Design Exposition with Literate Visualization

Jo Wood, Alexander Kachkaev & Jason Dykes

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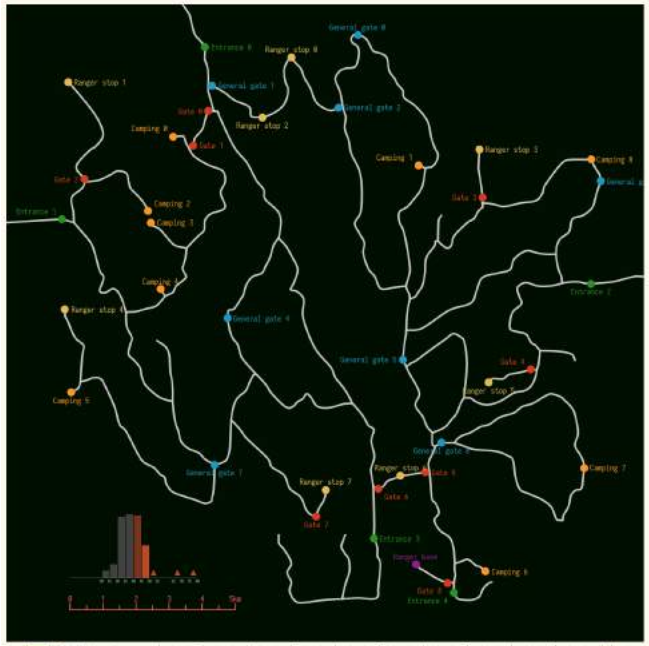
 @jwoLondon @kachkaev @jsndyks

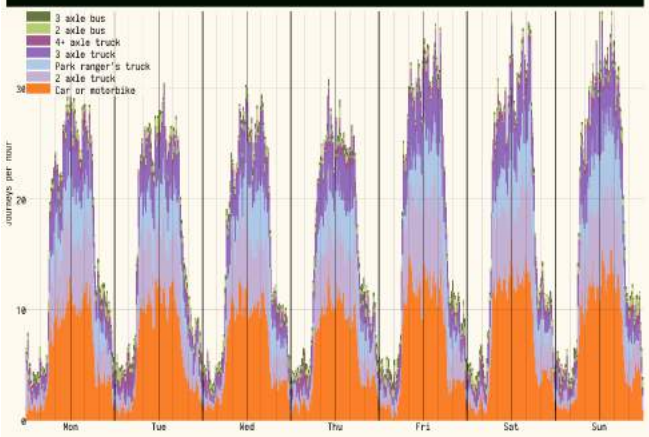
For the details...

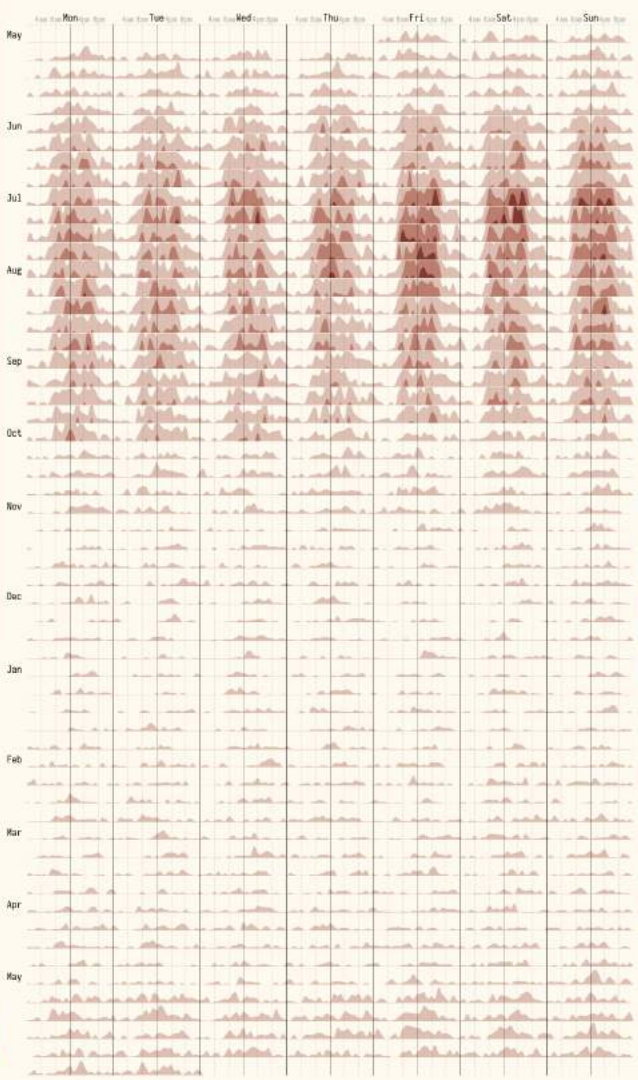
`litvis.org`

(paper, software, examples, tutorials, talks)

We have a “validity crisis” in visualization


Ranger stop 1
Entrance 0
Ranger stop 0
General gate 0
General gate 1
Gate 10
Ranger stop 2
Camping 0
Gate 1
General gate 2
Camping 1
Ranger stop 3
Camping 8
Gate 2
Gate 3
Entrance 1
Camping 2
Camping 3
Camping 4
Ranger stop 4
General gate 4
Entrance 2
General gate 5
Gate 4
Ranger stop 5
Camping 5
General gate 6
Ranger stop 6
Gate 5
Camping 7
General gate 7
Ranger stop 7
Gate 6
Gate 7
Entrance 3
Ranger base
Camping 6
Gate 8
Entrance 4
5km


3 axle bus
2 axle bus
4+ axle truck
3 axle truck
Park ranger's truck
2 axle truck
Car or motorbike
30
20
10
0
Journeys per hour
Mon
Tue
Wed
Thu
Fri
Sat
Sun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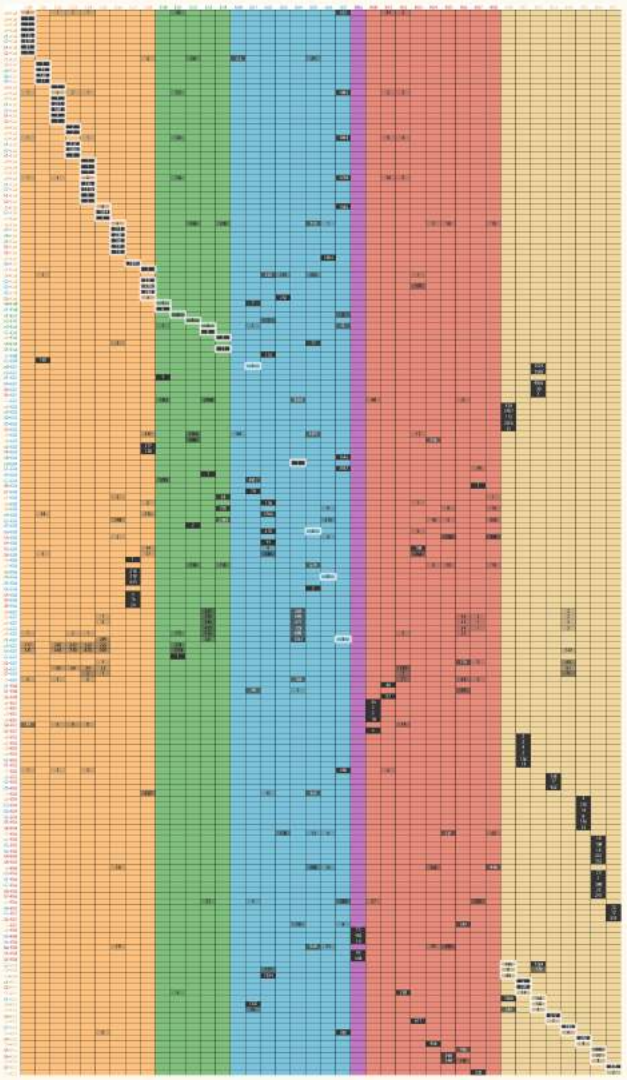

How do we know the visual led to the conclusions drawn?

How did our design choices shape the way we built our knowledge?

How do we learn from the visual design contributions of others?

