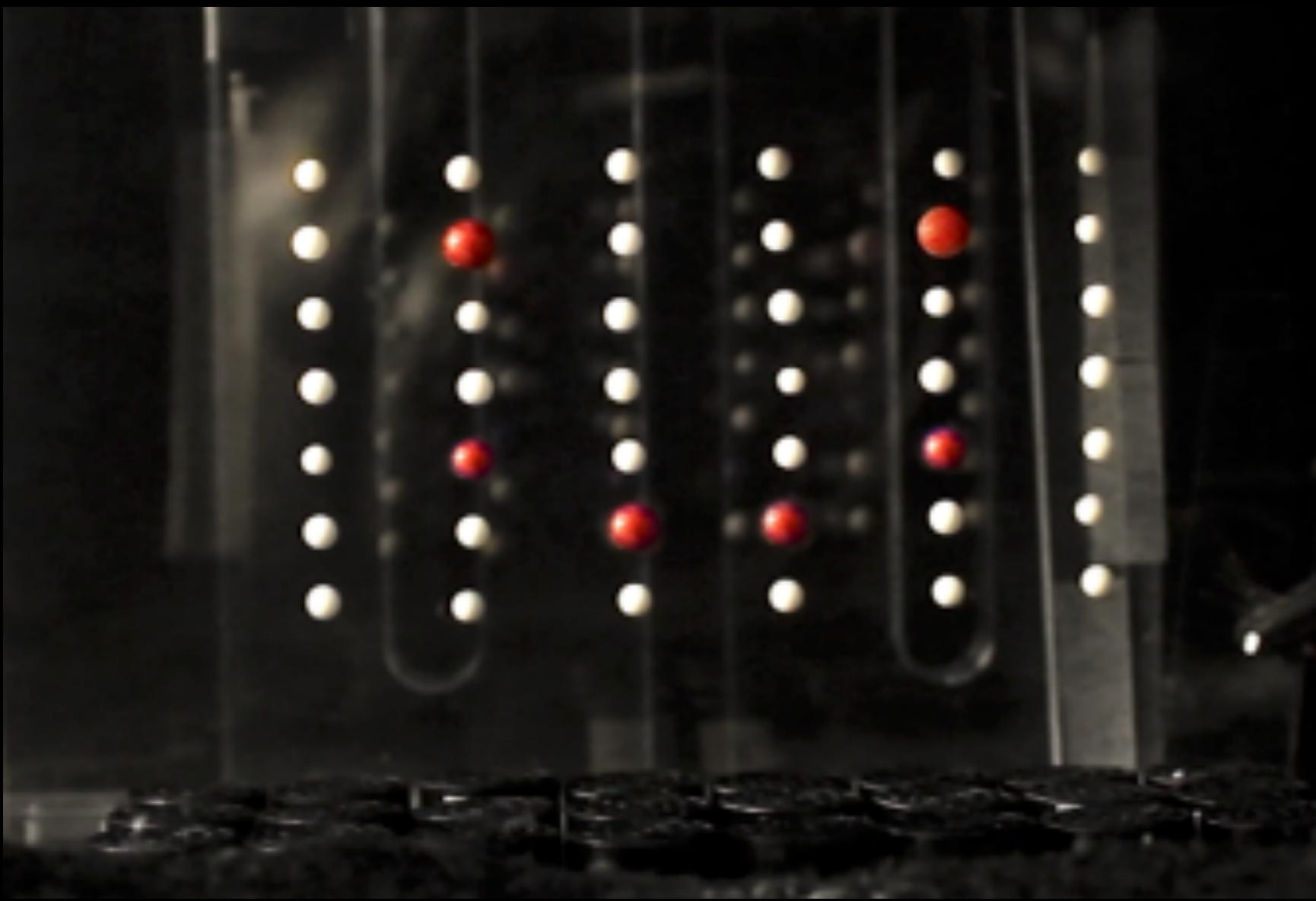
Yet unknown:

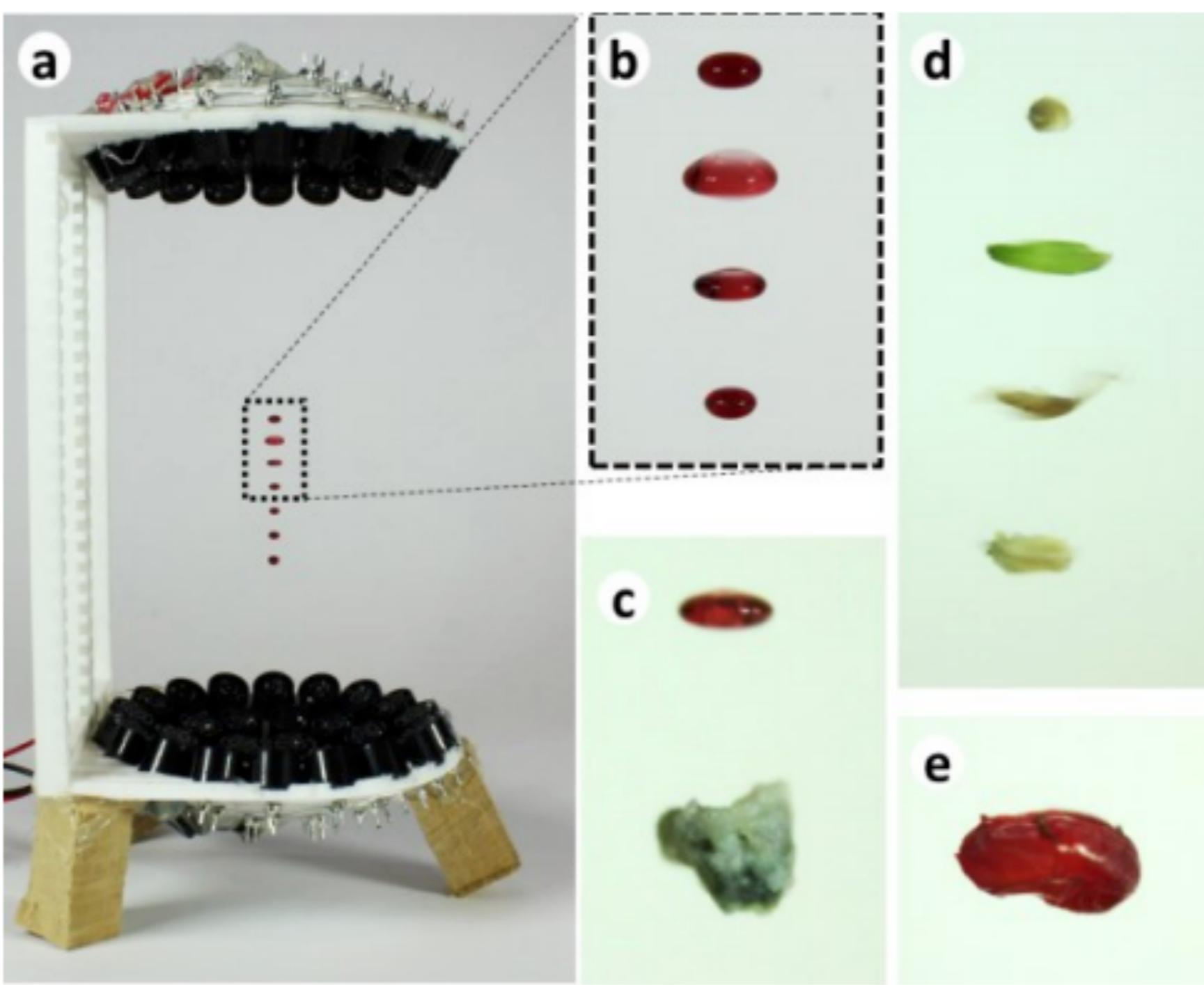
Are there “physical channels” that are more potent than existing visual channel -> print ones?



In Floating Charts objects are **moved individually**







INTRODUCTION

From Anakin Skywalker trying to woo Amidala by floating a piece of pear into her mouth (*Star Wars: Episode II*) to the restaurant *Sublimotion* [46] offering food in hovering plates, levitation of food has sparked the imagination of designers, scientists, and chefs around the world. For instance, chef

