Advanced Data Visualization

CS 6965

Fall 2019

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University of Utah

Lecture 10

Project 2: Getting started

- What type of personal data would you like to visualize? (The one from yourself, or someone you know closely)
- How do you obtain the data?
- Why studying such a data set is important and meaningful for you?
- What sort of insights do you expect to get out of this visualization project? (And what sort of insights you end up getting?)

- Creative and original
- Interpretable and Informative

- Portable: please bring it to class on the due date.
- If it is not portable, please let me know ahead of time.

Possible medium or building blocks

- Legos, Play-Doh, threads…
- Being creative: cereals, mud, grass…
- Be cost-effective

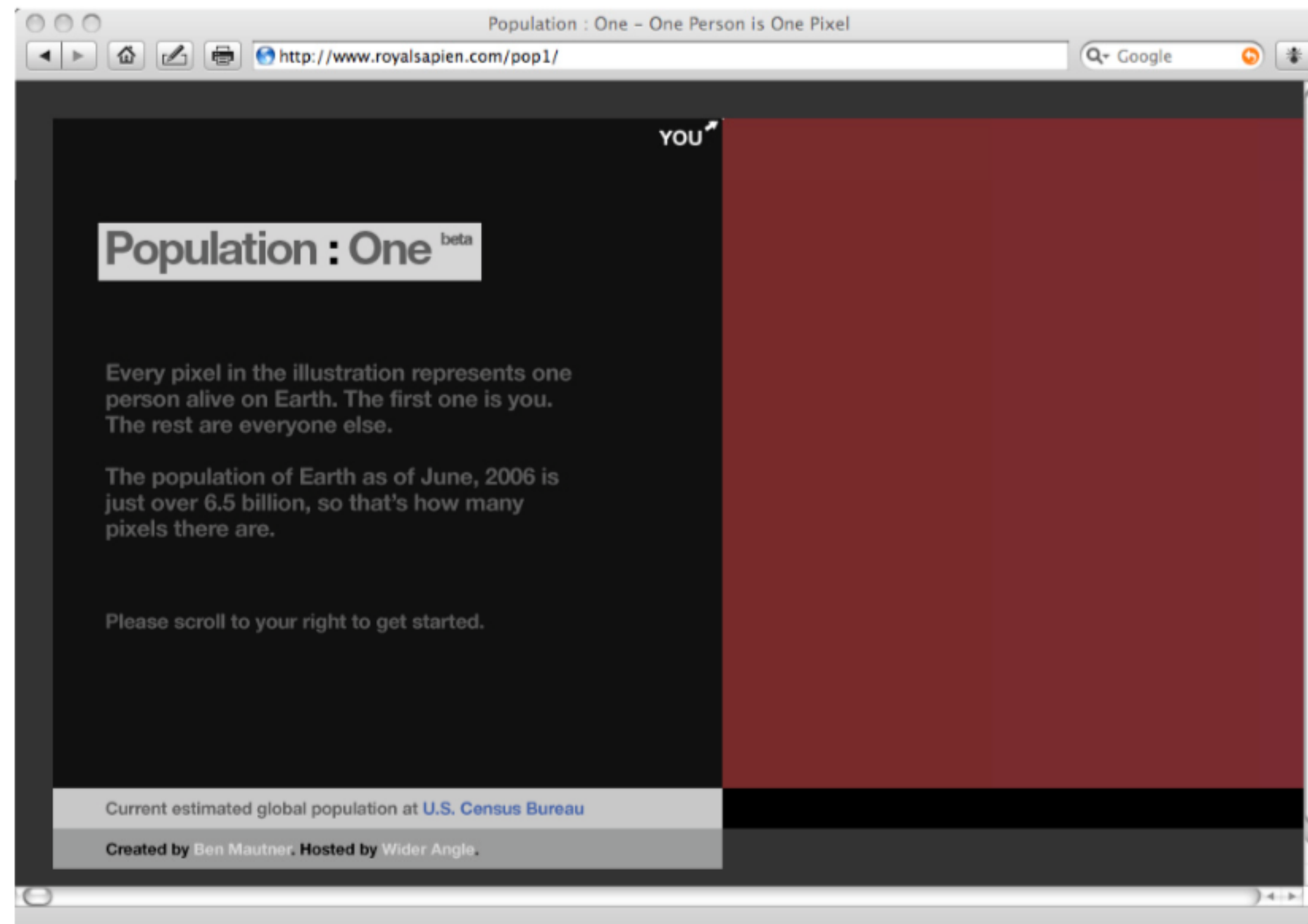# Announcement

- How is everyone doing with the final project?

Data Sculptures

Physical information visualization

Fig. 1. Screen-based versus physical data representation of an identical dataset. *Left*: World Population One [10]. One person is one *pixel*: the world's population represented as a large, scrollable image. *Right*: Of All the People in all the World [11]. One person is one *rice grain*: here, the population of the US as a one heap of rice.

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Symbolic Data Representation

Fig. 2. Graph-like symbolic data sculptures. *Left*: dataLix. Comparison of unemployment rate between males and females in Australia (1978-2005). The (male and female) helix revolutions are indicative of the number of people looking for work, while creases in the ribbon accentuate the rate of data change. (Student: Andrew Wallace) *Center:* Crime Association Cluster. Balls are colored to indicate the different associations victims have with the crime committed against them, with volume equivalent to the number of occurrences. (Student: Mitchell Page). *Right*: Money Fire. Two adjacent surfaces made up by ribbons compare the industry performance of large versus small companies over time. The size of data variances is mapped as color brightness to result in a holistic destructive flame. (Student: Jenny Song)