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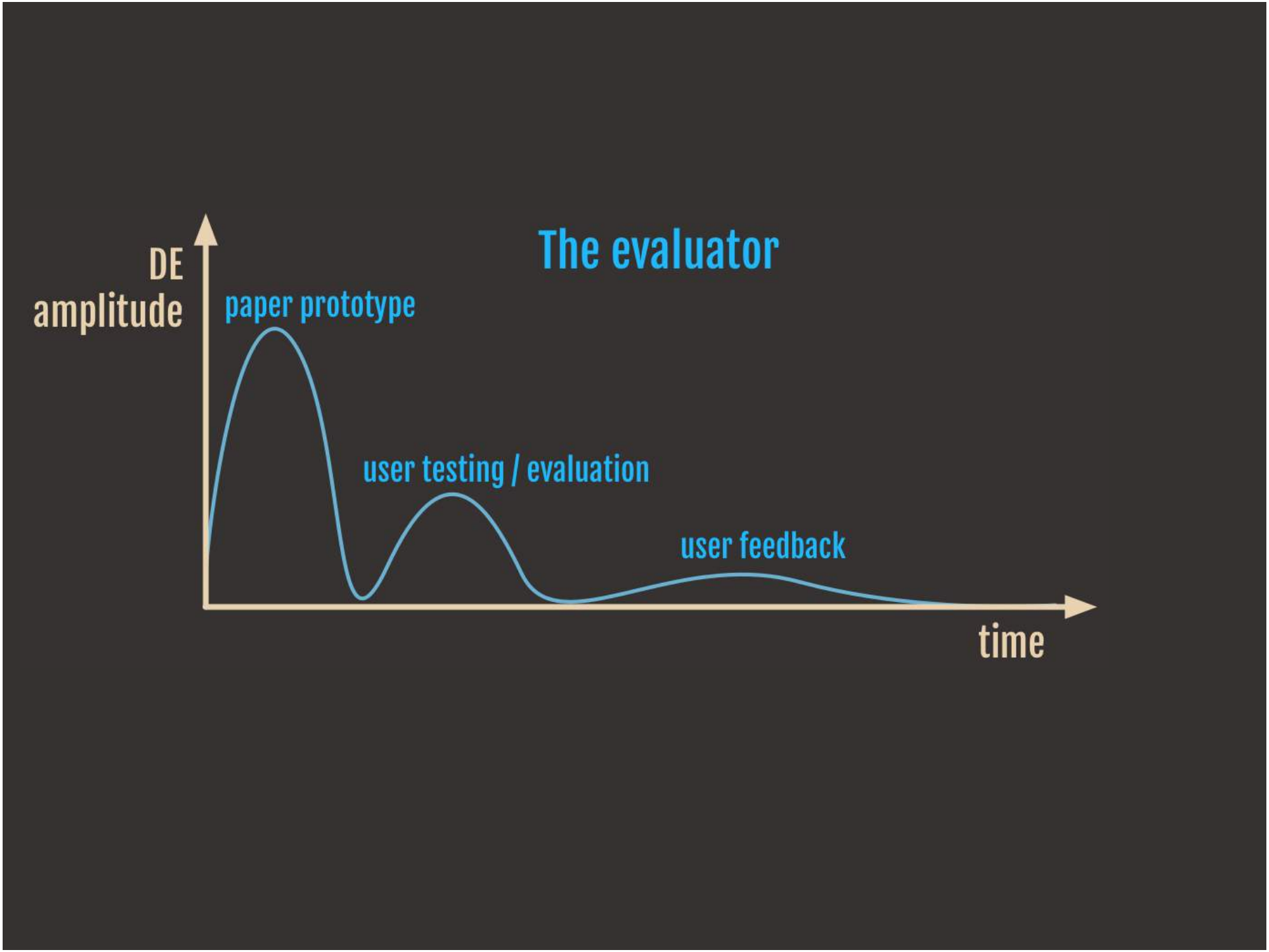
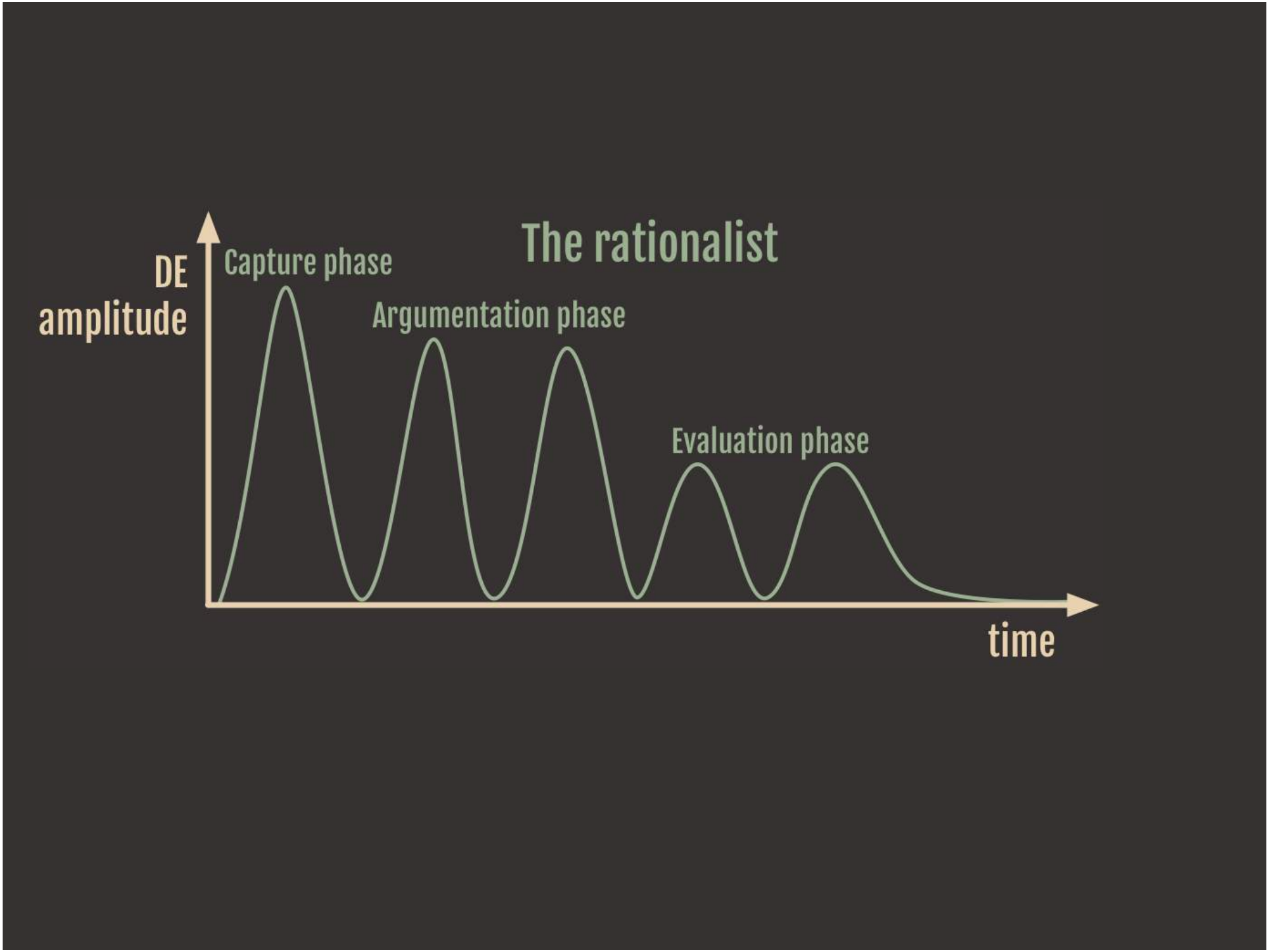
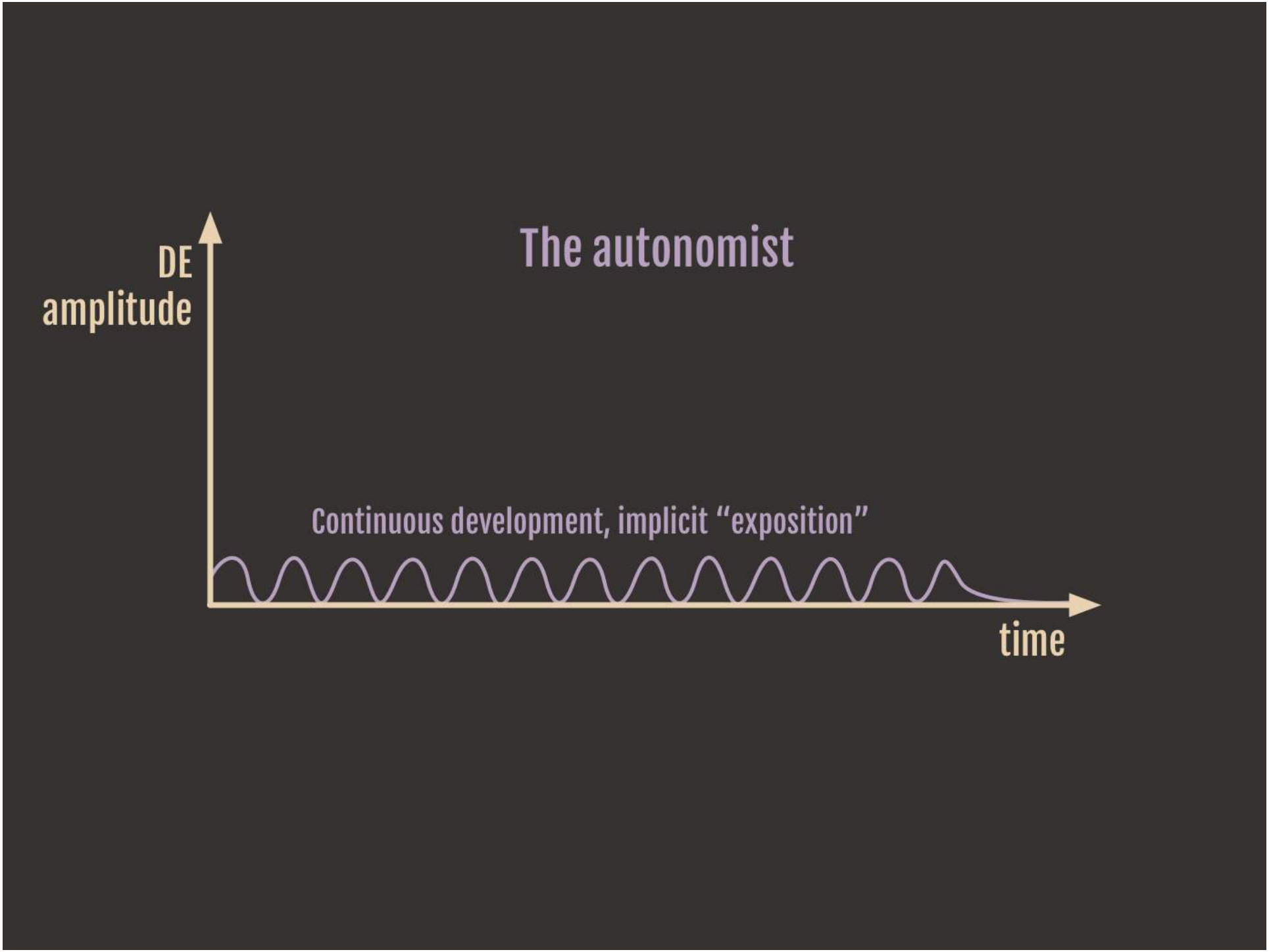
How did our design choices shape the way we built our knowledge?