Physical Visualizations

1. Can we make automate the process? – **YES**
2. Is it really worth it?



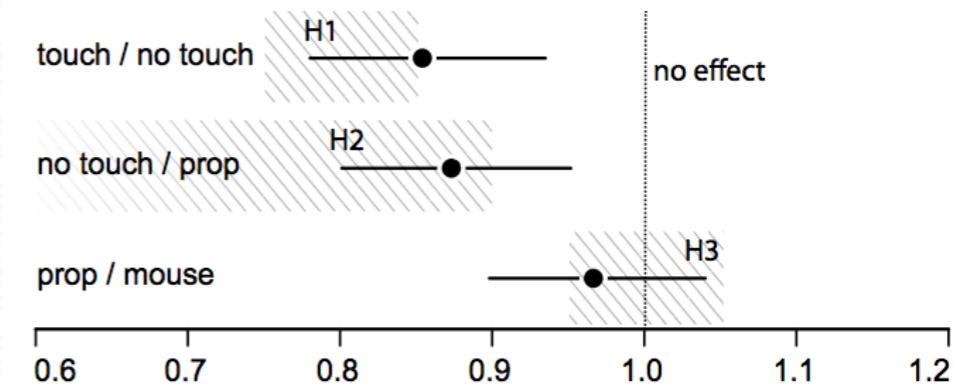
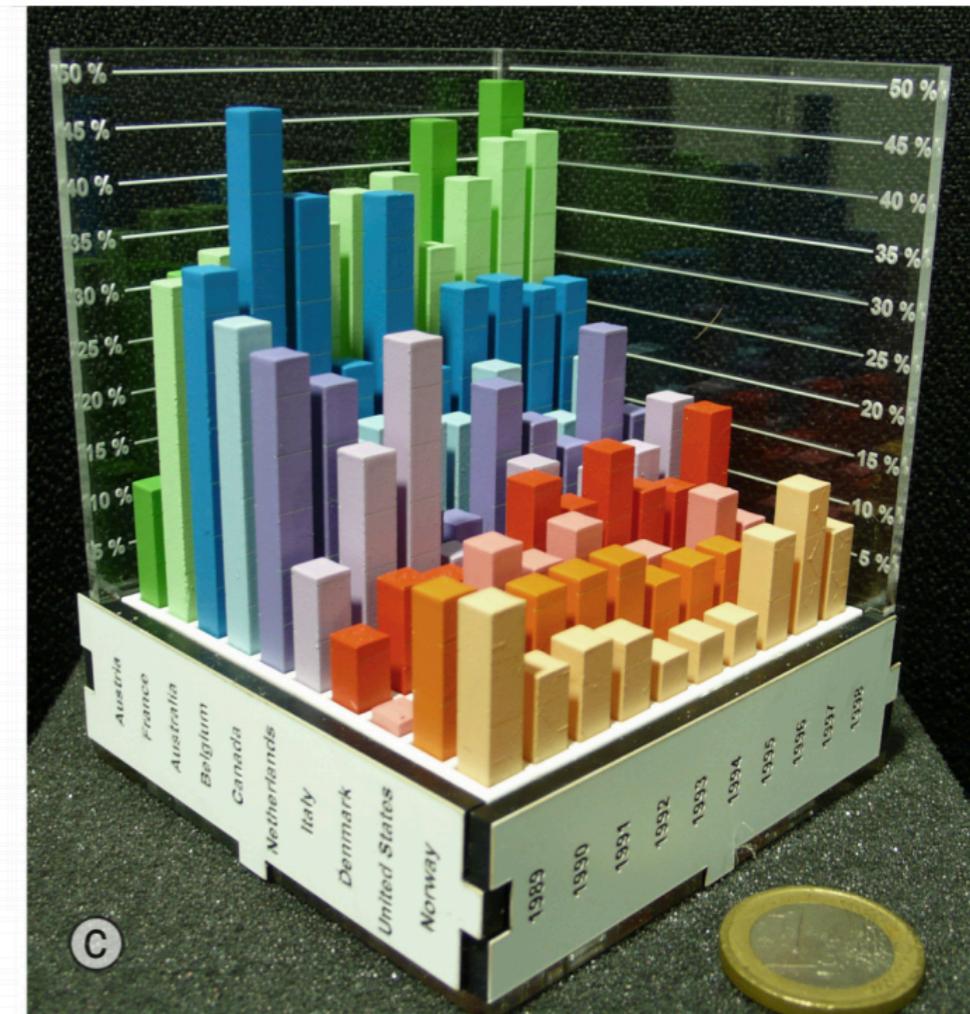
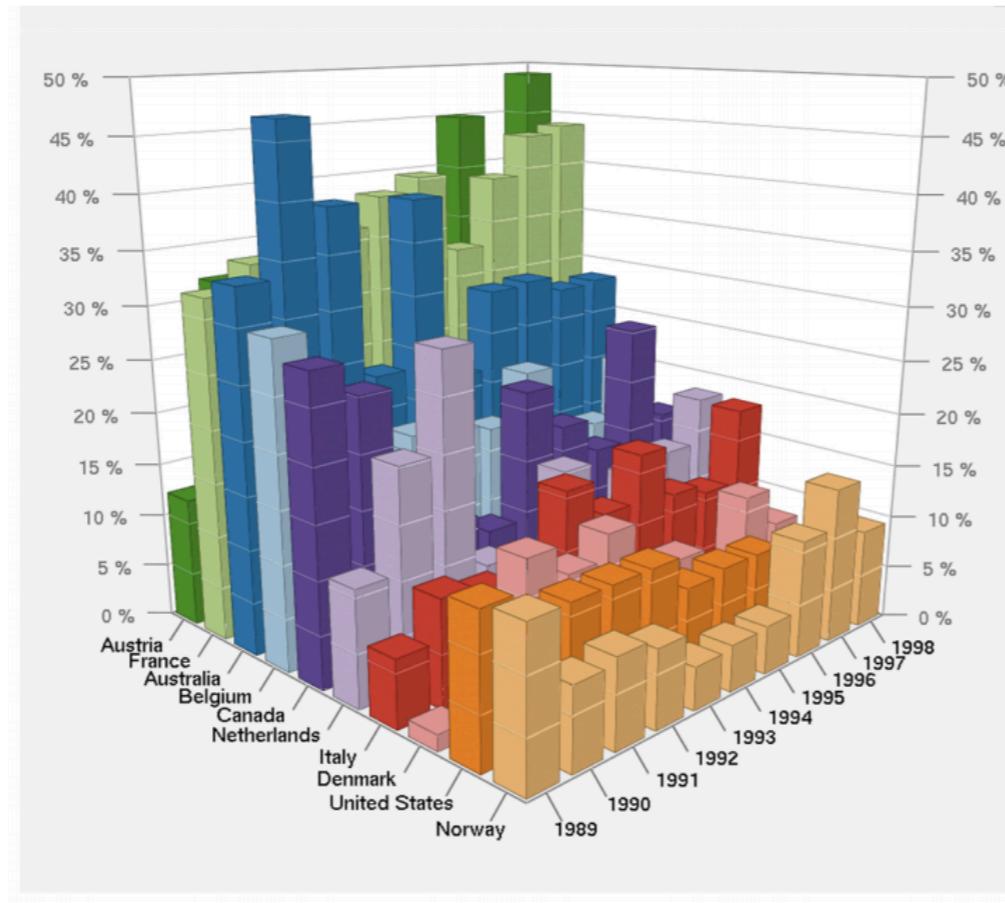


Figure 6. Time ratios between techniques, with 95% CIs. Hatched areas indicate expected effect sizes as expressed in our hypotheses.

Physical Visualizations

1. Can we make automate the process? – **YES**
2. Is it really worth it? – **SORTA**



Interacting With Physical Visualizations

Previous authors noted:

Rotating, moving whole diagram, finger marking,
path following, finger comparisons

What kinds of interaction techniques exist for physical visualizations, and are they “new”?