Symbolic Data Representation

Fig. 4. Iconic Data Sculptures. *Left*: Budget Flower. Three layers of 12 petals show the relative growth of the Australian economy between 1979 and 1981. The explicit imbalance of the flower highlights a monthly periodicity in economic growth, with revenue being mapped to the perimeter of the petals while width is dependent on expenditure. (Student: Andrea Lau) *Right:* Rose, divorce, marriage. Hardships of love are iconically represented through the metaphor of a rose. Its petals have been plucked and pierced to represent the relative amount of recorded divorces and re-marriages between 2000 and 2002. (Student: Ellis Lum Mow)
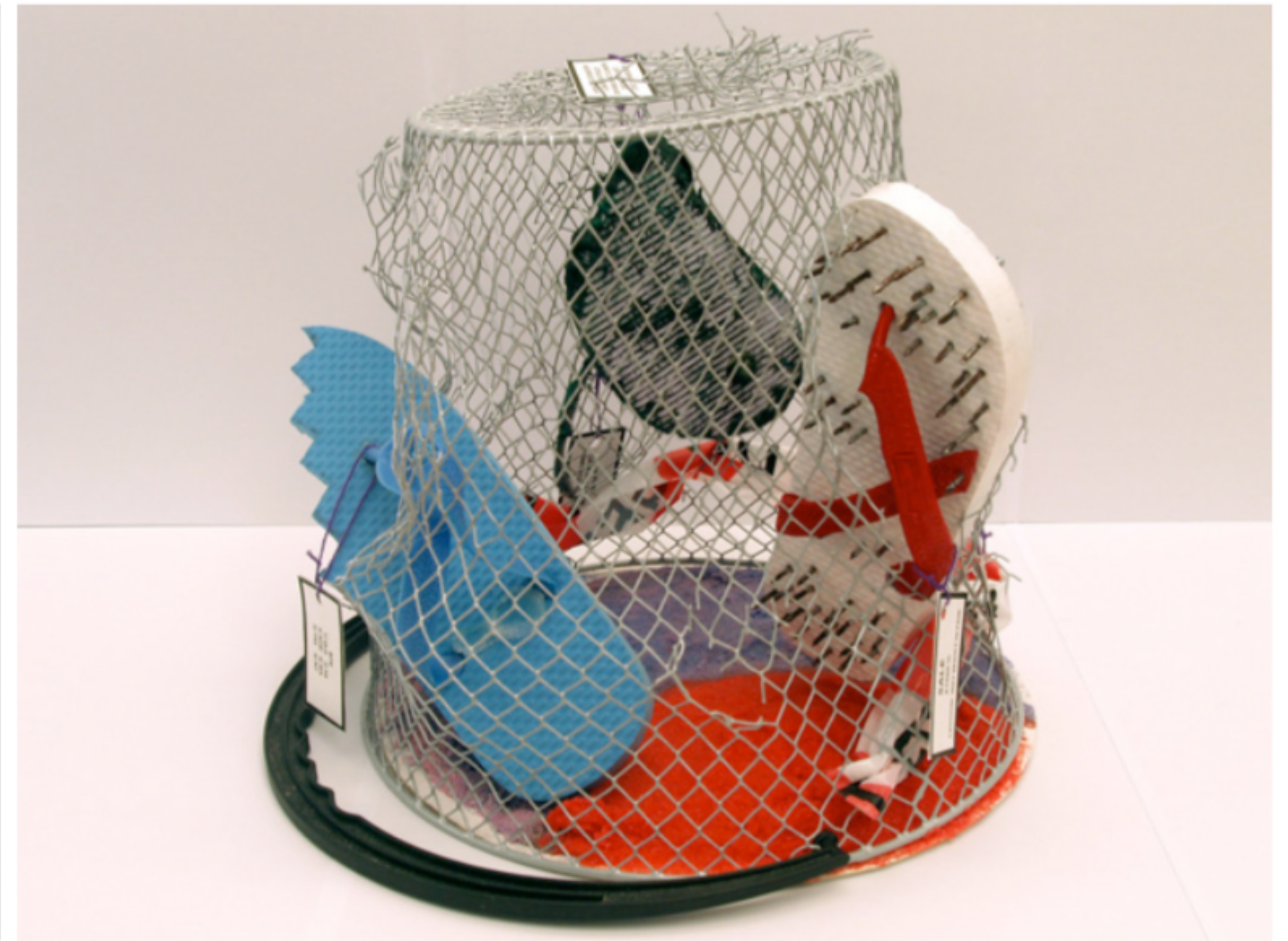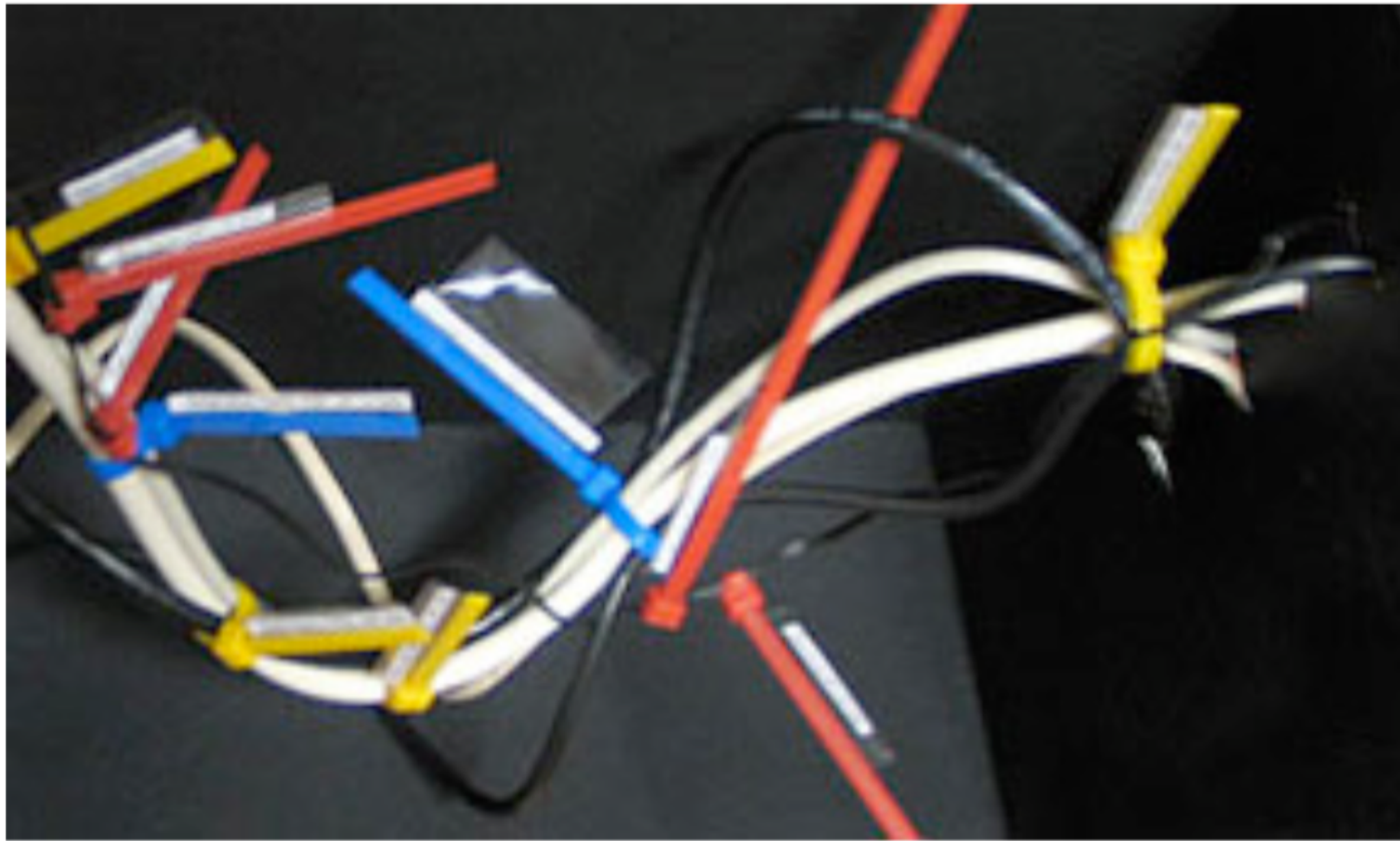
Fig. 5. Indexical Data Sculptures. *Left*: Daily Networking. Different types of network cables are interweaved amongst each other to reflect the relative length of time spent using particular network technologies during an average day. (Student: Nikash Singh) *Right*: Thongs. The dangers associated with wearing thongs are reflected by a series of physical thongs that have been pierced with a nail for every thousand thong-related injury requiring hospitalization. (Student: Rebecca Young)

Representations that bear a direct relationship (either physically or causally) with the signified are defined as being indexical.