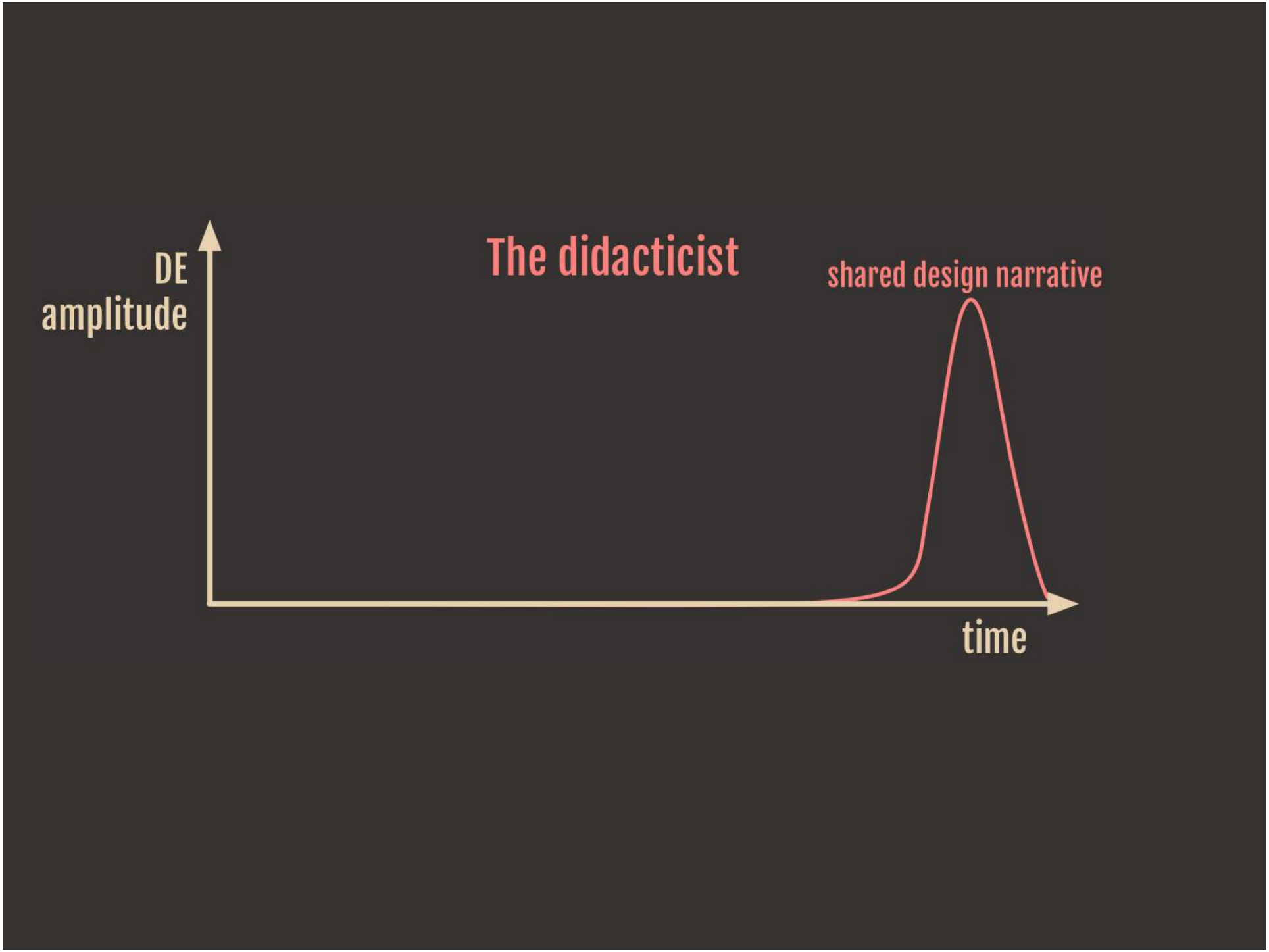
How do we learn from the visual design contributions of others?

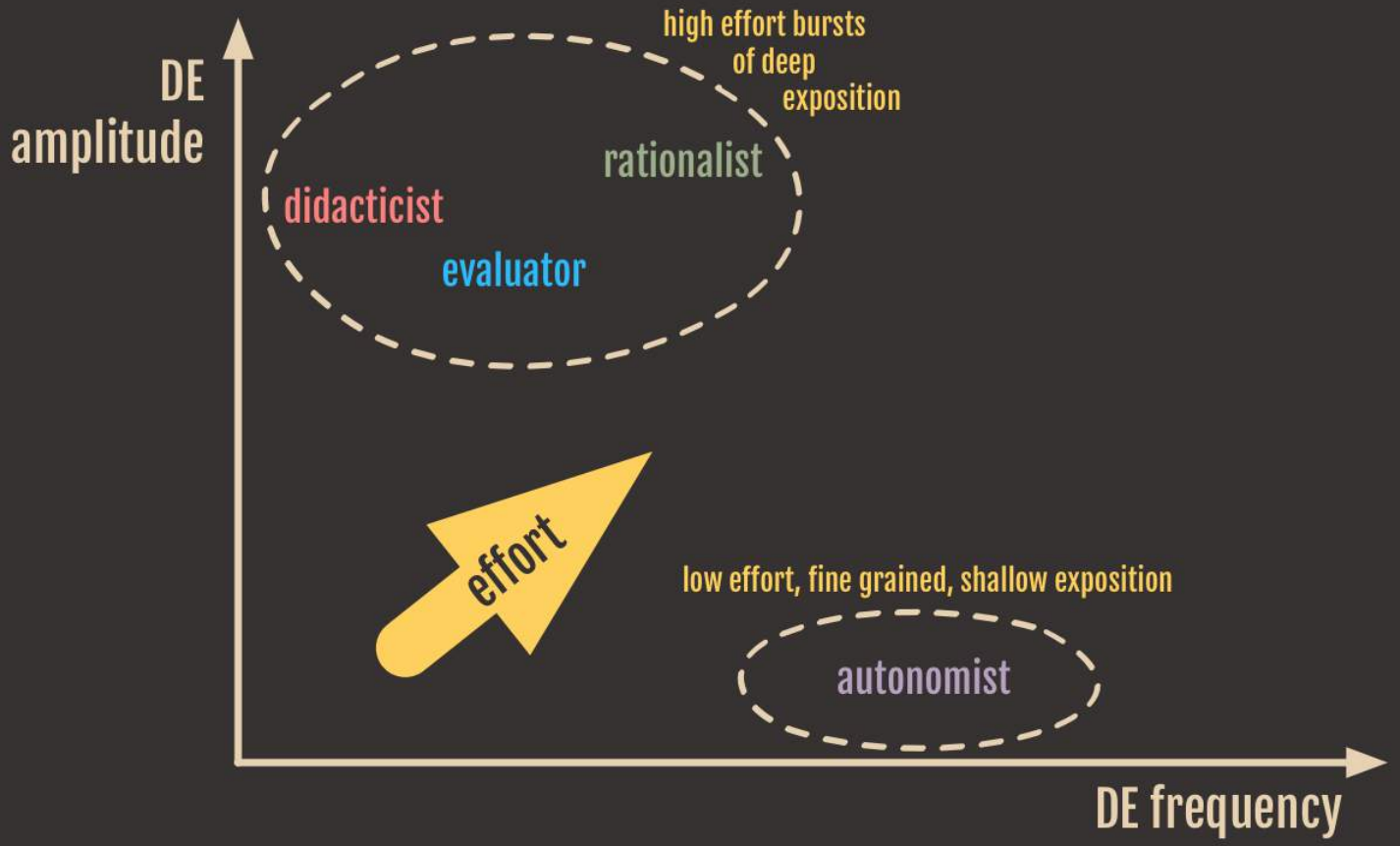
design exposition


The evaluator
DE amplitude
paper prototype
user testing / evaluation
user feedback
time


The rationalist
DE amplitude
Capture phase
Argumentation phase
Evaluation phase
time


The autonomist
DE amplitude
Continuous development, implicit “exposition”
time


The didacticist
DE amplitude
shared design narrative
time


DE
amplitude
high effort bursts
of deep
exposition
rationalist
didacticist
evaluator
effort
low effort, fine grained, shallow exposition
autonomist
DE frequency

Literate Visualization

based on Donald Knuth's Literate Programming, **literate visualization** marries vis construction with design narrative.

textual narrative promoted to a **first class citizen** in a programming environment. Content determined by **narrative sequence**, not coding constraints.

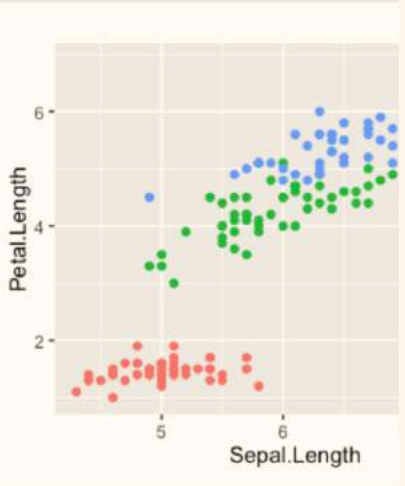
RStudio Source Editor

notebook-demo.Rmd

Preview · Insert · Run

```
Try executing this chunk by clicking the *Run* button within the
chunk or by placing your cursor inside it and pressing
*Cmd+Shift+Enter*.