Exploring Interactions with Physically Dynamic Bar Charts

Faisal Taher ¹

John Hardy ¹

Abhijit Karnik ¹

Christian Weichel ¹

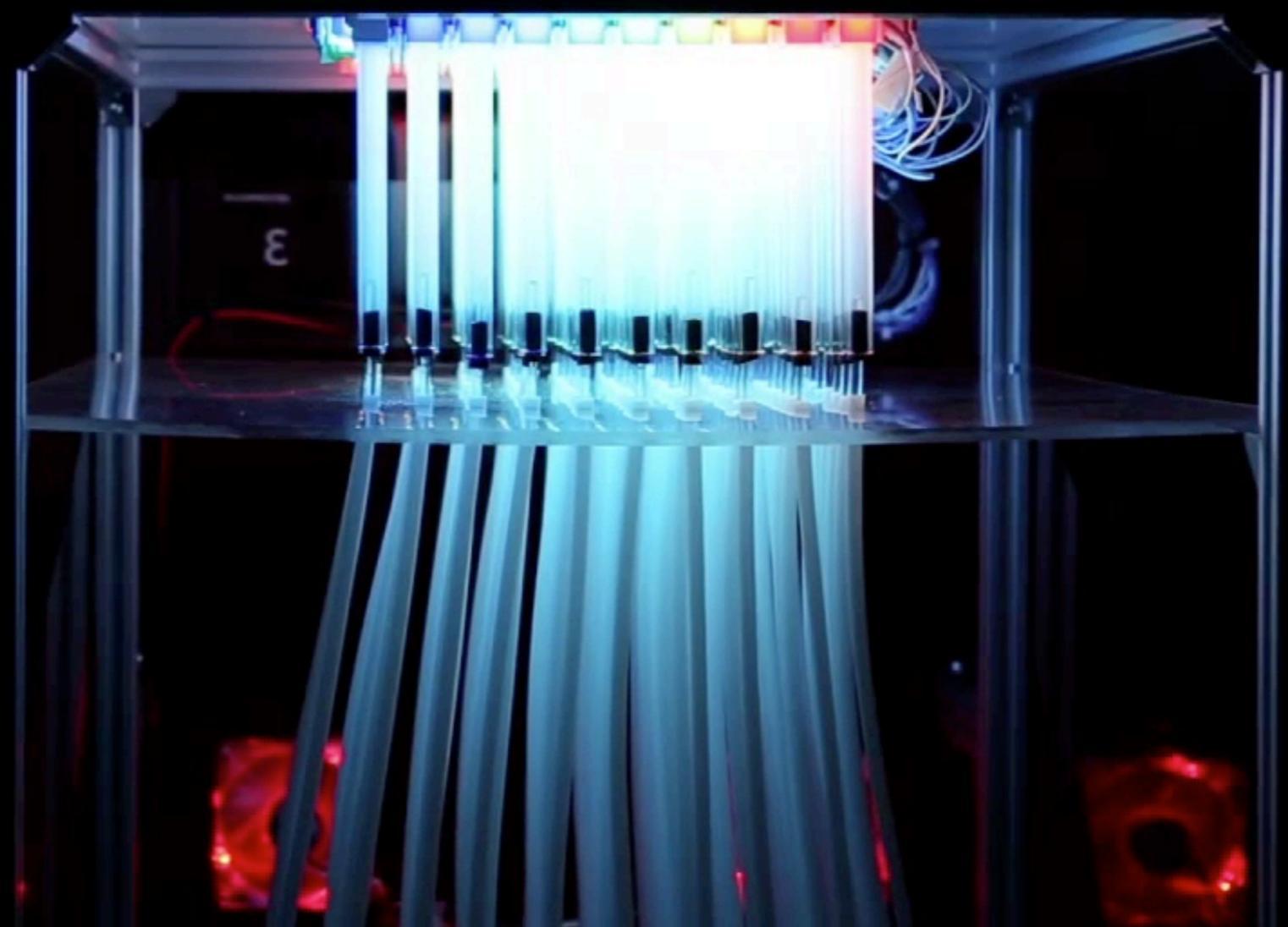
Yvonne Jansen ²

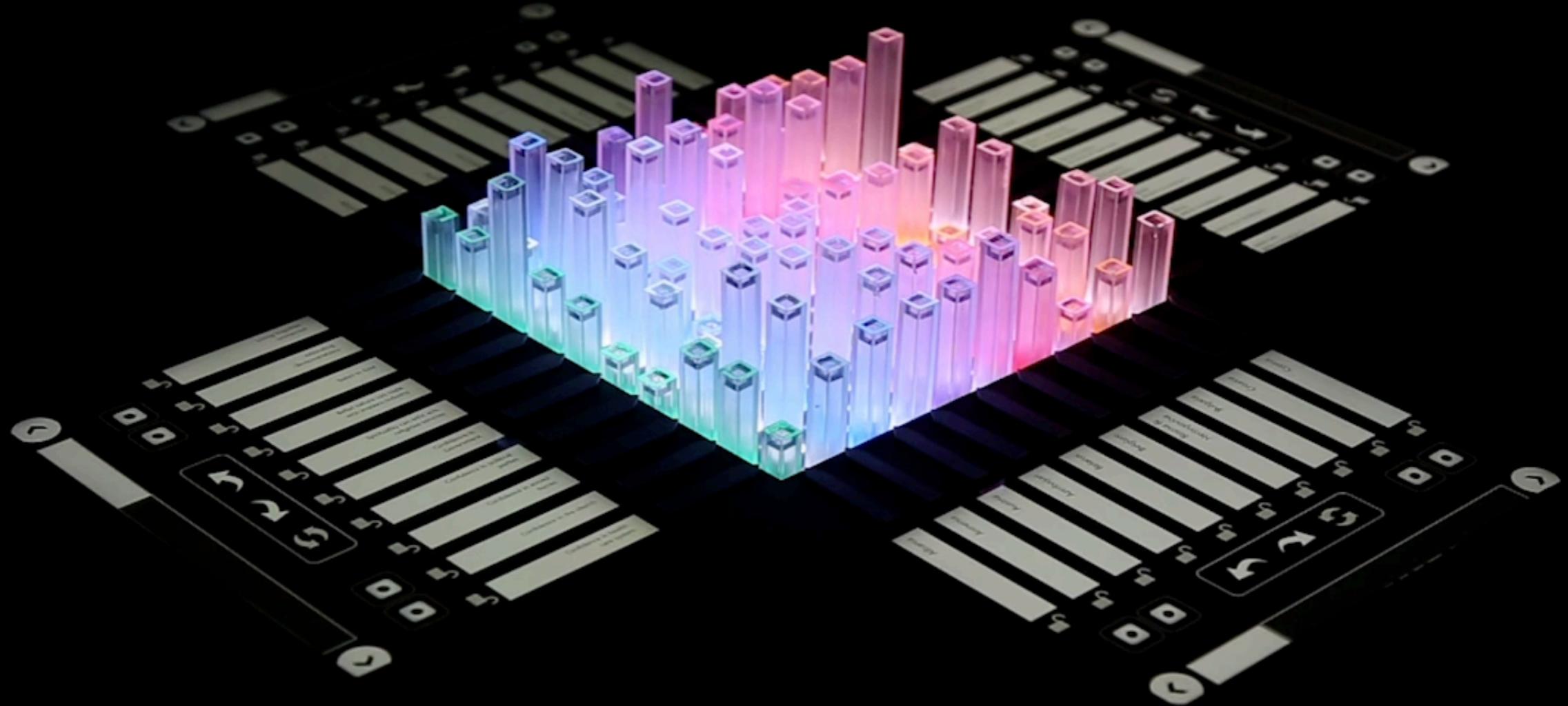
Kasper Hornbæk ²

Jason Alexander ¹