Conceptual movement in design
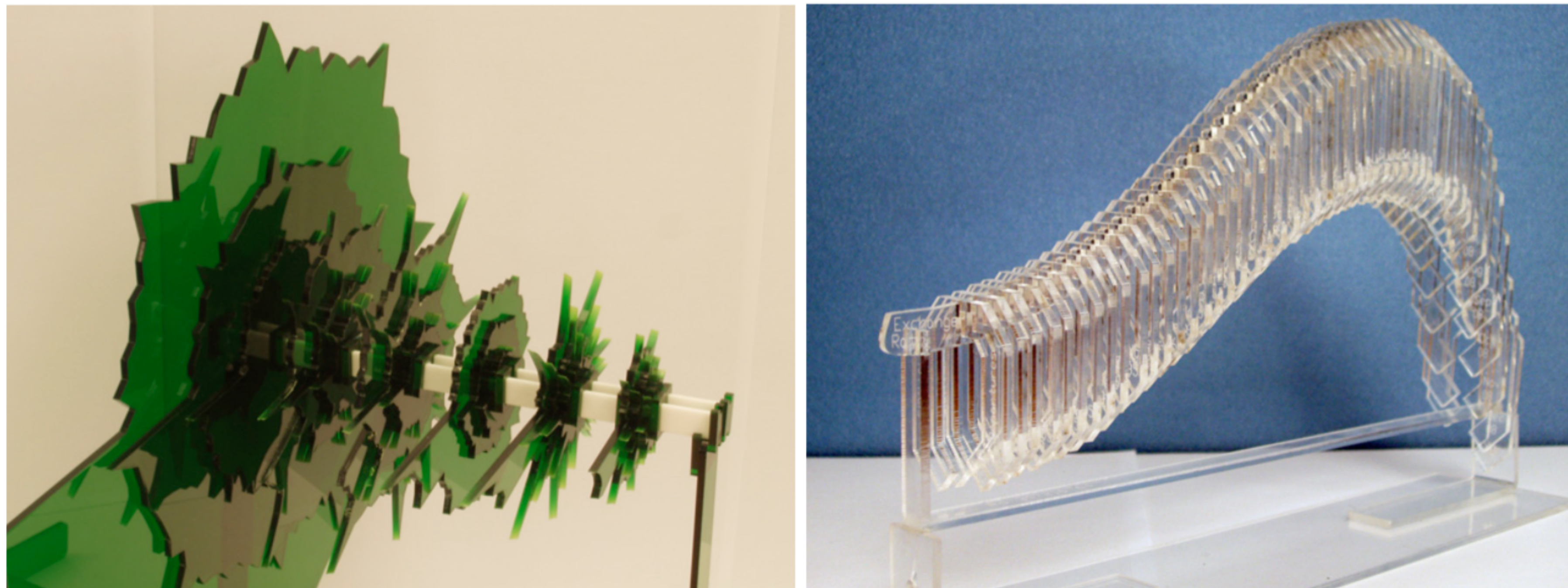
Fig. 6. Symbolic to Iconic. *Left*: Data Spikes. Australian retail sales between 1982 and 2009. The sharp retail "spikes" around Christmas were metaphorically linked to the color and external characteristics of a (sliced) Christmas tree. (Student: Drew Cosgrove) *Right*: Economic impact on the tourism industry in Australia (2005-2009). Monthly tourism arrivals have steadily increased, yet experienced an abrupt fall due to the recent economic downturn. The curvature of a spinal backbone metaphorically enhances the curvature of this data trend. (Student: Lucy Ro)

Going beyond putting depth to virtual visualization to physical visualization…

VandeMoerePatel2009

Conceptual movement in design

Fig. 7. Iconic to Symbolic. *Left*: NRL Trophy. Yearly rugby team performances are contrasted between each other, with the radii of the waves measured proportional to crowd attendance and thickness to ranking. (Student: Ali Malla) *Center*: Karma. Comparison between murder rates (1997-2007) and occurrence of natural disasters in the United States (1998-2008). The strands represent each dataset, and are intertwined more tightly together as the two reflect equivalent rates of change. (Student: Jean Viengkhou) *Right*: Ikebana. Prosperity of the Australian economy is measurable by the different plant types, their directional placement and relative lengths. (Student: Joyce Wong)

Beyond iconic representation that was specifically designed to manifest the meaning underlying the data...

Conceptual movement in design

Fig. 8. Symbolic to Indexical. *Left*: GigaHarp. Increasing capabilities of CPUs over time are reflected by the tones generated by the plucking of the harp strings. The frame is derived from the gradient increase in computer processing speeds, with the strings tuned to each other to create a reverberation relative of transistor size. (Student: Kevin Chen) *Right*: Alcohol's Filtered Influence. Each filter is comprised of a matrix of holes that allows water to filter through each layer in a timeframe reflective of the delayed effect of alcohol. (Student: Trent Robinson)

Conceptual movement in design

Fig. 9. Indexical to Symbolic. *Left*. Keyboards. A keyboard is modified to reflect the usage of the keyboard as an input device. Individual keys are raised at a height measurable to the average number of times they have been pressed over time. (Student: Alex Duckmanton) *Right*: Playing Cards. Packs of playing cards are modeled into a series of abstract components. Flower blossom-shaped cards create a visual appeal akin to the luring effect of gambling, which surround a tower of cards reflective the revenue generated by typical card-gaming tables. (Student: Andrew Morrisson)

Conceptual movement in design
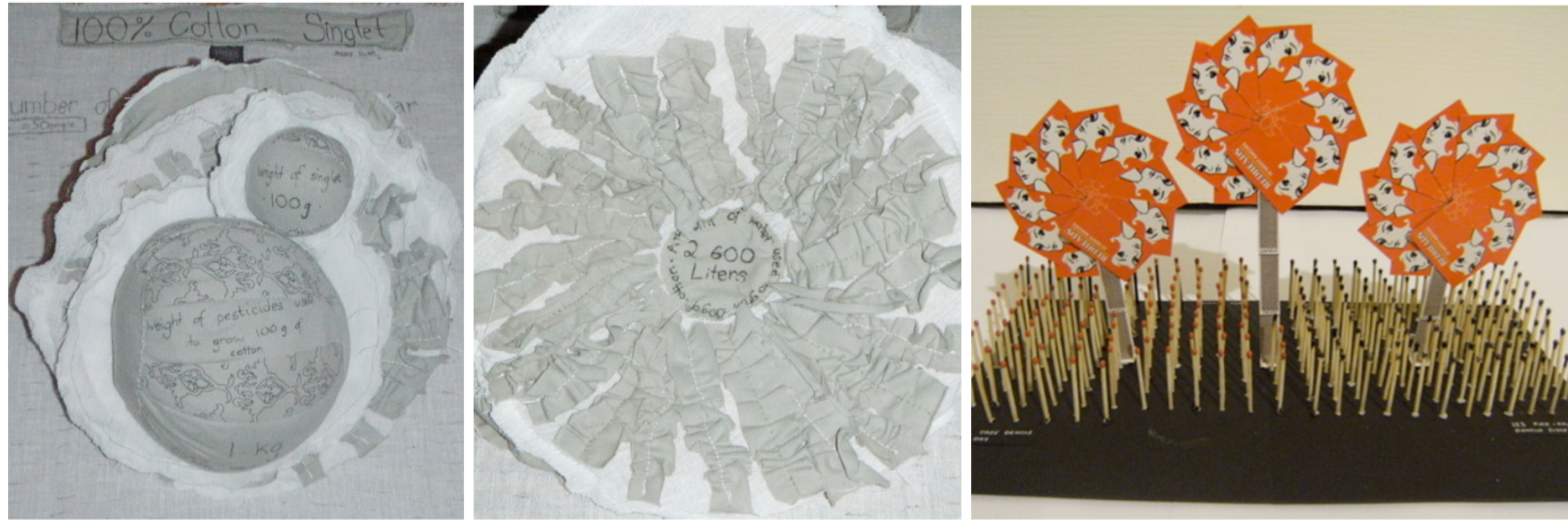
Fig. 10. Iconic to Indexical. *Left and Middle:* 100% Cotton. The sculpture shows the implications on the environment resulting from the water usage requirements for creating a 100g cotton singlet. Individual components iconically represent separate statistics, which brought together, form the structure of a cotton plant flower. (Student: Jessie Heppel). *Right:* Redheads. Each fire match is representative of the number of trees killed per day to meet the demand for matchstick production. Of those matches that are extinguished, each is representative of a human death. (Student: Madeline Reader).