```{r}
library(ggplot2)
ggplot(iris, aes(Sepal.Length, Petal.Length)) +
  geom_point(aes(colour = Species))
```
```

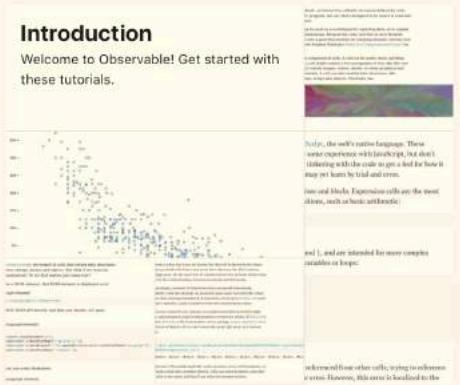


18:14 (Top Level)

Featured collections

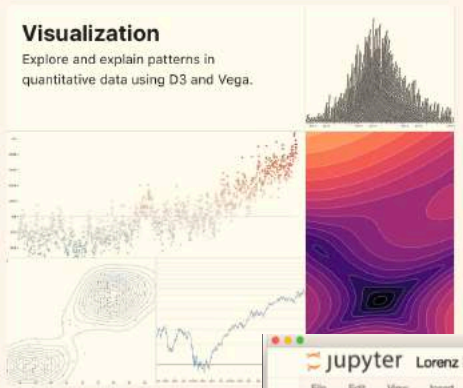
Introduction

Welcome to Observable! Get started with these tutorials.



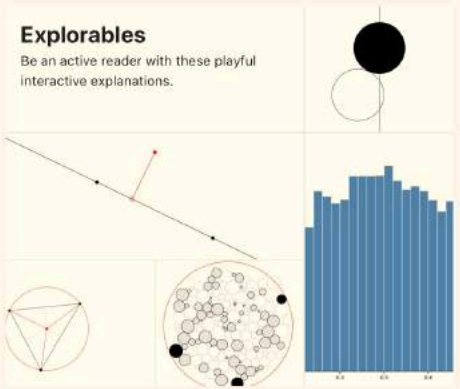
Visualization

Explore and explain patterns in quantitative data using D3 and Vega.



Explorables

Be an active reader with these playful interactive explanations.



jupyter Welcome to P

jupyter

Welcome to the

This Notebook Server wa

WARNING

Don't rely on this ser

Your server is hosted tha

Run some Python

To run the code below:

1. Click on the cell to se
2. Press SHIFT+ENTER

A full tutorial for using the

```
In [ ]: %matplotlib inline
import pandas as pd
import numpy as np
import matplotlib
```

jupyter Lorenz Differential Equations autosaved

File Edit View Insert Cell Kernel Help Python 3

Code Cell Toolbar: None

Exploring the Lorenz System

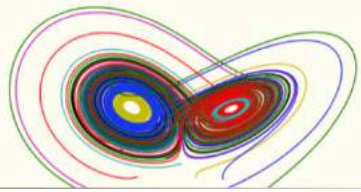
In this Notebook we explore the Lorenz system of differential equations:

$$\dot{x} = \sigma(y - x)$$
$$\dot{y} = \rho x - y - xz$$
$$\dot{z} = -\beta z + xy$$

This is one of the classic systems in non-linear differential equations. It exhibits a range of complex behaviors as the parameters (σ, β, ρ) are varied, including what are known as chaotic solutions. The system was originally developed as a simplified mathematical model for atmospheric convection in 1963.

```
In [7]: interact(Lorenz, N=fixed(10), angle=(0.,360.),
                 σ=(0.0,50.0),β=(0.,5), ρ=(0.0,50.0))
```

angle 308.2
max_time 12
σ 10
β 2.6
ρ 28



"We analyzed over **1 million computational notebooks** on GitHub, finding that one in four had **no explanatory text** but consisted entirely of visualizations or code"

Rule, Tabard and Hollan (2018) Exploration and Explanation in Computational Notebooks