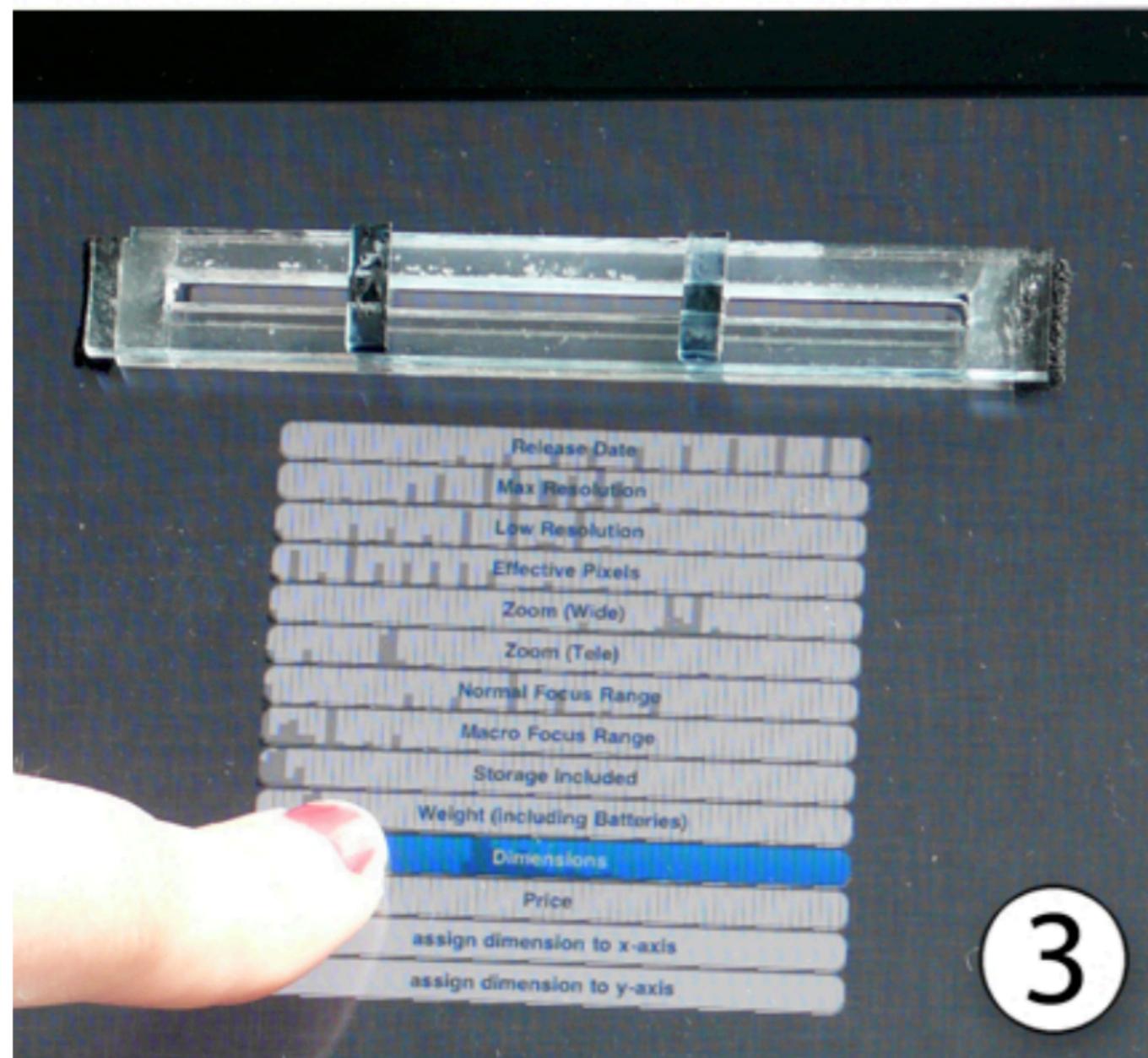
¹ Lancaster University, UK

² University of Copenhagen, Denmark

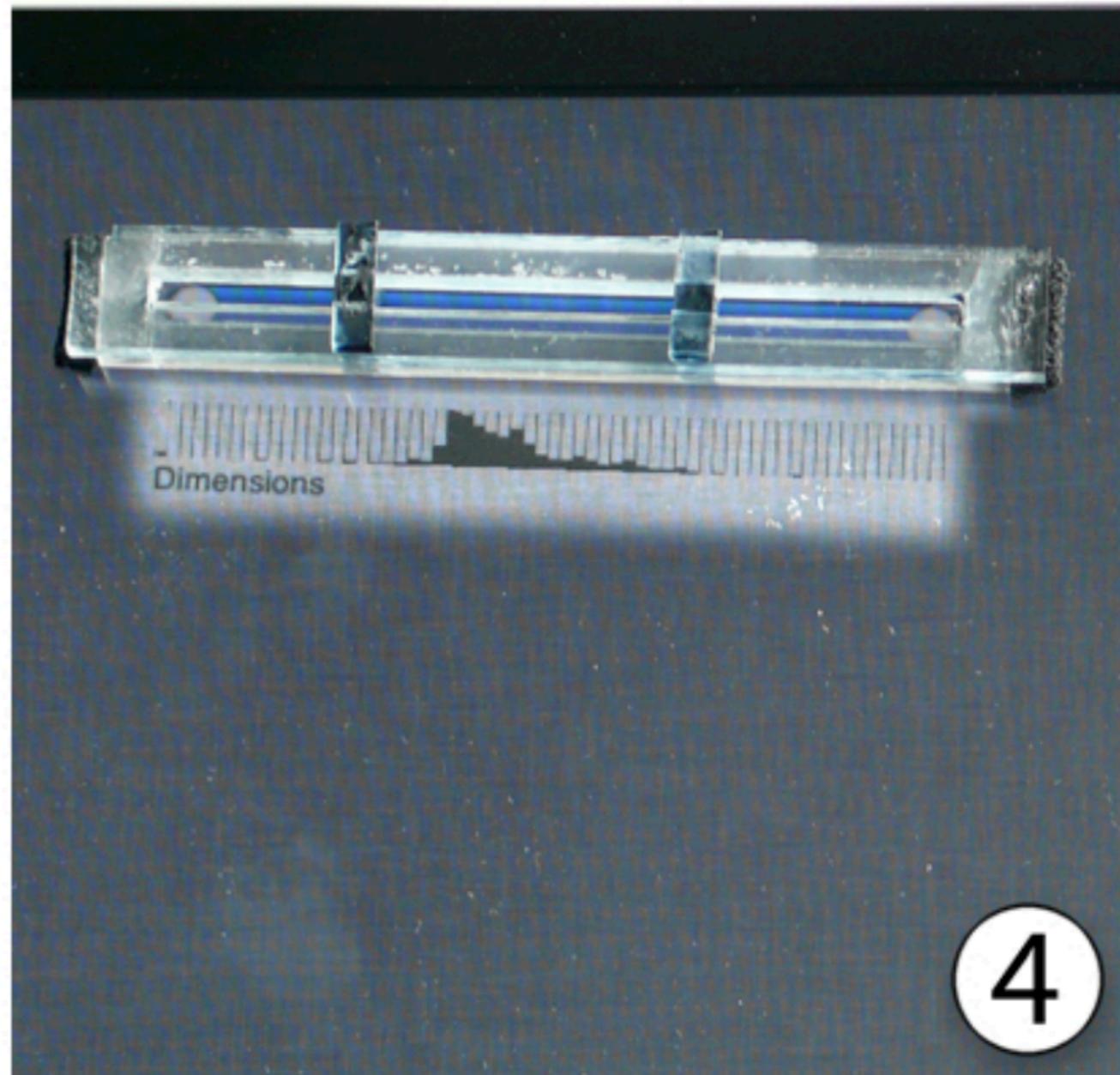




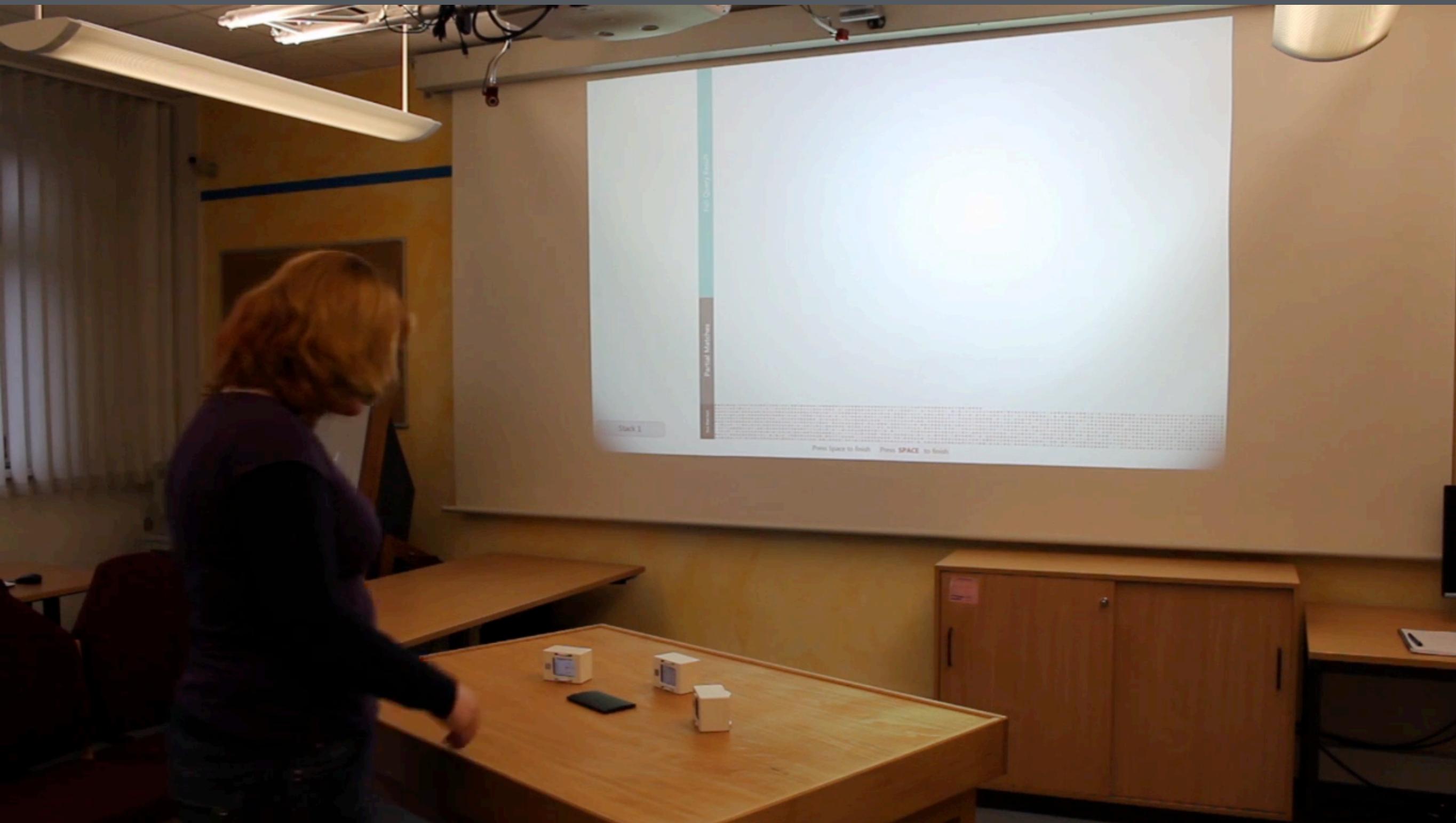
We ran a user study with 16 participants who explored a dataset and presented their observations.