Conceptual movement in design
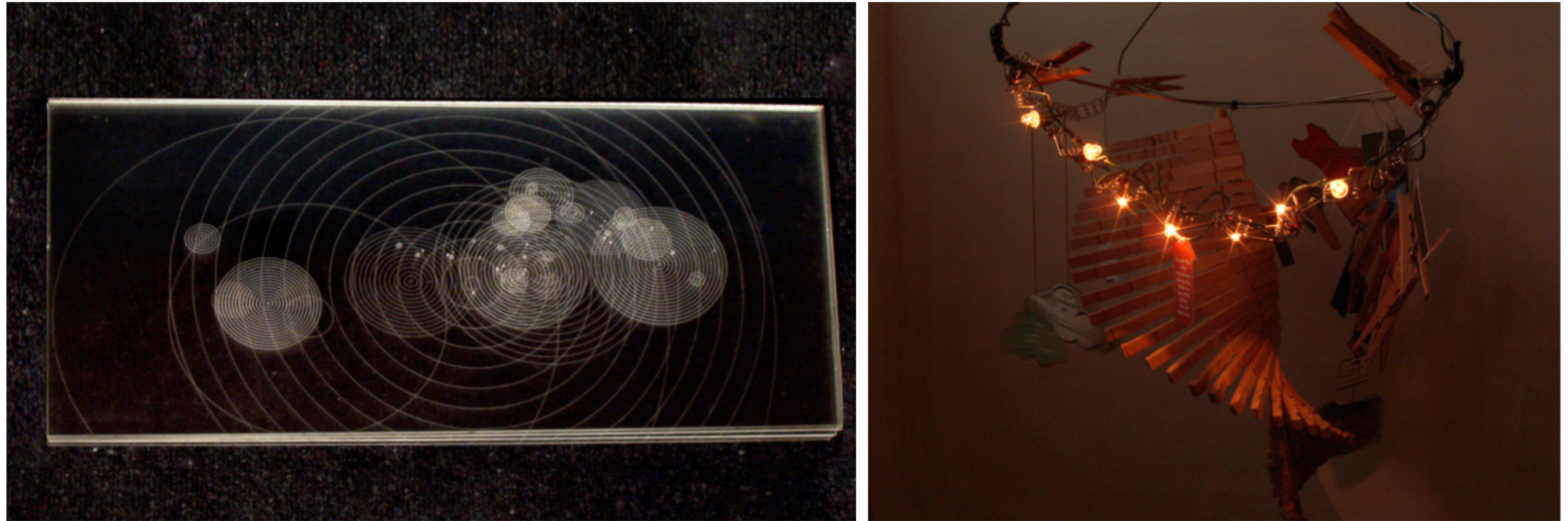
Fig. 11. Indexical to Iconic. Left: Ripples of Conflict. Layers of Perspex sheets are stacked on top of one another to reveal a geographic mapping of concentric circles equivalent to the number of human deaths associated with global conflicts. (Student: Martha Gouniai) *Right*: Clothes Pegs. A series of light globes reflect the percentage of total energy saved when line-drying clothes as oppose to using a clothes dryer. (Student: Stephanie Patel)
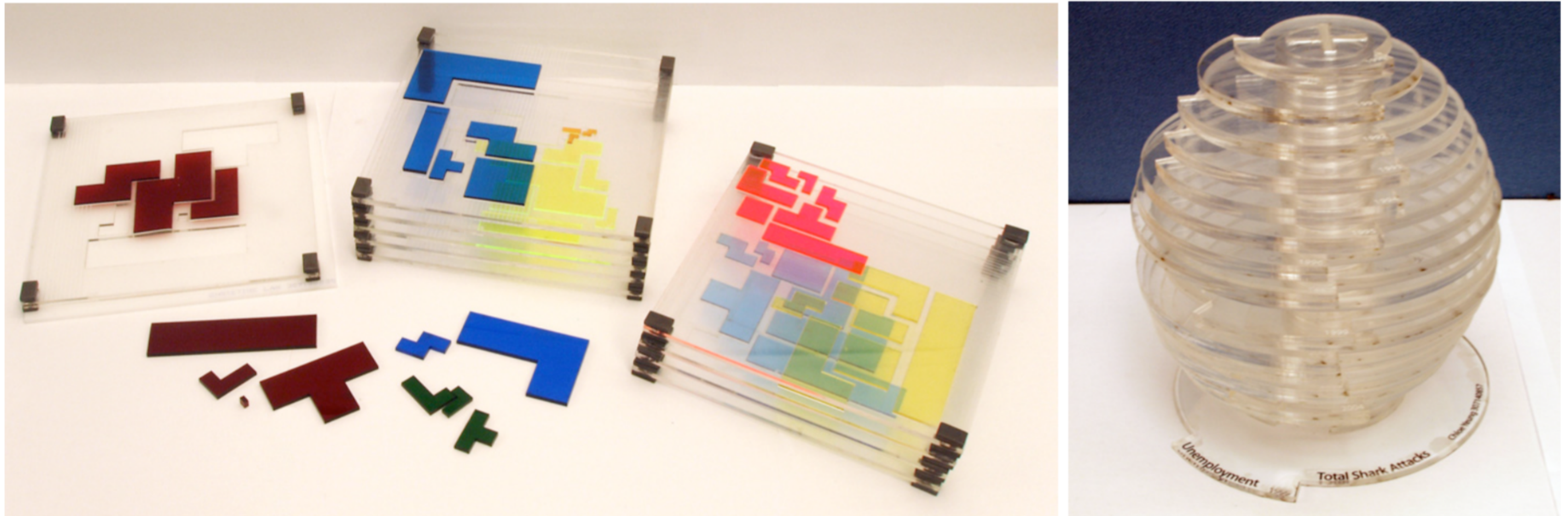
Interactivity and Play
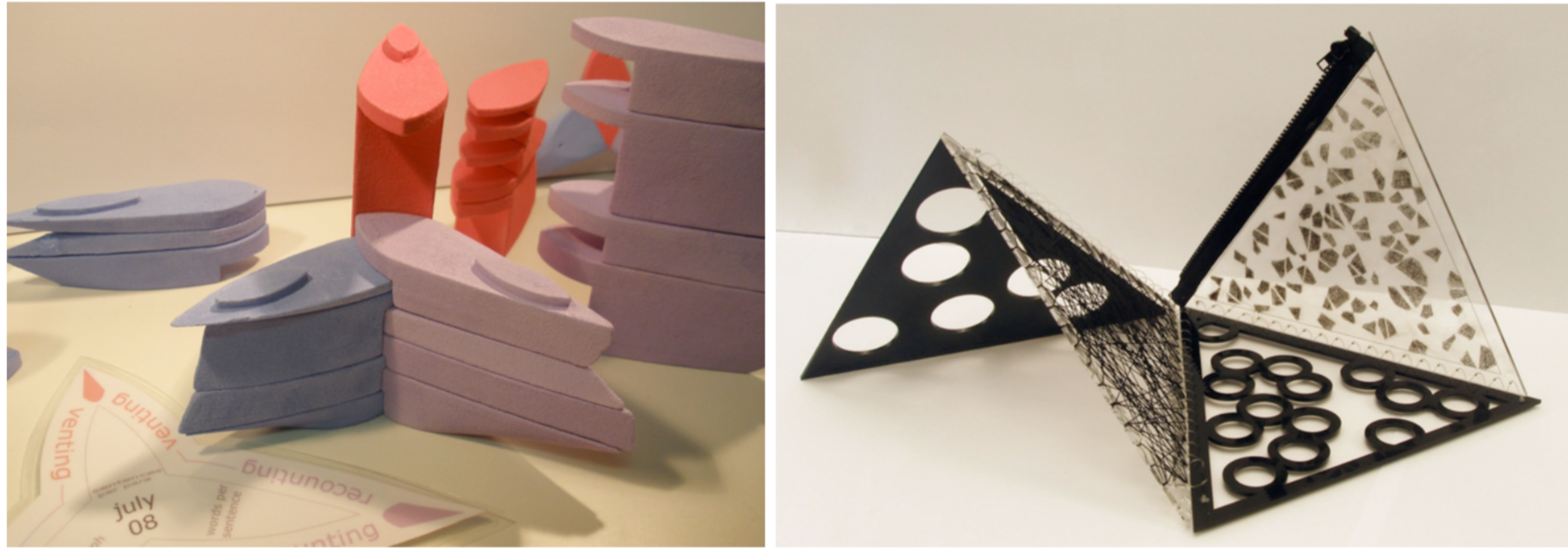
Fig. 14. Interactivity and Play. *Left*: Diary Entries. A set of puzzle blocks are shaped and colored to reflect the semantic analysis and overall mood of each diary entry. Each block is uniquely shaped and parameterized, while interlocking together as an historical timeline of entries. (Student: Mandy Leung) *Right*: Social Behavior Pyramid. The facing sides of the pyramid are inversed to each other, reflecting the stark opposites in behaviors observed among train commuters with and without MP3 players. Users are encouraged to unfold the sculpture into diverse shapes, to compare all possible pairs of opposing sides. (Student: Georgie Pope)