litvis

github.com/gicentre/litvis

algebra.md

```
## Principle of Unambiguous Data Depiction

{( unambiguity |}

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Systematic shifts by 5% of votes cast towards leave or remain are easily detectable where they affect the majorty (shift between red and blue).
Systematic shifts that don't cross the 50% boundary are also detectable, although less obvious.
See for example size of blue circles in Scotland or red circles in Midlands/Northern England.
Therefore, no evidence for _confusers_ in design.

-  [x] passed?

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algebra.md preview

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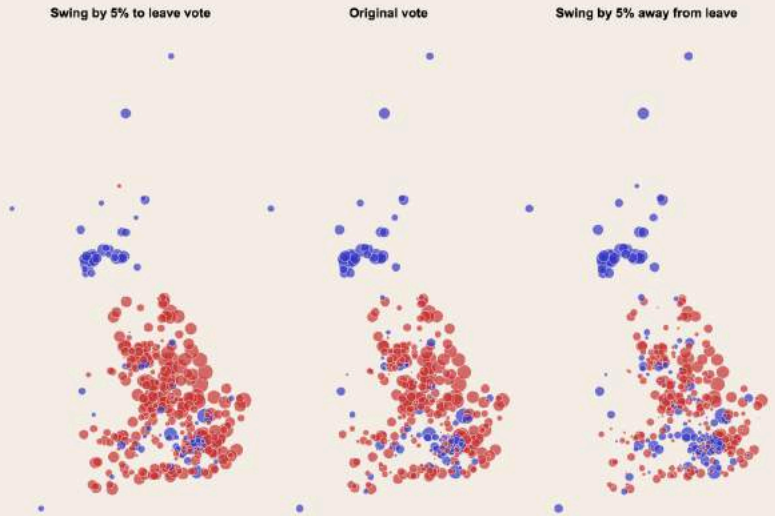

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Linter

Severity	Provider	Description	Line	File
Warning	Litvis	each description of visual-data correspondence should be followed by an assessment of it. (narrative-schema:rule-validation)	0:0	/Users/jwo/Dropbox/home_work_transfer/research/literateProgramming/litvisSandbox/algebra.md
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algebra.md

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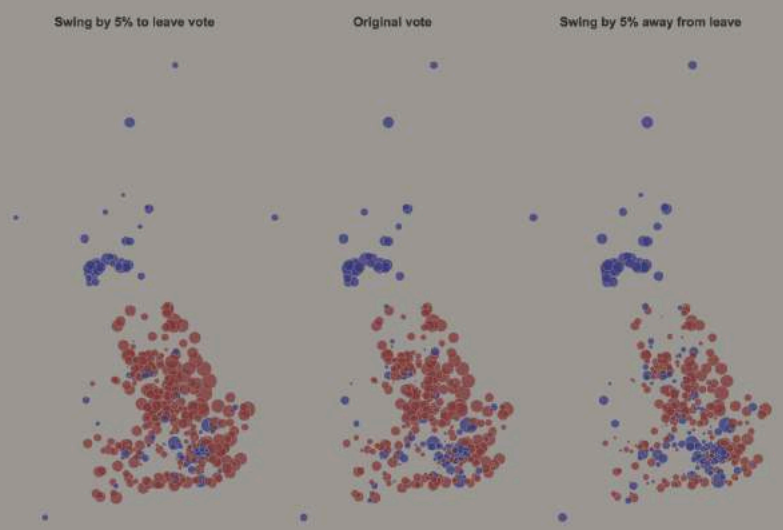

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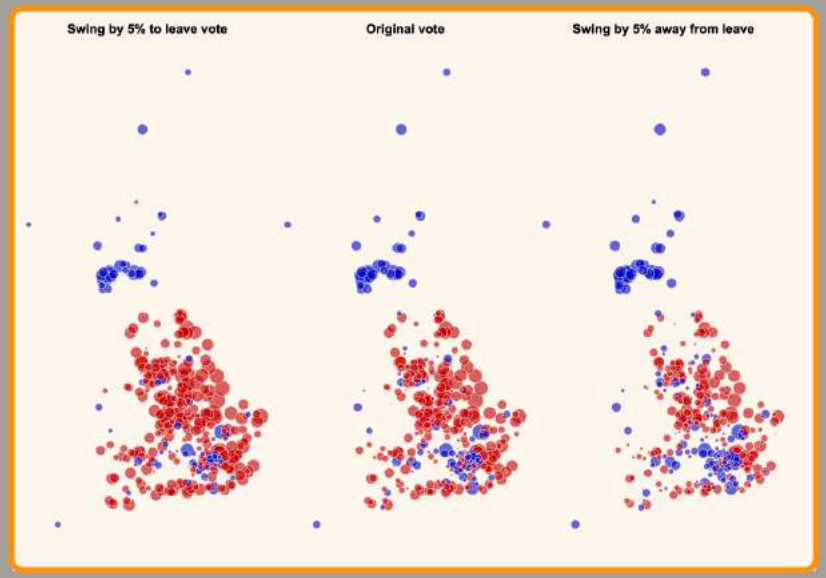

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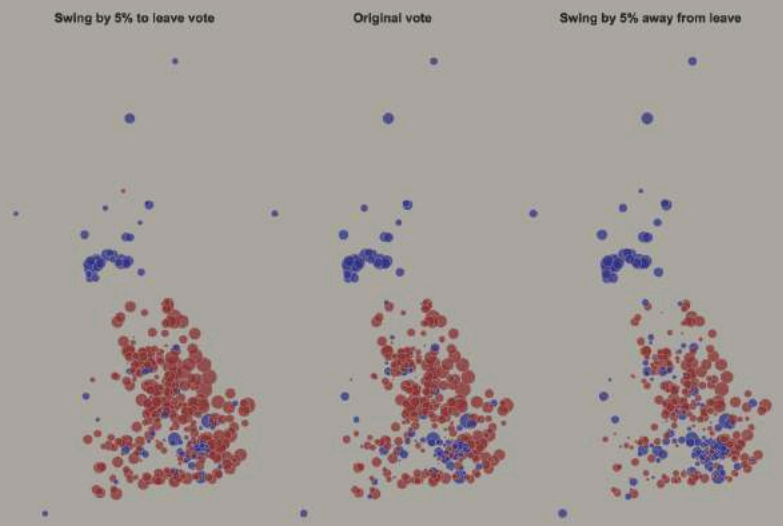

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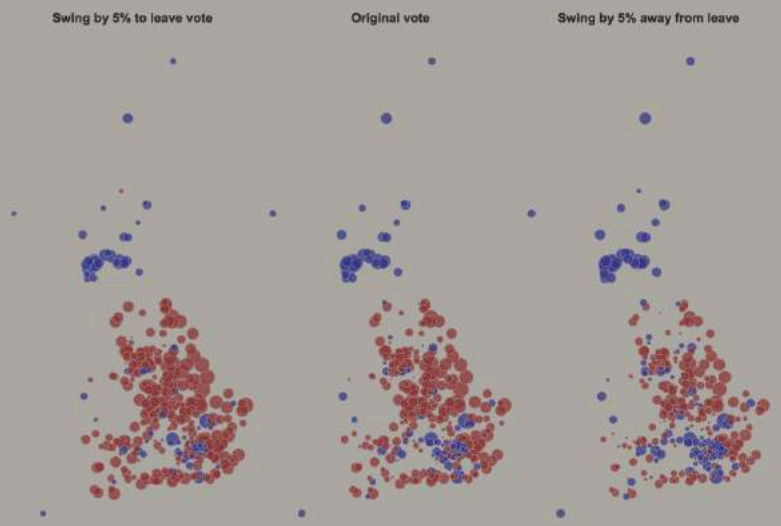

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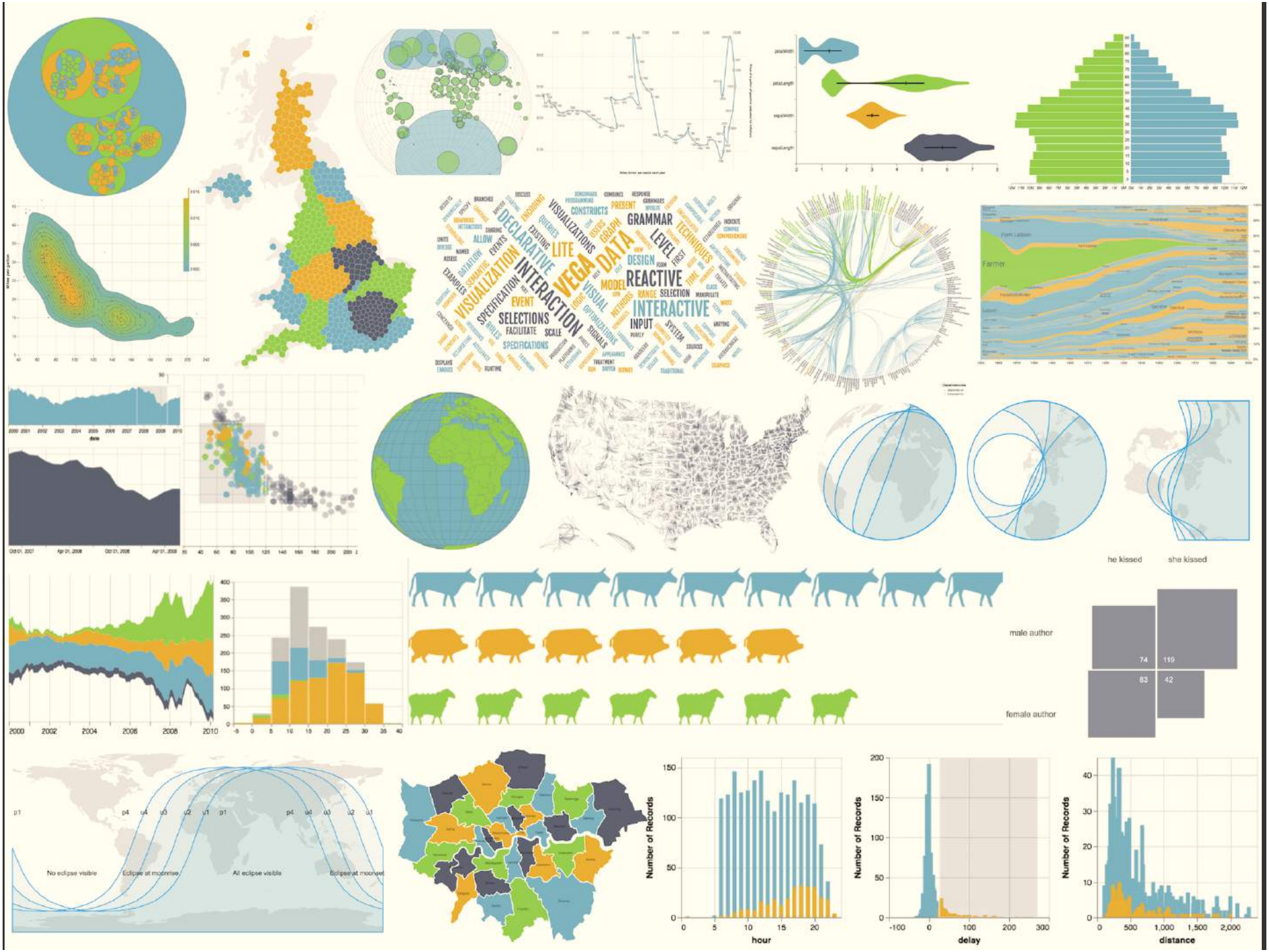
LF UTF-8 Markdown 0 files
```

litvis visualization specification

github.com/gicentre/elm-vegalite

github.com/gicentre/elm-vega

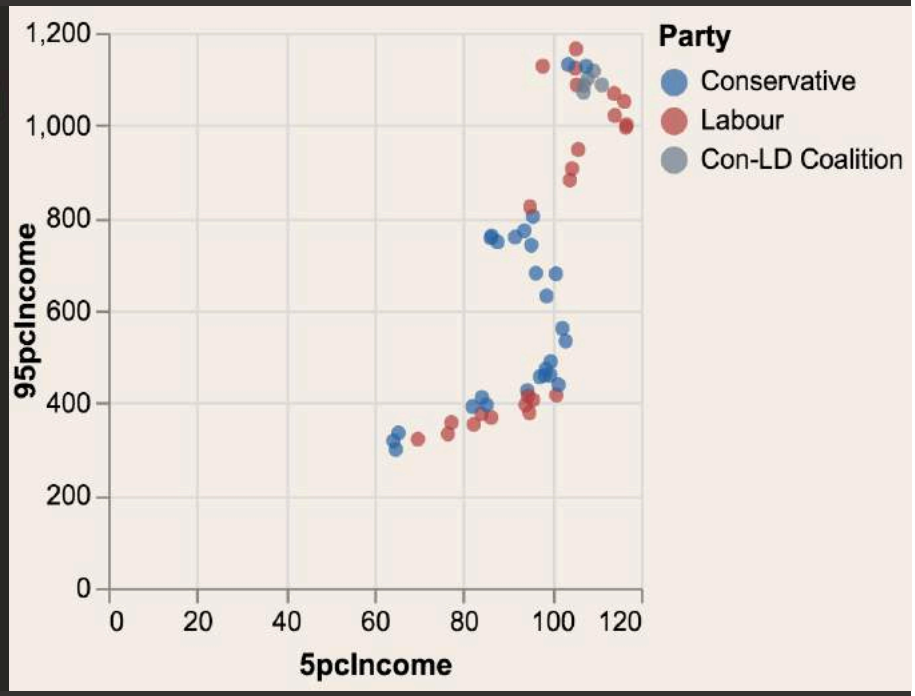

GRAMMAR
VISUALIZATIONS
DECLARATIVE
VISUALIZATION
INTERACTION
VEGA
DATA
REACTIVE
INTERACTIVE
SELECTIONS
SPECIFICATIONS
he kissed
she kissed
male author
female author
74
119
83
42
No eclipse visible
Eclipse at moonrise
All eclipse visible
Eclipse at moonset
Number of Records
hour
delay
distance

litvis visualization specification

```
let
    data =
        dataFromUrl "https://gicentre.github.io/data/incomeInequality.csv" []

    partyColours =
        categoricalDomainMap
            [ ( "Conservative", "#2863a5" )
            , ( "Labour", "#b43e3e" )
            , ( "Con-LD Coalition", "#6a7b8e" )
            ]

    enc =
        encoding
            << position X [ pName "5pcIncome", pMType Quantitative ]
            << position Y [ pName "95pcIncome", pMType Quantitative ]
            << color [ mName "Party", mMType Nominal, mScale partyColours ]
in
toVegaLite [ data, circle [], enc [] ]
```



Working in a literate visualization style

Experimenting

linecharts.md

Income Inequality: Line Charts

Household income of the richest 5 percent after housing costs and adjusted for inflation:

And the same for the poorest 5% (5th percentile):

Comparison between the two is quite hard, so perhaps it would be easier on the same chart:

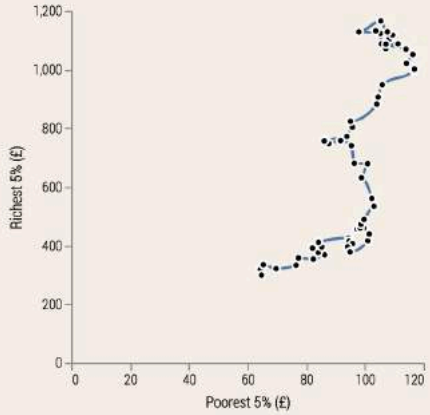
Noting that the income of the richest 5% is an order of magnitude greater than the poorest 5%, while we can now compare both sets of figures, it is difficult to see any significant variation in the 5% line (in red).
So perhaps it would be better to give each line its own scale on a dual-axis linechart:

But now it is more dificult to know which line refers to which percentile, and those artibrary crossing lines are rather distracting.