3

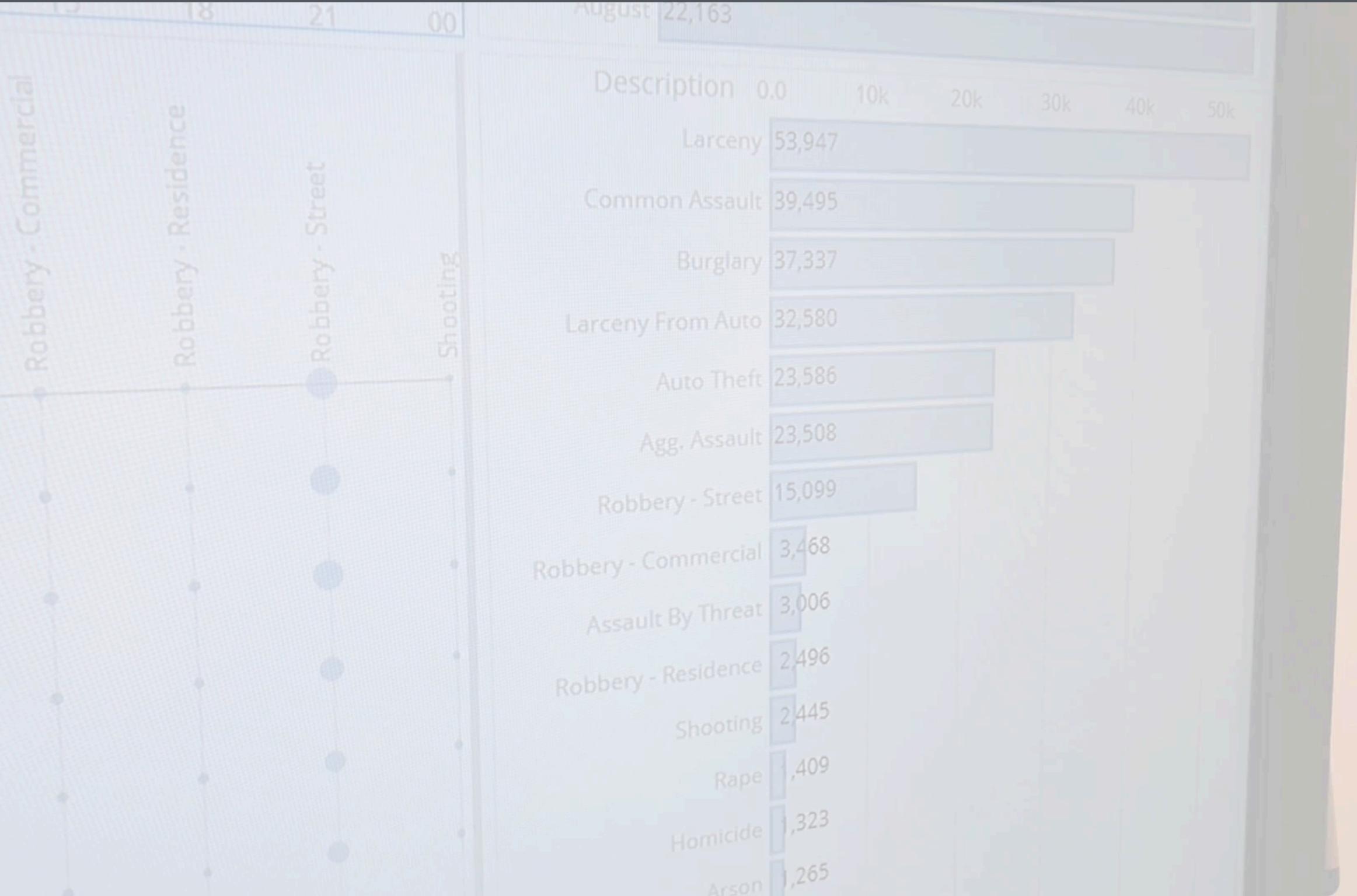


4



Time domain searching





Physical Visualizations

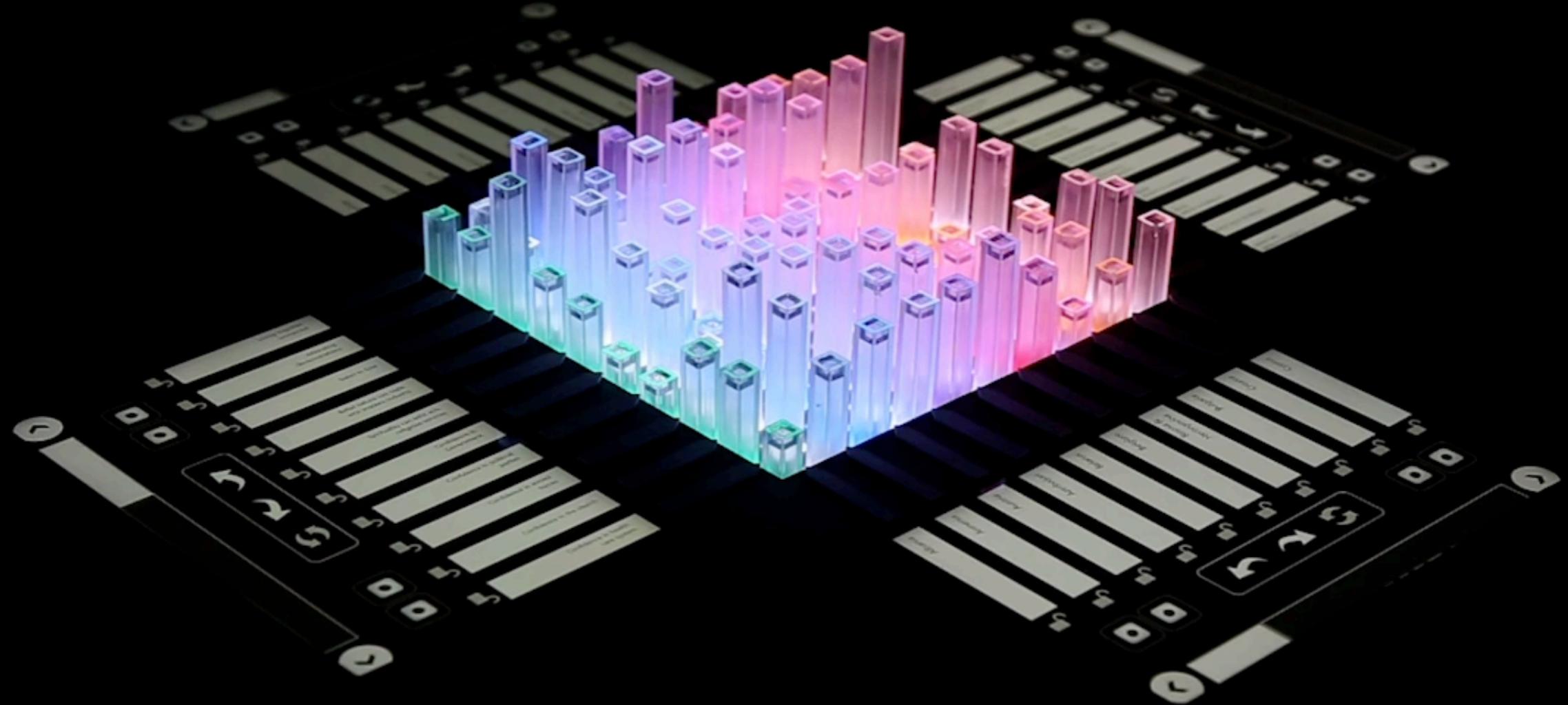
1. Can we make automate the process? – **YES**
2. Is it really worth it? – **SORTA**
3. Should we keep exploring? – **YES**



Visualizations marginalize many potential data consumers because of their dependence on visual channels.

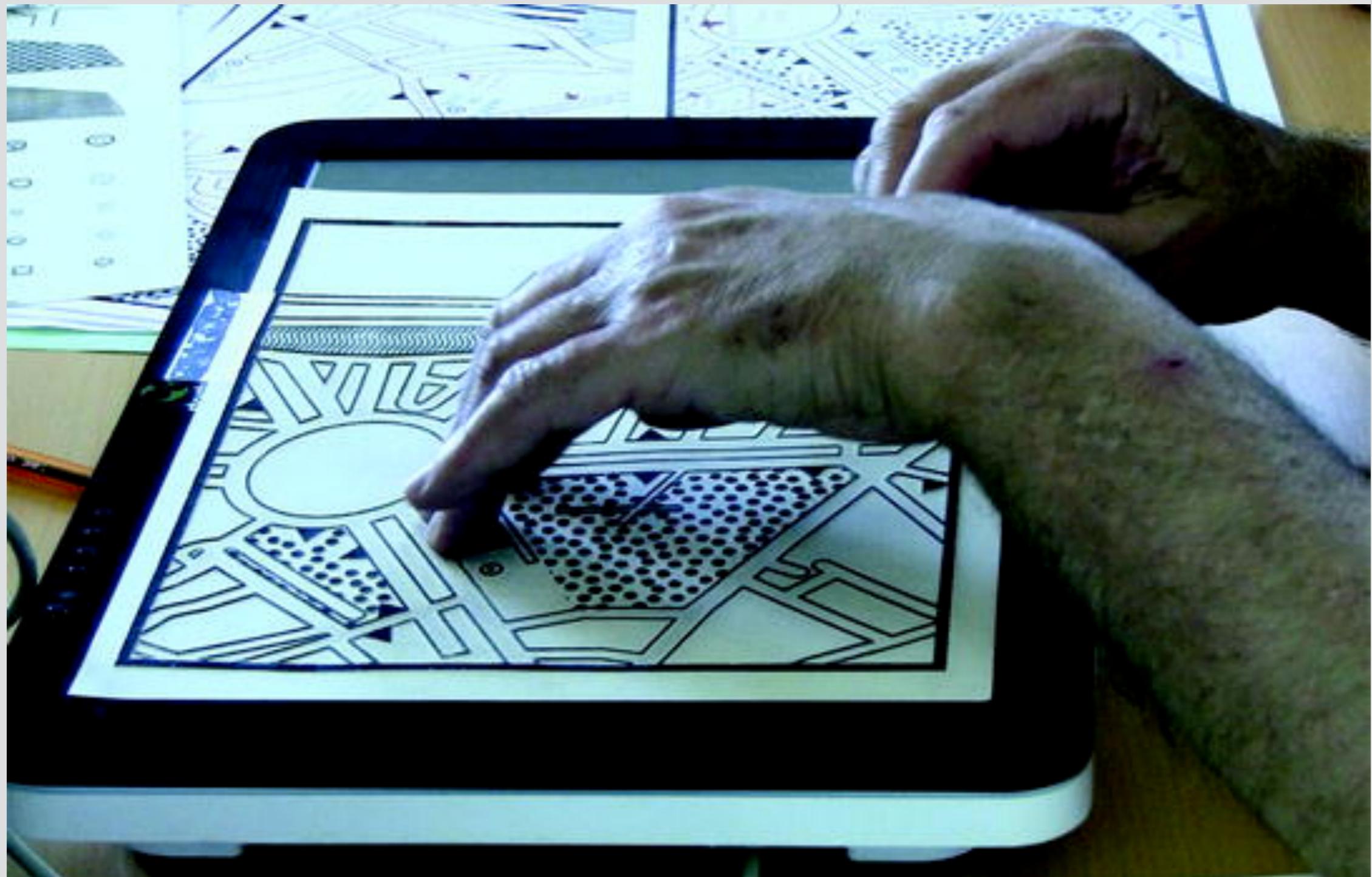


Could data physicalizations help the visually impaired?