Interactivity and Play

Fig. 15. Interactivity and Play. *Left*: Tetris Stack. Each physical layer represents a level within a Tetris game, comprising of six designated slots for each of the typical Tetris blocks, their sizes relative to the number of times they appeared in the level. (Student: Christine Lam) *Right*: Economy and Shark Attacks. The orbital shape of the sculpture brings together a contrasting relationship between the state of the economy and the number of shark attacks. It affords users to easily turn and rotate any of the discs to line up. (Student: Chloe Yueng)

Constructive Visualization

InfoVis Authoring

- Finding effective visual mapping…

- How people construct visual mapping?
- How people transform data into visual representation?
- Create, update and explain their own information visualization using tangible building blocks

Fig. 1. Constructing a visualization with tokens: right hand positions tokens, left hand points to the corresponding data.

Abstract—The accessibility of infovis authoring tools to a wide audience has been identified as a major research challenge. A key task in the authoring process is the development of visual mappings. While the infovis community has long been deeply interested in finding *effective* visual mappings, comparatively little attention has been placed on *how* people construct visual mappings. In this paper, we present the results of a study designed to shed light on how people transform data into visual representations. We asked people to create, update and explain their own information visualizations using only tangible building blocks. We learned that all participants, most of whom had little experience in visualization authoring, were readily able to create and talk about their own visualizations. Based on our observations, we discuss participants' actions during the development of their visual representations and during their analytic activities. We conclude by suggesting implications for tool design to enable broader support for infovis authoring.

Samuel Huron, Yvonne Jansen, Sheelagh Carpendale, 2013

Create a Visualization

- A friend has asked for their help with his financial situation.
- He admits to having trouble managing his expenses and to being unsure how to resolve the situation.
- The facilitator points to the dataset and comments that currently changes over time are hard to see, and a visual representation might be helpful.
- The available tools for creating such a representation are the tokens placed on the table.
- All values in the dataset are divisible by 25, a mapping of 1 token ~ 25 seems reasonable.
- Participants are then invited to take all the time they need and to inform the facilitator once they are finished.

Update a Visualization

- The facilitator tells the participants that the friend provides them with one more month of data.
- The facilitator slides up the data printout to reveal a month previously hidden by a paper mask.
- Participants are asked to update the visualization to include the new data, using all the time they need.

Annotate a Visualization

- The facilitator informed the participants that their friend was not currently able to receive their advice.
- The facilitator provided participants with 4 pens of different colors and a variety of post-its and asked them to annotate their visualization explaining what they did and what they discovered.
- Participants were explicitly asked to provide sufficient information such that their friend could:
  - Read the visualization
  - Understand it
  - Be able to re-create it if needed.
- Participants were asked to indicate possible budget improvements.
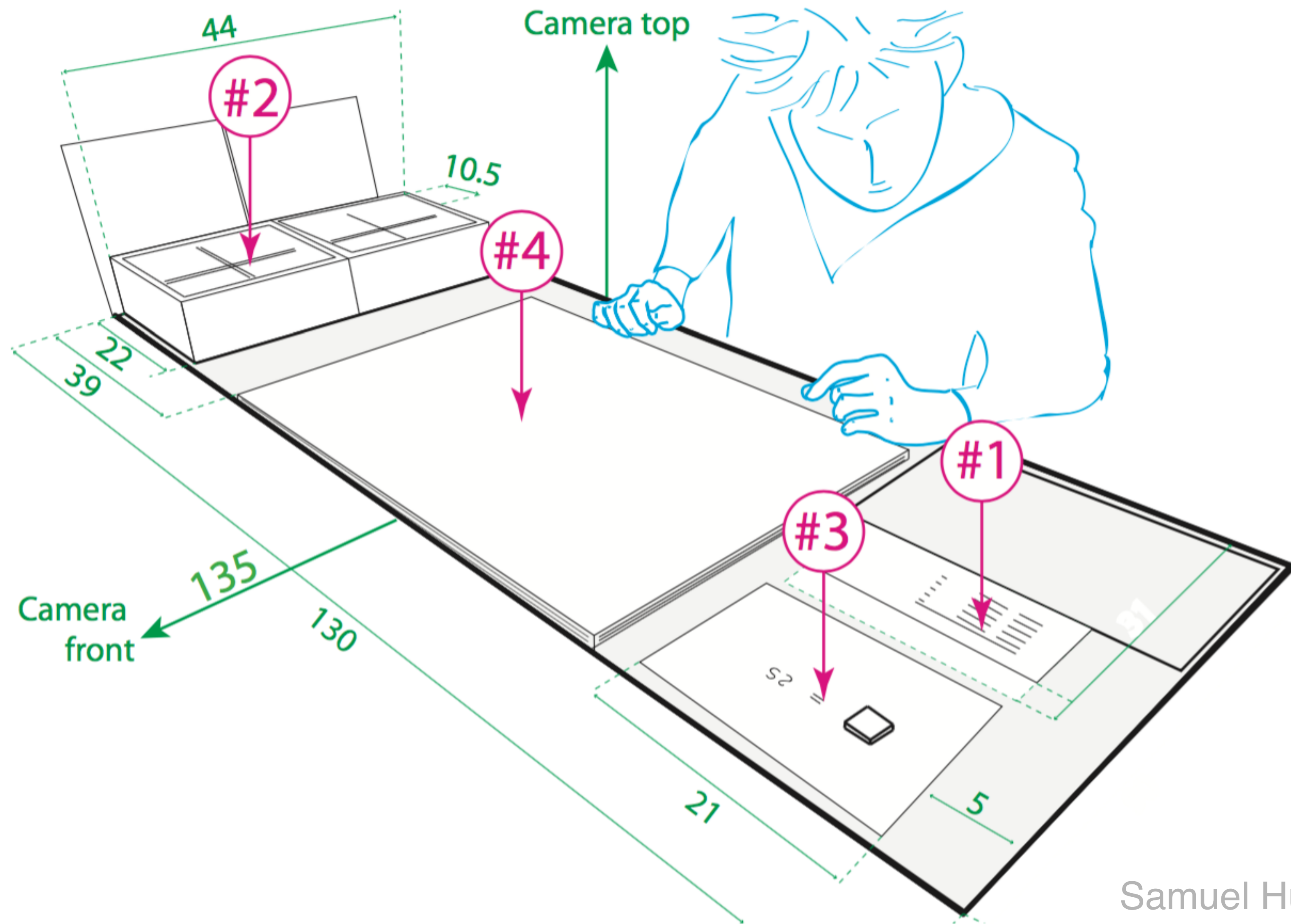
Fig. 3. Study setup (all measurements are in centimetres).