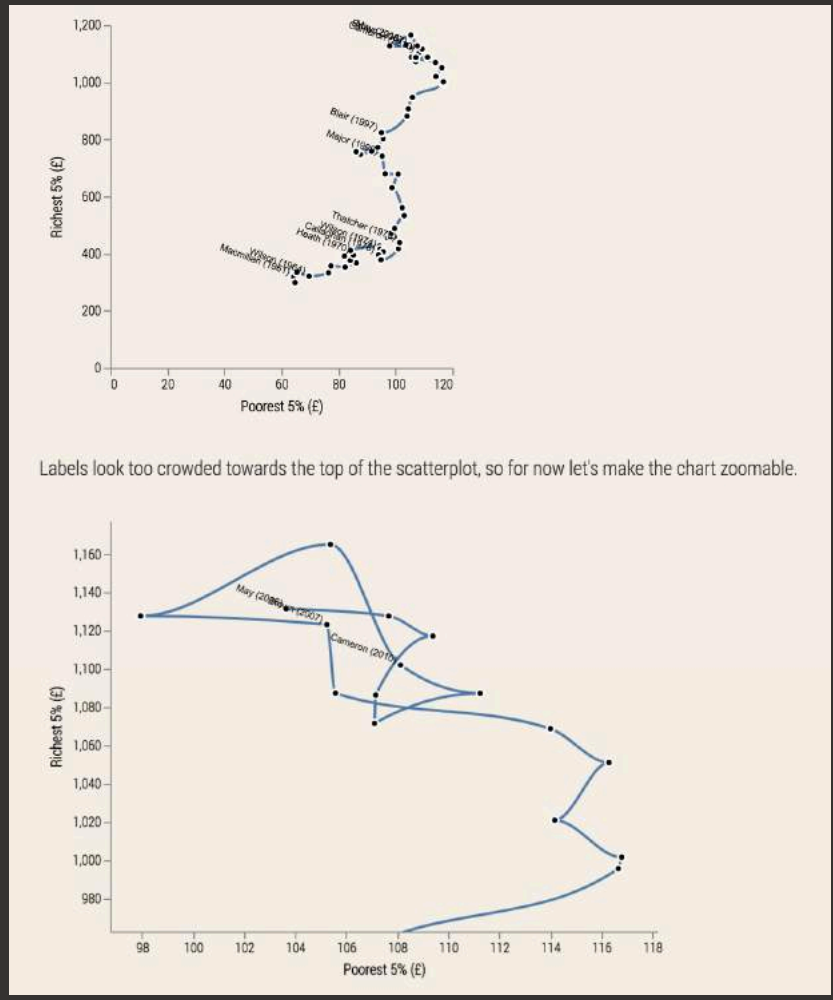
Scatterplots.md

Income Inequality : Connected Scatterplots

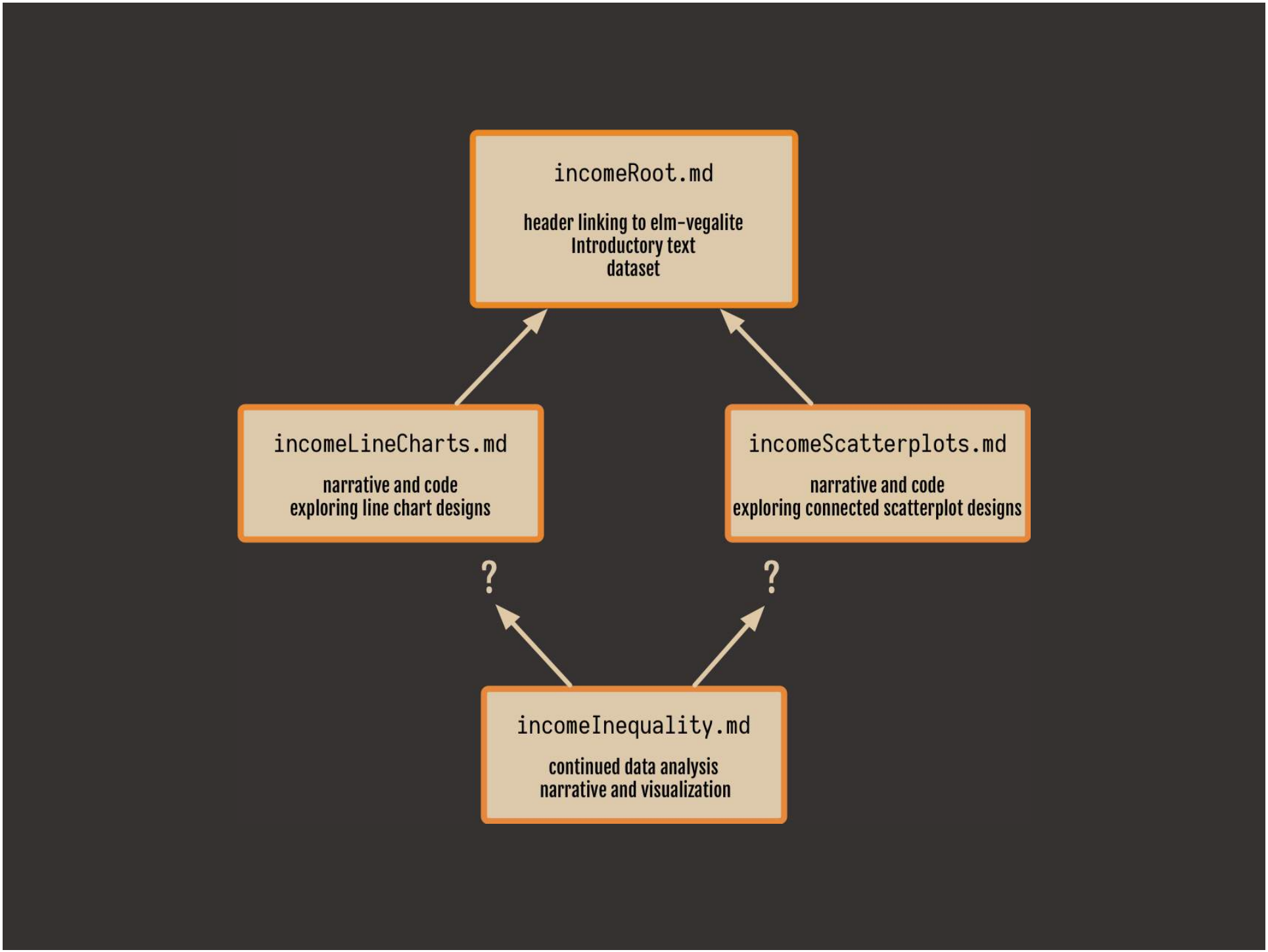
Rather than separate the 5% and 95% income quantiles, consider a connected scatterplot that joins the points in temporal order (1961 in bottom left, 2016 at top right):



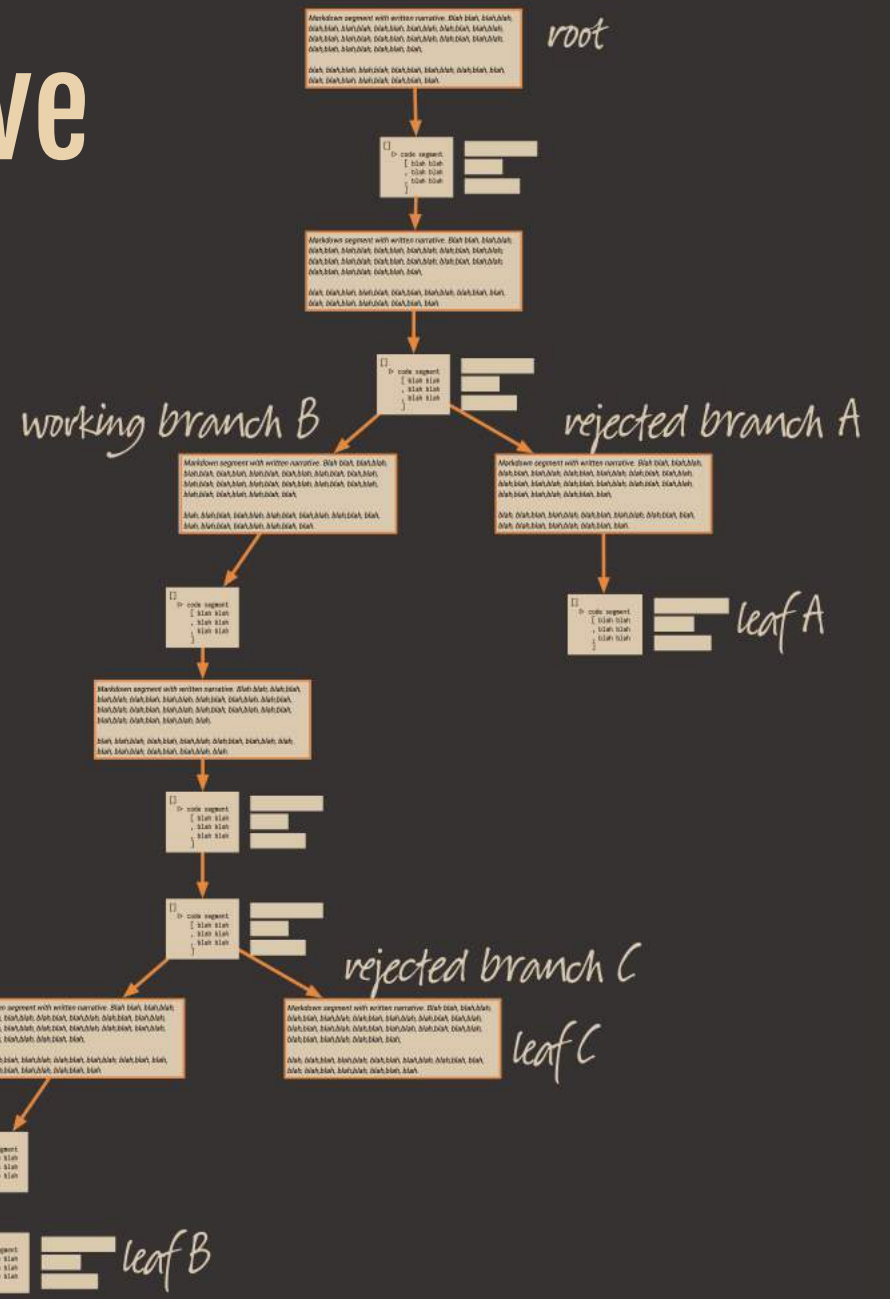
The plot still lacks important context (which dots refer to which years), so we can overlay some text labels indicating the year of every new Prime Minister:



Labels look too crowded towards the top of the scatterplot, so for now let's make the chart zoomable.


incomeRoot.md
header linking to elm-vegalite
Introductory text
dataset
incomeLineCharts.md
narrative and code
exploring line chart designs
incomeScatterplots.md
narrative and code
exploring connected scatterplot designs
?
?
incomeInequality.md
continued data analysis
narrative and visualization

Branching narrative



Working in a literate visualization style

Structuring Narrative

Guiding design exposition with

Narrative Schemas

Socratic questioning schema

```yaml
dependencies:
  - dialogue

labels:
  - name: question
    aliasFor: voiceA
  - name: answer
    aliasFor: voiceB

rules:
  - description: Question “What are you trying to achieve with this visualization?” should be before “Why have you chosen this data source and sample?”
    selector:
      label: voiceA
      trimmedContent: "What are you trying to achieve with this visualization?"
    before:
      selector:
        label: voiceA
        trimmedContent: "Why have you chosen this data source and sample?"

  - description: Question “Why have you chosen this data source and sample?” should be before “Why have you made these visual mark design choices?”
    selector:
      label: voiceA
      trimmedContent: "Why have you chosen this data source and sample?"
    before:
      selector:
        label: voiceA
        trimmedContent: "Why have you made these visual mark design choices?"
```

Socratic questioning schema

{(question|}

{(answer|}

{| question)}

{| answer)}

airPollutionDark.md

```
Why have you made these visual mark design choices?

-   Roadside emission data are very peaky during the day, so it makes sense to overly the NOx
levels for each 24 hour period to avoid having to spot patterns in rapidly oscillating signals.
-   There are many hundreds of profiles, so need to be symbolised with thin semi-transparent
lines that scale well when overlaid.
-   Need to distinguish clearly between the 'Ride London' Sundays and all others while affording
comparison, so using hue and line thickness to do this.
-   Can summarise the complexity of the many hundreds of Sunday readings with an average making
the 24 hour trend clearer.
-   To reduce visual clutter, only show grid lines at 4 hour intervals. This helps also to anchor
the day at midday.

```elm {v siding}
airPollution : Spec
airPollution =
    let
        data =
            dataFromUrl "https://gicentre.github.io/data/putneyAirQuality.csv"
                [ parse [ ( "dateTime", foDate "%Y-%m-%dT%H:%M" ) ] ]

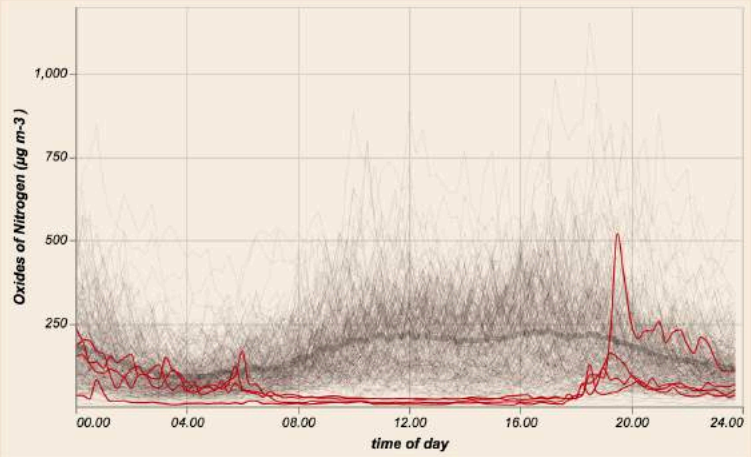
        backgroundTrans =
            transform
                << filter (fiExpr "datum.reading > 0")
                << calculateAs
                "datetime(year(datum.dateTime),month(datum.dateTime),date(datum.dateTime))" "day"
                << calculateAs "hours(datum.dateTime)+(minutes(datum.dateTime)/60)" "time of day"

        backgroundEnc =
            encoding
                << position X
                    [ pName "time of day"
```

airPollutionDark.md pr...

Why have you made these visual mark design choices?

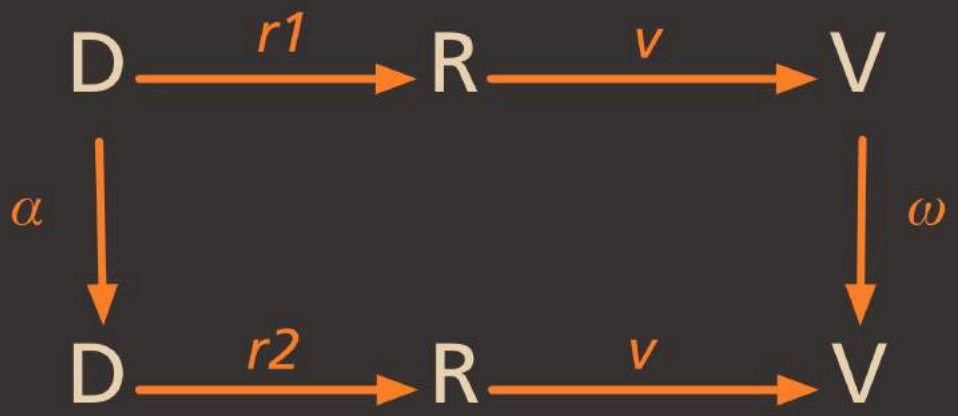
- *Roadside emission data are very peaky during the day, so it makes sense to overly the NOx levels for each 24 hour period to avoid having to spot patterns in rapidly oscillating signals.*
- *There are many hundreds of profiles, so need to be symbolised with thin semi-transparent lines that scale well when overlaid.*
- *Need to distinguish clearly between the 'Ride London' Sundays and all others while affording comparison, so using hue and line thickness to do this.*
- *Can summarise the complexity of the many hundreds of Sunday readings with an average making the 24 hour trend clearer.*
- *To reduce visual clutter, only show grid lines at 4 hour intervals. This helps also to anchor the day at midday.*



Iteration 3
```

Guidance with Narrative Schema

Algebra for design validity



Kindlmann & Scheidegger (2014) An Algebraic Process for Visualization Design, IEEE VIS

```
labels:
  - name: invariance
    paired:
      htmlTemplate: '<div class="invariance">
                     <div class="invarianceHeader">α = 1<sub>D</sub> ⇒ ω = 1<sub>V</sub>:
                          Confirm that non-meaningful changes in data representation,
                          such as table row order have no discernable effect on visualization.
                     </div>{{children}}</div>'

  - name: invarianceAssessment
    paired:
      htmlTemplate: <div class="invarianceAssessment">{{children}}</div>

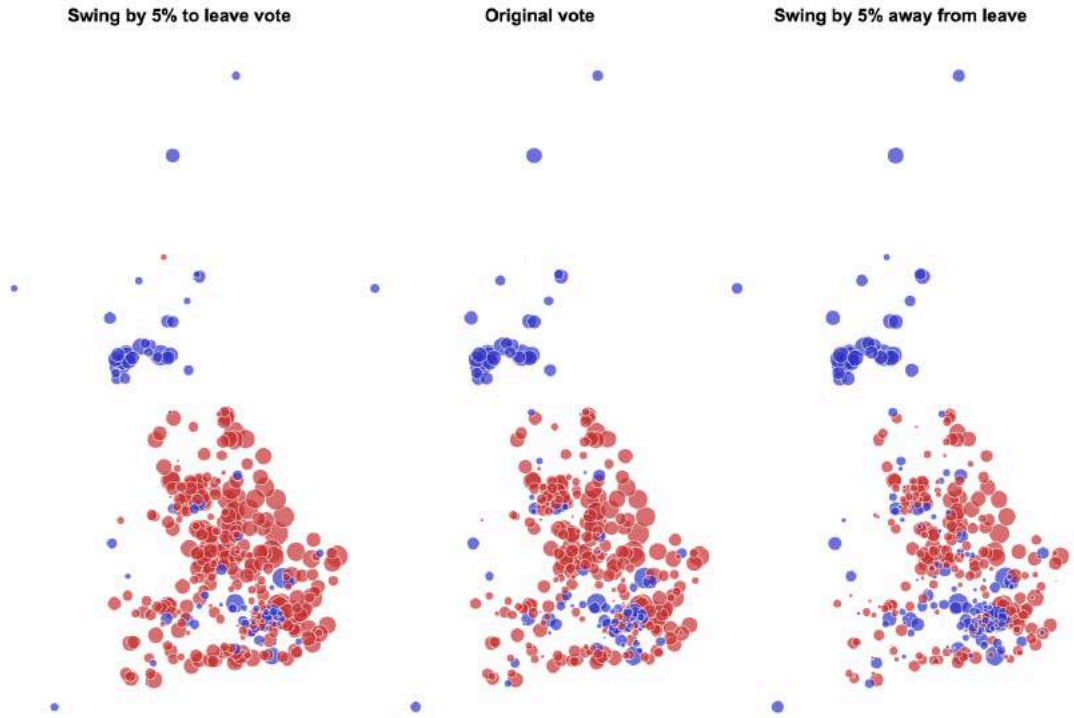
rules:
  - description: Kindlmann and Scheidegger's principle of data representation invariance.
    selector:
      label: invariance
    minimumOccurrences: 1

  - description: each description of possible invariance should be followed by an assessment of it.
    selector:
      label: invariance
    followedBy:
      selector:
        label: invarianceAssessment

  - description: assessment cannot be blank
    selector:
      label: invarianceAssessment
    children:
      minimumTrimmedTextLength: 1
```