We ran a user study with 16 participants who explored a dataset and presented their observations.

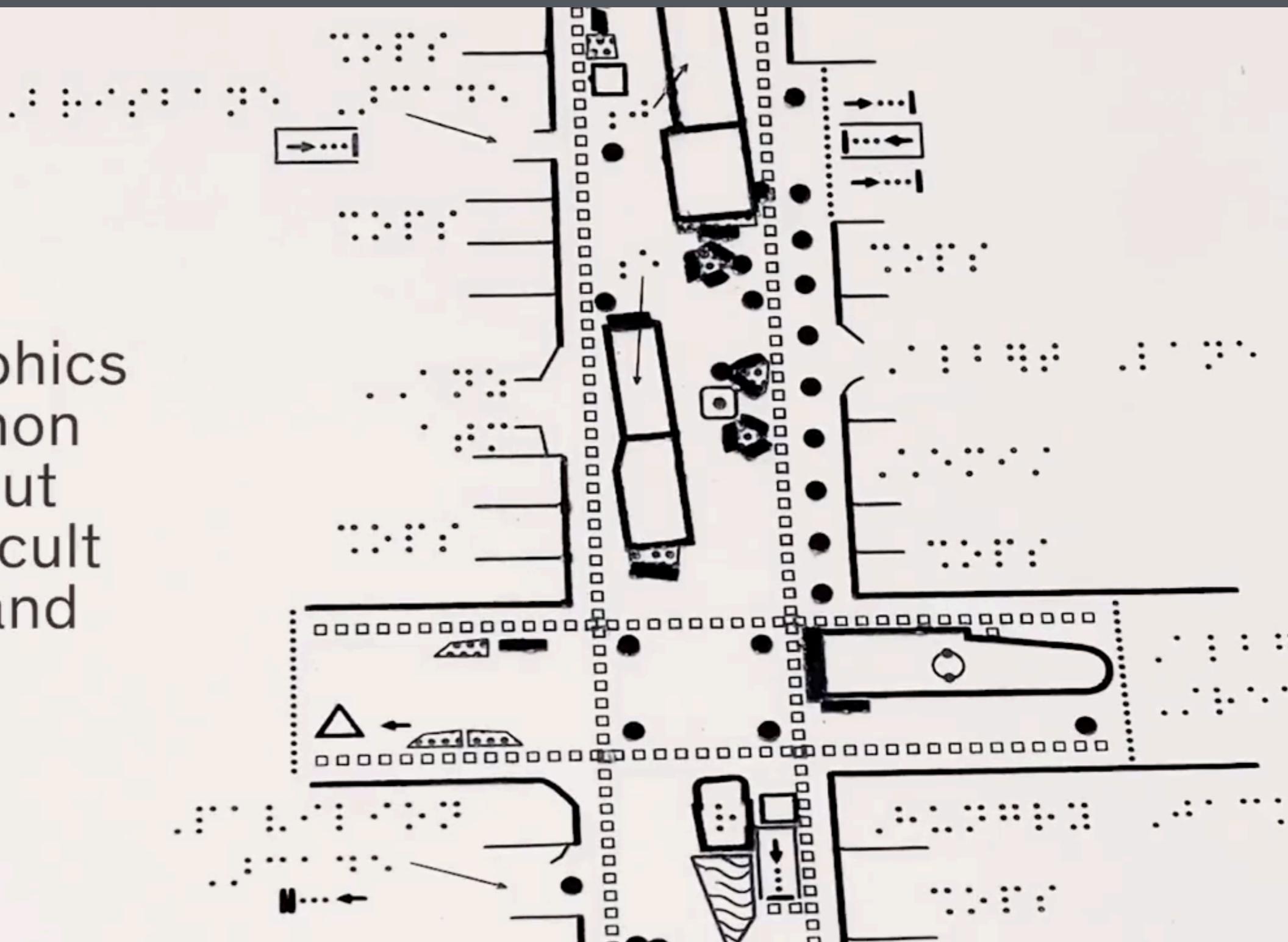
What are the benefits / drawbacks of tactile maps?



Parkes D (1988) "NOMAD": an audio-tactile tool for the acquisition, use and management of spatially distributed information by partially sighted and blind persons.



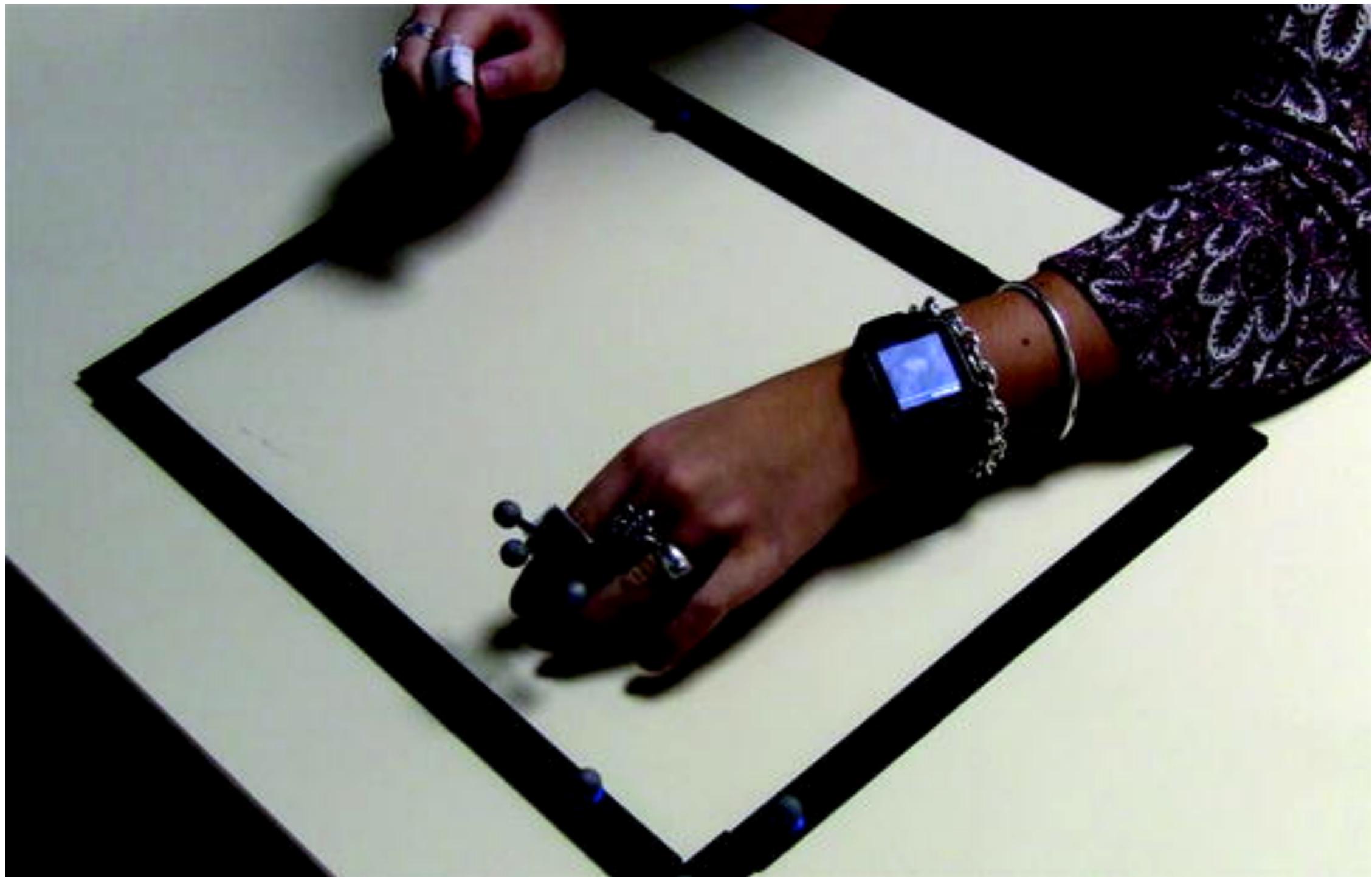
Tactile graphics
are a common
solution - but
can be difficult
to understand







When he points to two elements,



Bardot S, Serrano M, Jouffrais C (2016) From tactile to virtual: using a smartwatch to improve spatial map exploration for visually impaired users.