Tangible Construction

https://youtu.be/TndAWaawqWY

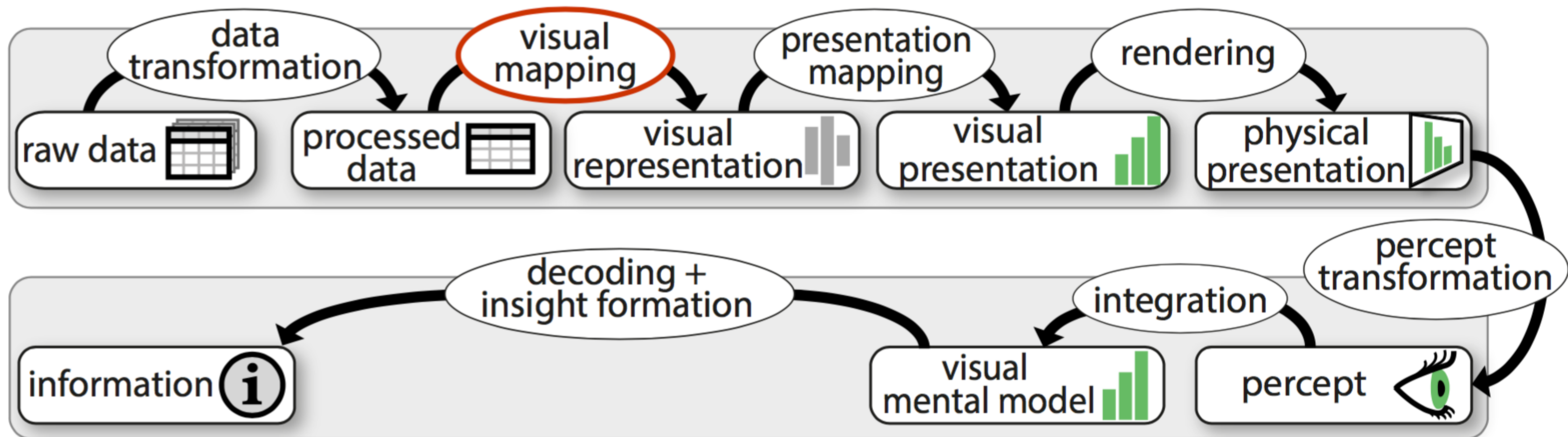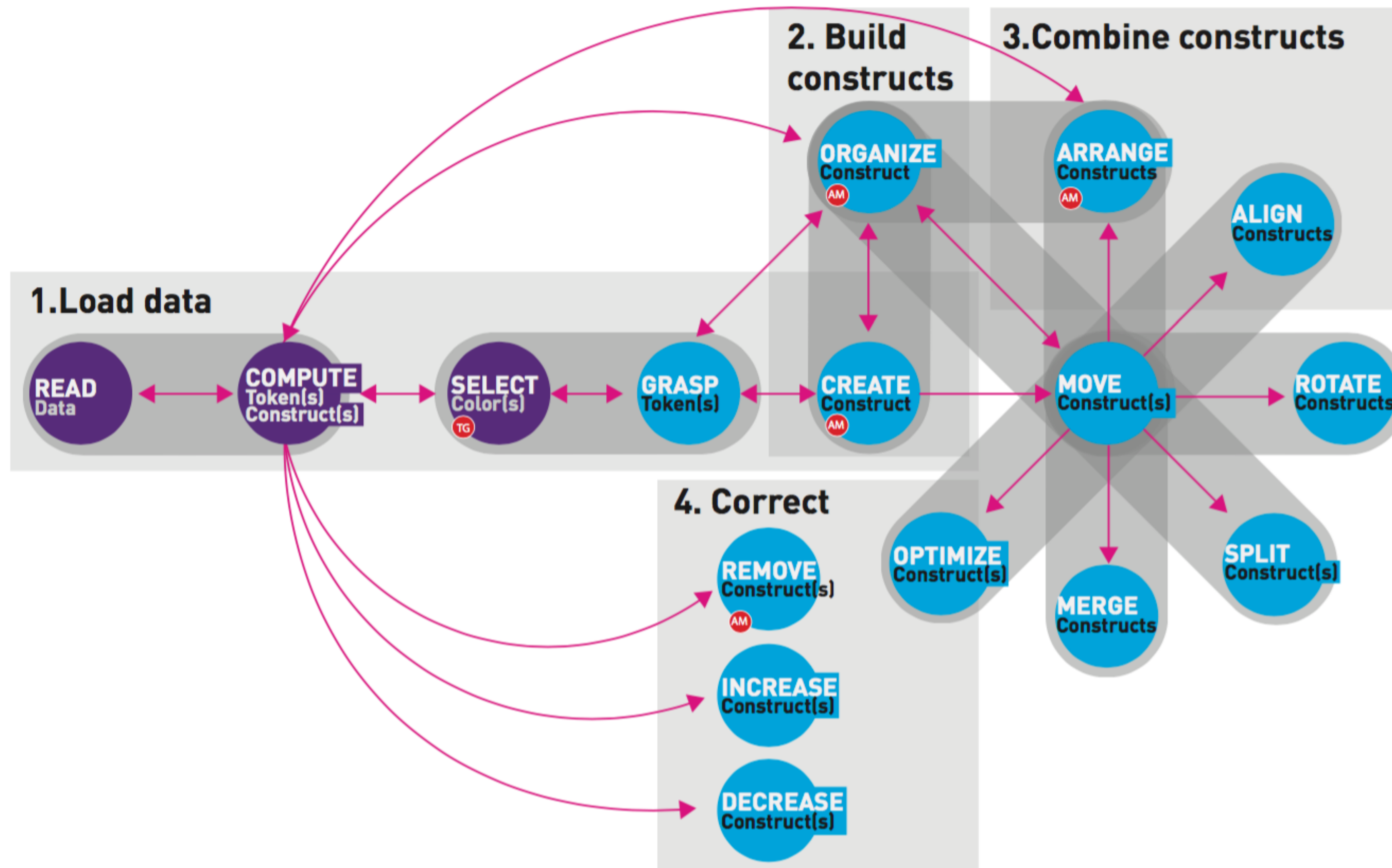Samuel Huron, Yvonne Jansen, Sheelagh Carpendale, 2013

Fig. 2. The extended visualization reference model [34], adapted to our terminology.