Principle of Unambiguous Data Depiction

$\omega = 1_V \Rightarrow a = 1_D$: What are the smallest meaningful changes in data that should result in identifiable changes in the visualization?



Systematic shifts by 5% of votes cast towards leave or remain are easily detectable where they affect the majorty (shift between red and blue).
Systematic shifts that don't cross the 50% boundary are also detectable, although less obvious.
See for example size of blue circles in Scotland or red circles in Midlands/Northern England.
Therefore, no evidence for *confusers* in design.

- [x] passed?

Guidance with Narrative Schema

Feminist data visualization

D'Ignazio & Klein (2016) Feminist Data Visualization, Workshop on Visualization for the Digital Humanities

```
labels:
  - name: binProcess
    paired:
      htmlTemplate: <div class="binP"><div class="binPHeader"><b>Rethinking binaries</b>
          Do my data impose a categorisation that denies the multiplicity of the phenomena being visualized?<br />
          How do I register characteristics that do not easily fall into my classification?</div>{{children}}</div>

  - name: binOutput
    paired:
      htmlTemplate: <div class="binO"><div class="binOHeader"><b>Rethinking binaries</b>
          How do I communicate the limits of my categories in the final representation?
          How do I allow the user to refactor the categories presented for view?</div>{{children}}</div>

  - name: pluProcess
    paired:
      htmlTemplate: <div class="pluP"><div class="pluPHeader"><b>Embracing pluralism</b>
          Whose voices are not being represented in your design team but might be important in conceptualising the project?<br />
          Whose perspectives have been excluded from the data collection/categorization?</div>{{children}}</div>

  - name: pluOutput
    paired:
      htmlTemplate: <div class="pluO"><div class="pluOHeader"><b>Embracing pluralism</b>
          Can the visualization communicate the subject positions of the researchers and designers in a transparent way?<br />
          Whose view of the world does the visualization represent?<br />
          Can the visualization communicate whose voices are missing?</div>{{children}}</div>
```

Questions of Process

Rethinking binaries Do my data impose a categorisation that denies the multiplicity of the phenomena being visualized?
How do I register characteristics that do not easily fall into my classification?

Embracing pluralism Whose voices are not being represented i
Whose perspectives have been excluded from the data collecti

Examining power How is power distributed across your design
Whose voice matters more and why?
How can end users' voices be more fully integrated into the de

Considering context Can you use user-centred and participator
How do we let insights that follow shape our design practice?

Legitimising affect How can we use embodied and affective ex
Do we have sufficient expertise in our design team in order to

Exposing labour Can the team work backwards from the data t
Has the team discussed roles, responsibilities and credit in adv

Questions of Output

Rethinking binaries How do I communicate the limits of my categories in the final representation? How do I allow the user to refactor the categories presented for view?

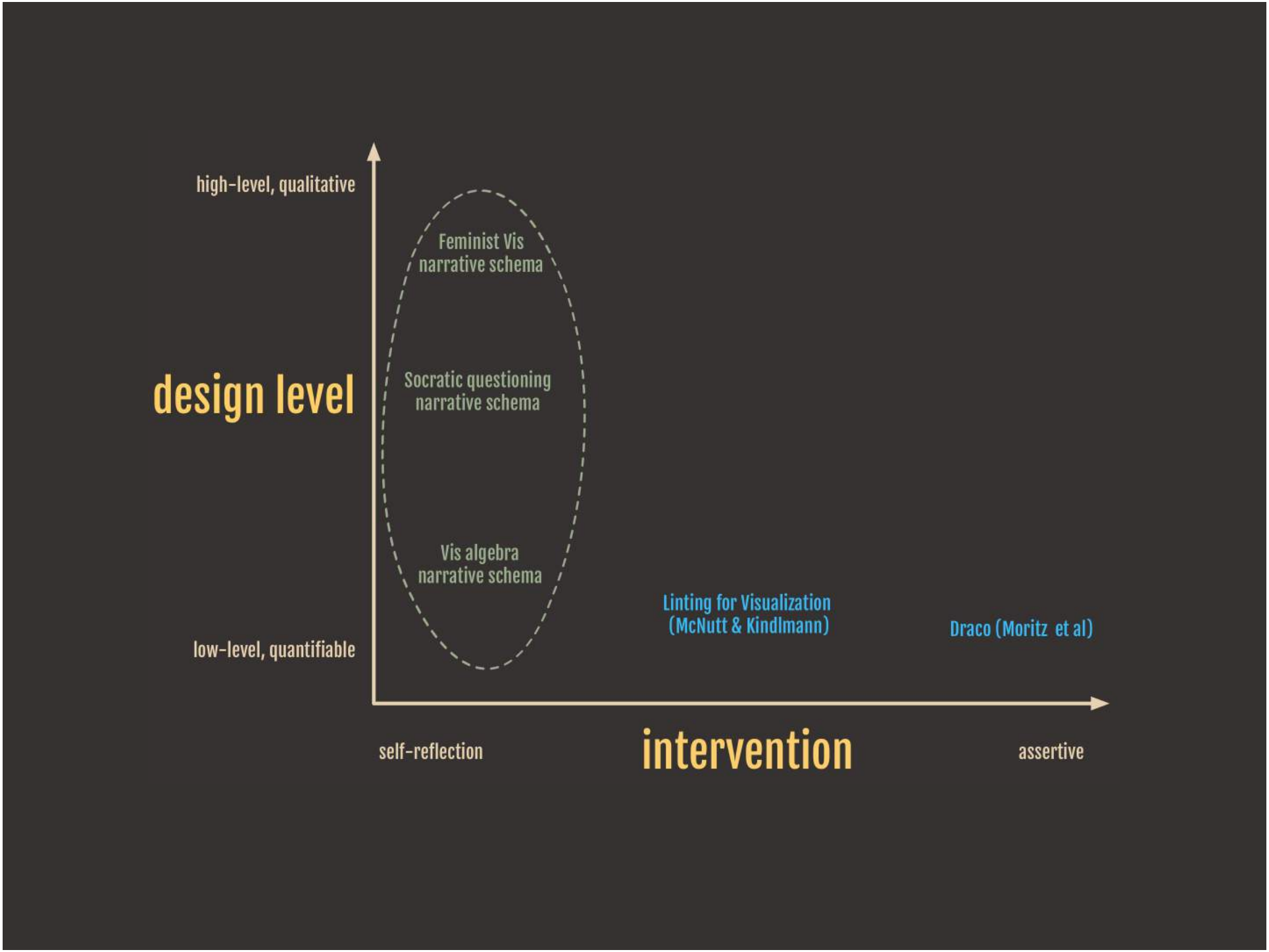
Embracing pluralism Can the visualization communicate the subject positions of the researchers and designers in a transparent way?
Whose view of the world does the visualization represent?
Can the visualization communicate whose voices are missing?

Examining power Can the visualization empower the end user and/or their community?
Can values assumed to be a social good, such as "choice" result in disempowerment?

Considering context What kinds of terminology, symbols and cultural artifacts have meaning to end users, and how can we incorporate those into our designs?
What might we learn if we were to visualize "messy" data?
How do we take context into account in the assessment of the visualization?

Legitimising affect What kinds of embodied and affective experience has meaning to end users?
Should we consider tactile, experiential or social ways of accessing the data visualization?

Exposing labour Is it feasible to provide a metadata visualization that shows the provenance of the data and their stakeholders (caregivers) at each step?
Have we properly attributed work on the project?


high-level, qualitative
design level
low-level, quantifiable
Feminist Vis
narrative schema
Socratic questioning
narrative schema
Vis algebra
narrative schema
Linting for Visualization
(McNutt & Kindlmann)
Draco (Moritz et al)
self-reflection
intervention
assertive

design exposition is beneficial as a reflective process and to allow others to learn from our work

literate visualization **eases** the integration of vis construction and reasoning about its **design**

branching narratives and narrative **schemas** supports this process by guiding and capturing design reflection.

litvis.org

Jo Wood, Alexander Kachkaev & Jason Dykes

 @jwoLondon @kachkaev @jsndyks