Accessible Visualizations

Tactile physical visualizations

Touch physical visualizations to learn properties

Haptic feedback

Vibration and texture to indicate data features

Auditory hints and TTS

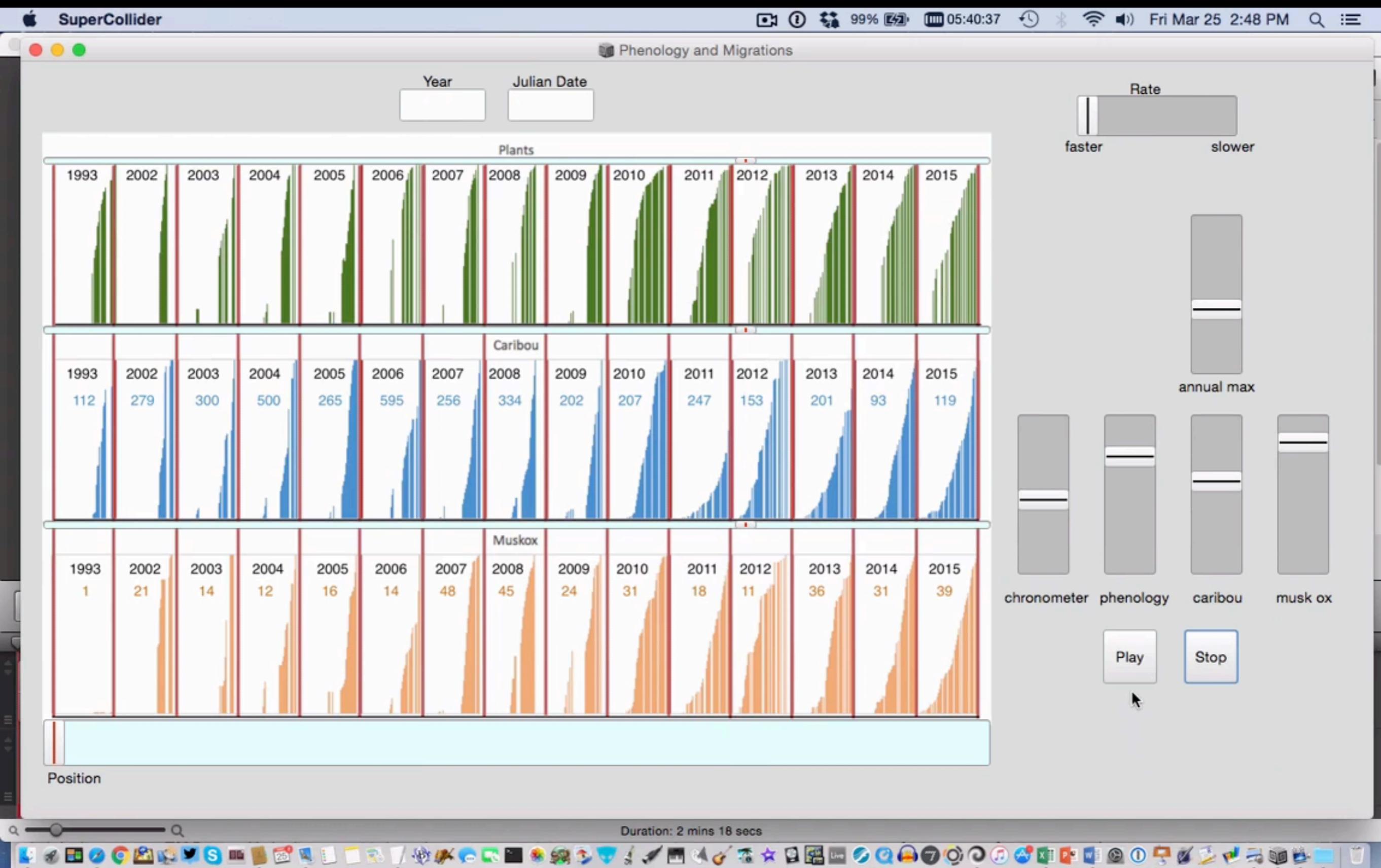
Augment visualizations with extra information / annotations

Data sonification

Use auditory channels instead of visual channels



Auditory exploration of the first cluster



Data Sonification

Auditory channels:

Frequency/pitch, loudness, rhythm, vibrato, etc.

Note: preferences for auditory channels & discernible differences are not the same between individuals!



Data Sonification

Is it really a good idea to sonify data alone?





AARONSON,L.H.



ALEXANDER,J.M.



ARMENTANO,A.J.



BERDON,R.I.



BRACKEN,J.J.



BURNS,E.B.



CALLAHAN,R.J.



COHEN,S.S.



DALY,J.J.



DANNEHY,J.F.

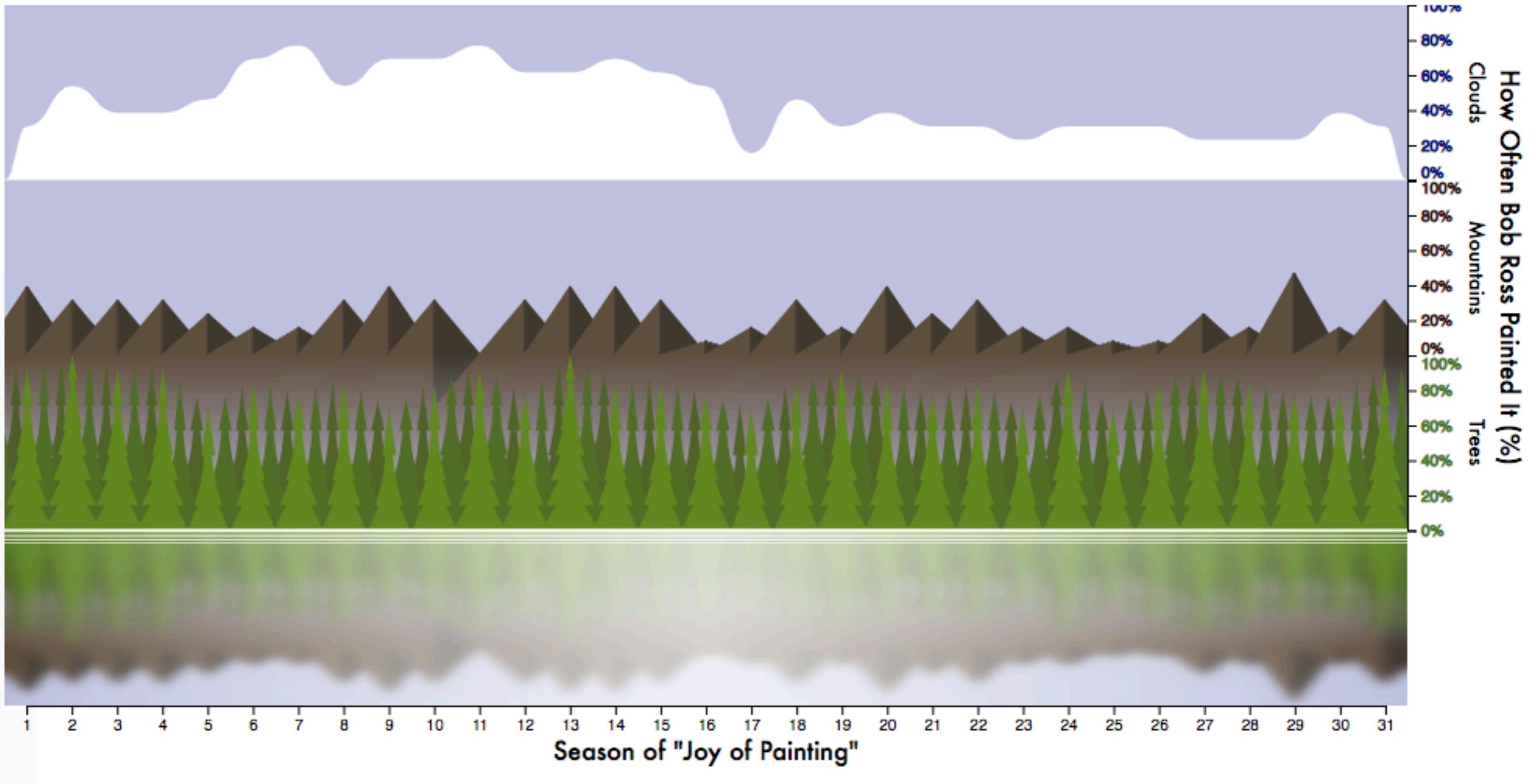


DEAN,H.H.