Why	What (logical task)	How (mental and physical actions)
Construction	1. Load data	READ, COMPUTE, SELECT COLOR, GRASP, CREATE
	2. Build constructs	ORGANIZE, MOVE
	3. Combine constructs	ARRANGE, ALIGN
	4. Extend	READ, COMPUTE, SELECT COLOR, GRASP, CREATE, ORGANIZE, MOVE, ARRANGE, ALIGN
	5. Correct	INCREASE, DECREASE, REMOVE
Computation	6. Categorize	SELECT COLOR, ARRANGE, MERGE, SPLIT
	7. Aggregate	MOVE, MERGE
	8. Compute New Value	SPLIT, COMPUTE + LOAD
	9. Unitize	ORGANIZE, ARRANGE, SPLIT, MERGE
Storytelling	10. Highlighting	SPLIT (temporarily)
	11. Marking	CREATE, SELECT COLOR

Table 2. Summary of identified goals, tasks, and actions.

Fig. 5. A flow diagram showing the most common paths. In purple: the mental tasks, in blue: the physical tasks. The gray background rectangles illustrate the logical tasks. The gray oblongs linking two spheres represent possibly concurrent actions.

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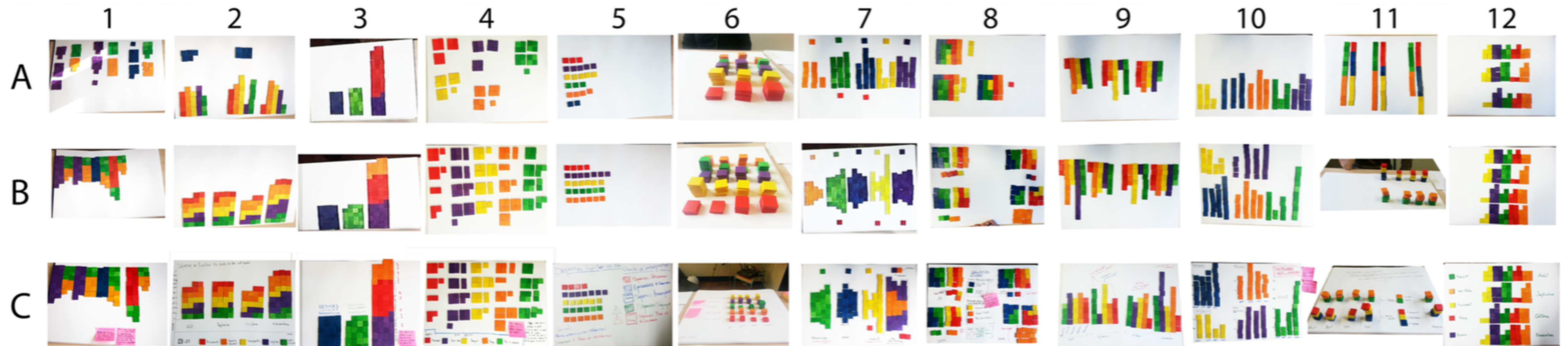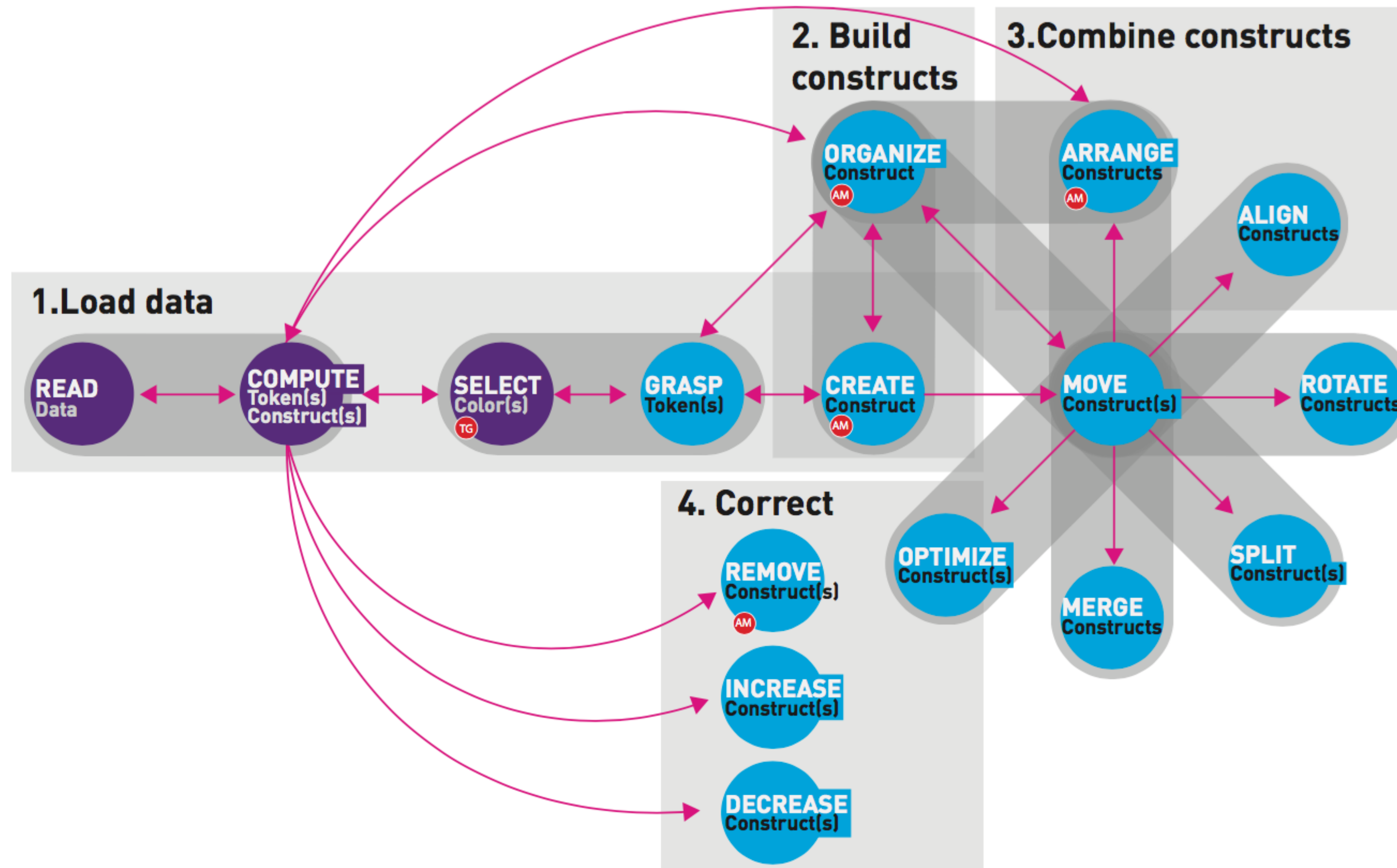
Tangible Construction

Fig. 4. All constructed visualizations. Columns represent participants, rows represent tasks: (A) create a visualization, (B) update, (C) annotate.

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Construction

- A visualization is a nested construct of tokens forming a representation of data.

Computation

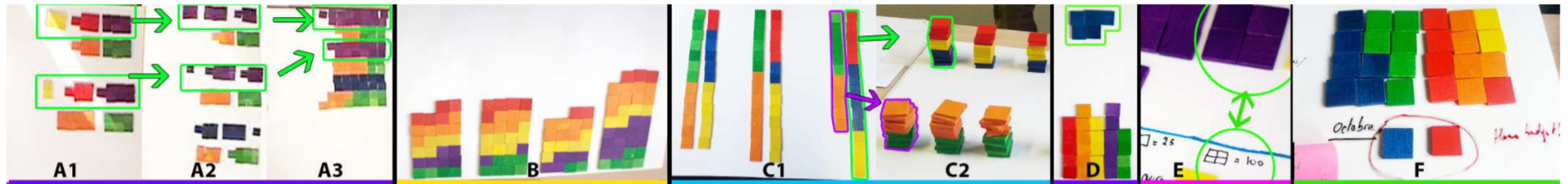- Compute additional values: categorize, aggregate, compute new value, and unitize.

Fig. 12. Computations: **A1/2:** *categorize* by color assignment; **A2/3:** *aggregation* by merging constructs; **B:** information preserving *aggregation*; **C1:** *aggregate* by spatial merge, *categorize* by proximity; **C2:** same categories as in C1 but different arrangement of constructs; **D:** *computation of delta* with another month in blue (highlighted); **E:** *unitized* construct ∼ 100; **F:** *unitized* and merged construct to illustrate a month's budget.

Storytelling

- Spontaneously manipulated the visualizations to support their arguments
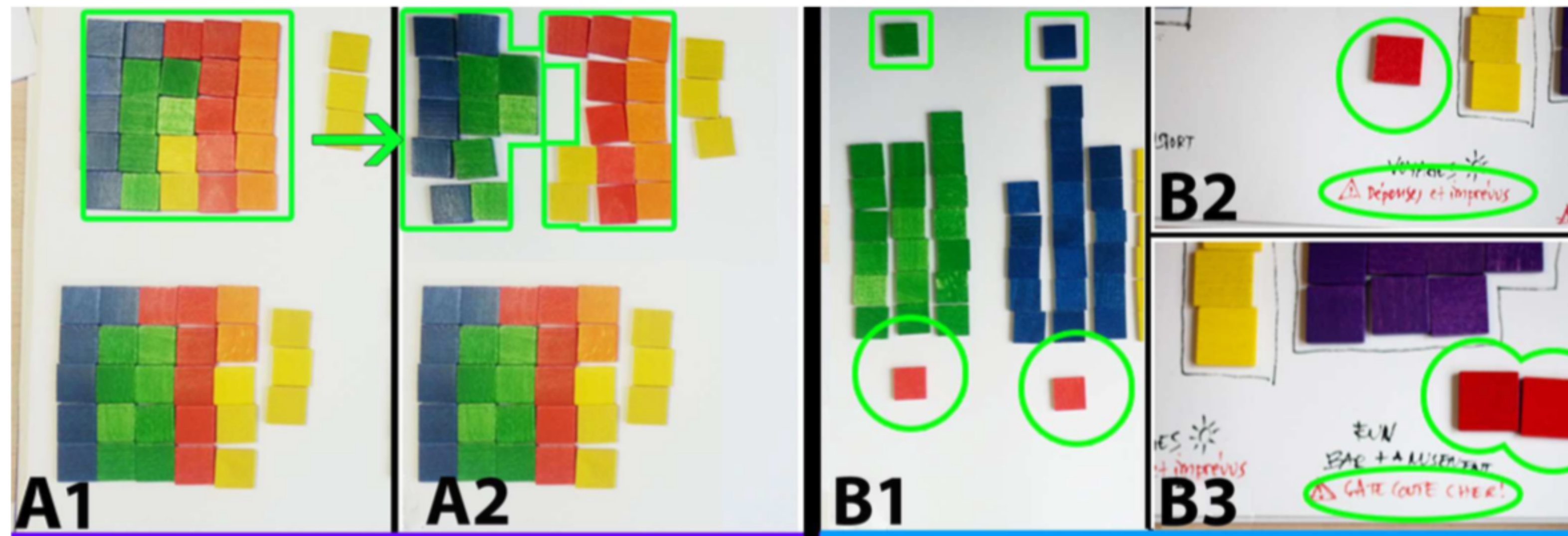- Highlighting and marking

Fig. 13. Storytelling: **A1:** *unitized* construct; **A2:** temporary SPLIT to explain the categories; **B1:** *marking* of categories exceeding budget; **B2/B3** *marking* and annotation how to optimize budget.

Implications: research and design

- Opening the black box visual mapping in the infovis pipeline.
- Participants were readily capable of constructing visual representations with this particular tangible environment.

- Most visualization authoring software requires first choosing a visualization technique and then the data dimensions to visualize.
- A top-down procedure: the visualization model needs to be selected before any data can be seen visually.

- Our study environment provided the opportunity to build visualizations bottom-up by manipulating a small part of the dataset and gradually defining an assembly model.
- Data is visible from the very beginning, and the visualization model develops iteratively during construction.

1

Supporting different construction procedures

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- How do different visualization authoring procedures impact the understanding of data?
- How does a bottom-up procedure transfer to different data types and tasks?
- What are the limits of a bottom-up procedure?
- How can we assure correctness of the result?
- Does this affect people's confidence in their constructions?

1

Open Questions

Processing fluency: the subjective experience of ease with which people process information.

- 200 years ago: teach mathematics to non-literate kindergarten children
- People without infovis skills can construct useful visual representations for themselves when offered a method with for which they already possess fluency.

2

Exploiting processing fluency

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- How do our results transfer to systems which are constructive but lack the tangible aspect?
- Would a constructive authoring tool implemented on an interactive touch surface provide similar benefits?
- How can we transform more complex infovis techniques into more fluent ones?

2

Open
Questions

- Physical affordances of tokens likely affected people's actions and their visual designs.
- While the wooden tiles used in our study could be piled, participants found them slippery and mostly created 2D designs.
- Other materials such as Lego bricks would facilitate stacking and might have led to more 3D encodings.
- Materials with programmable properties may be promising for constructive visualization purposes.

3

Tangible design

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- Which material properties are most salient in their effect on constructive strategies?
- Which properties are most effective?
- How would the increased complexity of programmable properties affect people's proficiency with physical objects?

3

Open
Questions

Programmable Materials

tinyurl.com/claytronics

https://www.youtube.com/watch?v=16vBZbna2rk

Programmable Materials

- Claytronics is an abstract future concept that combines nanoscale robotics and computer science to create individual nanometer-scale computers called claytronic atoms, or catoms, which can interact with each other to form tangible 3D objects that a user can interact with.

4D Programmable Materials

https://www.youtube.com/watch?v=hi8QQ89kzho

Additional Reading

- Personal Visualization: Exploring Data in Everyday Life
  - http://www.vis4me.com/personalvis15/index.html

Thanks!

Any questions?

You can find me at: beiwang@sci.utah.edu

CREDITS

Special thanks to all people who made and share these awesome resources for free:

→ Presentation template designed by Slidesmash

→ Photographs by unsplash.com and pexels.com

→ Vector Icons by Matthew Skiles

Presentation Design

This presentation uses the following typographies and colors:

Free Fonts used:

http://www.1001fonts.com/oswald-font.html

https://www.fontsquirrel.com/fonts/open-sans

Colors used