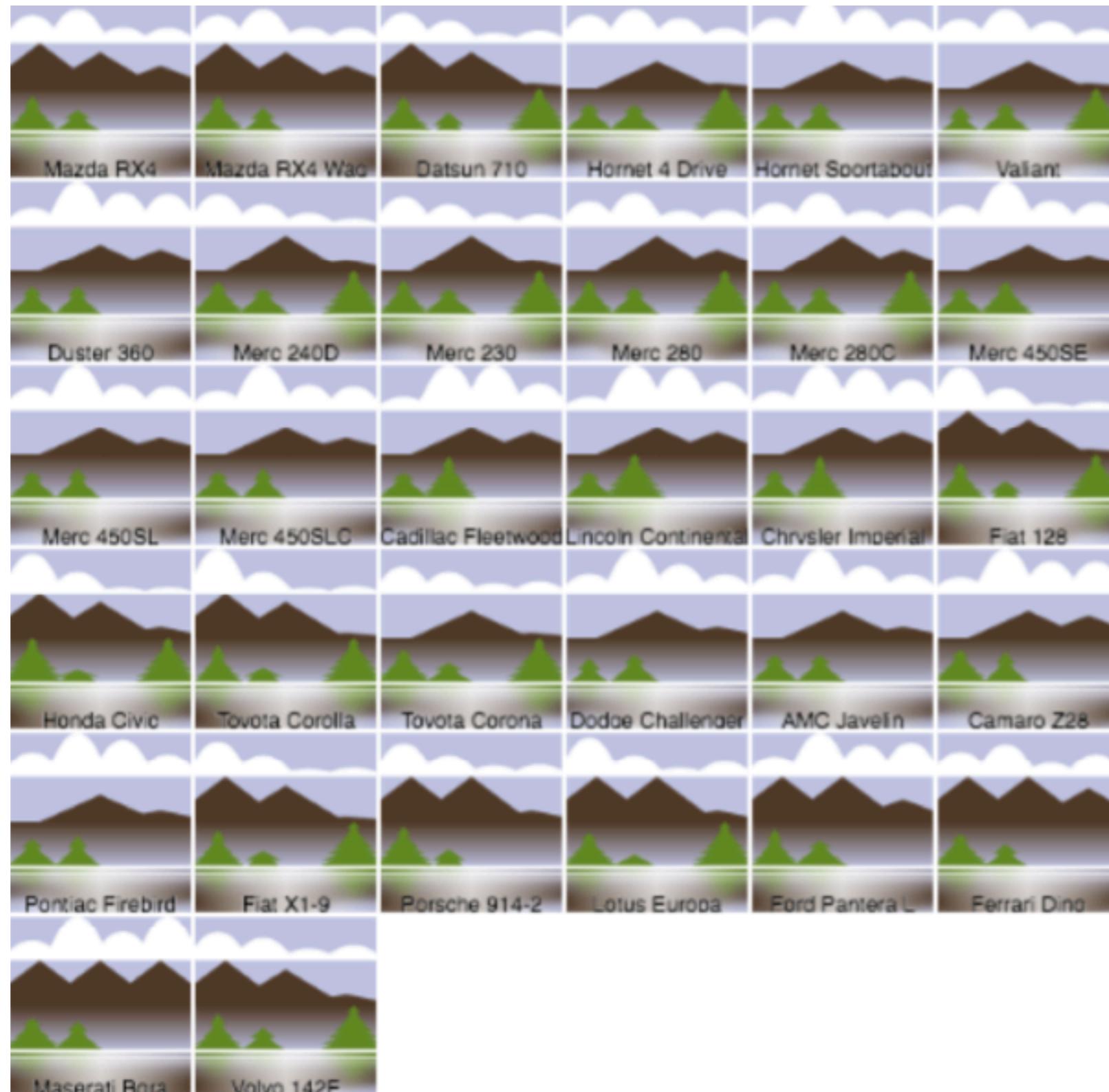
DEVITA,H.J.

Ross-Chernoff Glyphs



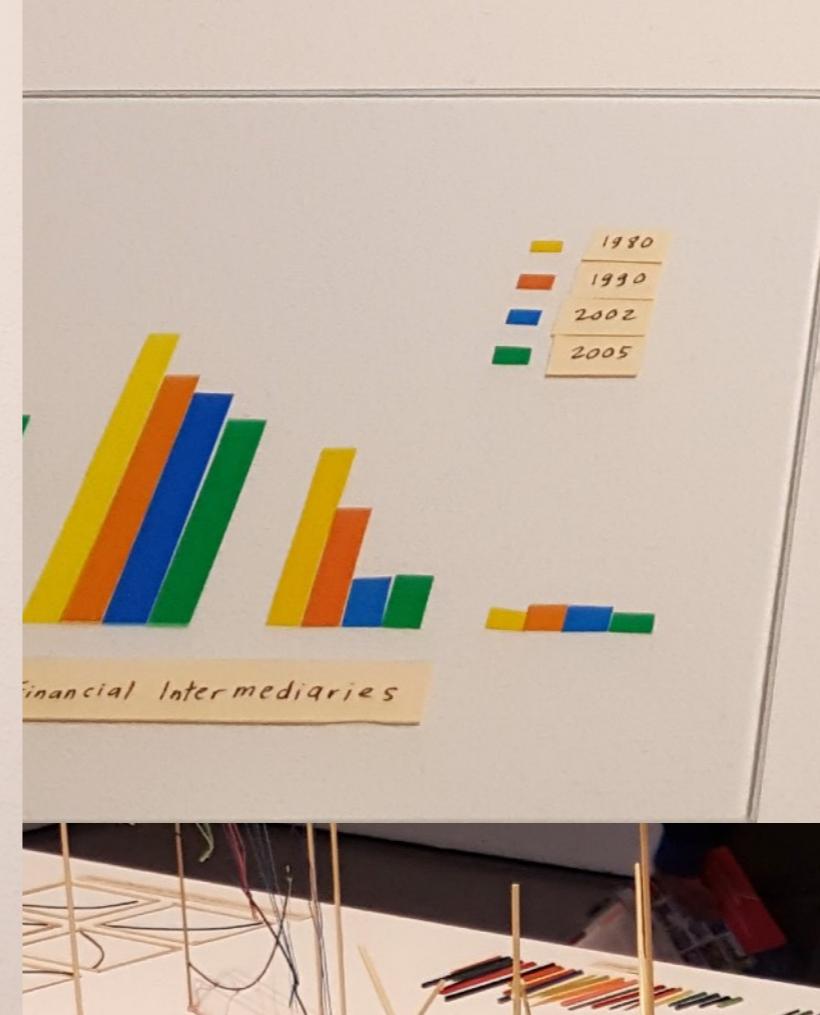
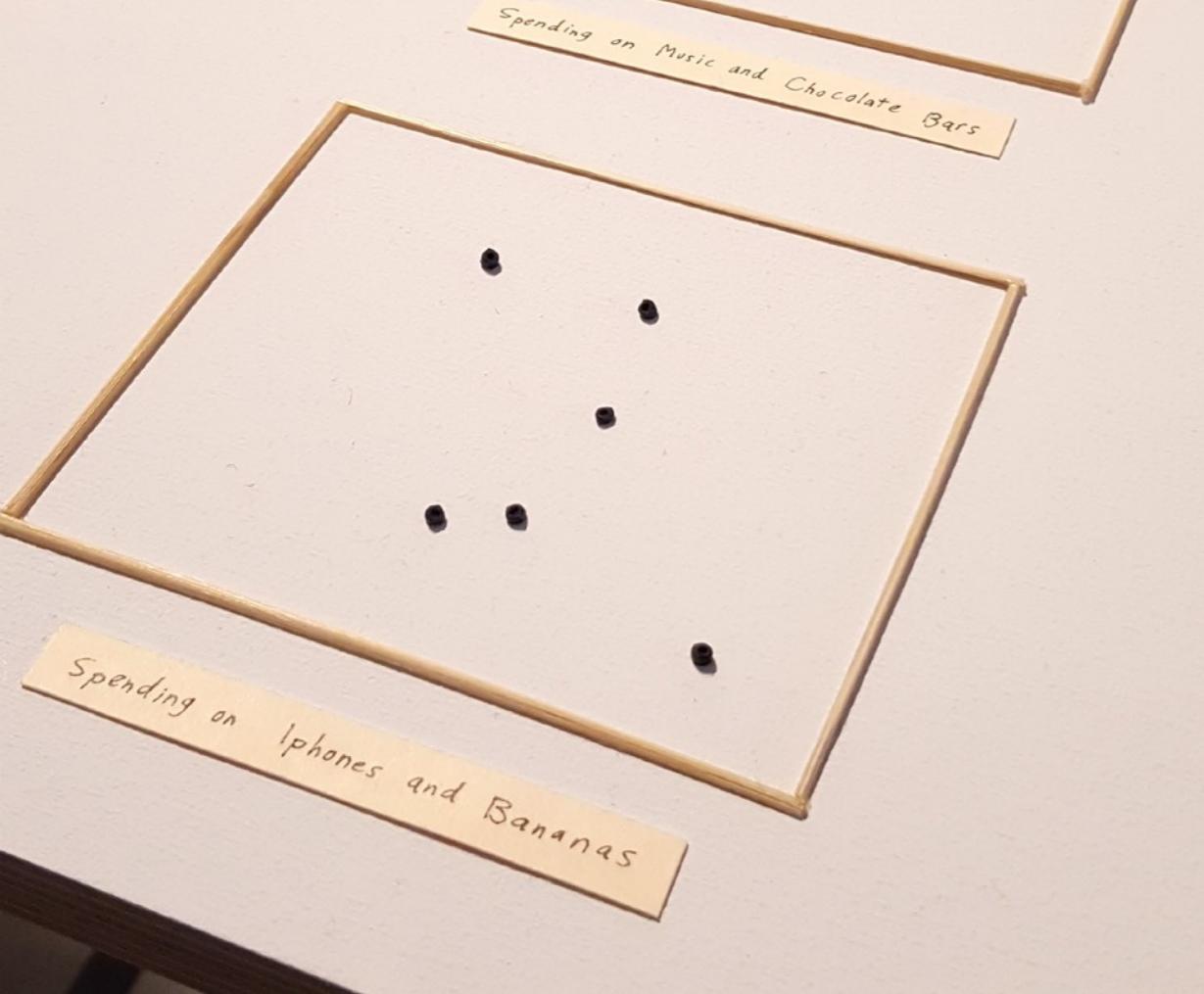
Code available at: <https://github.com/mcorrell/ross-chernoff>





Code available at: <https://github.com/mcorrell/ross-chernoff>





Ibghy and Lemmens, The Prophets, 2013-5



It is your job as a visualization designer to...

...pre-process and explore your data to detect trends and potential problems ahead of time. Show this uncertainty

...choose appropriate visual channels and metaphors.

...help users understand what you are showing by training, directing attention, or adding narrative.

...use new visual metaphors, interaction techniques, animations, and new kinds of data cautiously

...also have fun doing it!



Thanks for taking
3300/5100 this semester!

