

Tuesday, July 25, 2023



*Ph.D. thesis defense*

# Tool Support for Knowledge Foraging, Structuring, & Transfer During Online Sensemaking

**Michael Xieyang Liu**

@lxieyang(@hci.social) / xieyangl@cs.cmu.edu

**CMU HCII**

Committee  
Brad A. Myers  
Aniket Kittur  
Kenneth Holstein  
Daniel M. Russell

# Sensemaking happens everyday...



Choosing a code library



Planning a vacation



Buying a stroller



Deciding treatment options

# Infinite amount of information available...

**Vue.js Is Good, But Is It Better Than Angular Or React?**

by Mantra Malhotra / May 19, 2021 / 16 Comments / 106302 Views

**SIMFORM** Simform → Blog → Web App Development →

## Best Frontend Frameworks of 2021 for Web Development

If you are looking for the best frontend frameworks in 2021, then this article will help you to choose the right one.

Hiren Dhadu January 5, 2021

### Quick Summary

the software development industry has been mainly arguing about which framework is better. React for their user interface, Angular for its security, and Vue.js for its performance.

### According to the stars of Vue.js

User experience is the most important factor in the market today. As we all know, Vue.js talks about the simplicity of the feature. No matter what you want to do, it's easy to do it with Vue.js. That is the principle behind the success of Vue.js. It's used on Netflix, Facebook, and many other big companies.

### React vs Angular vs Vue 2021: Which to Choose for Your Web App?

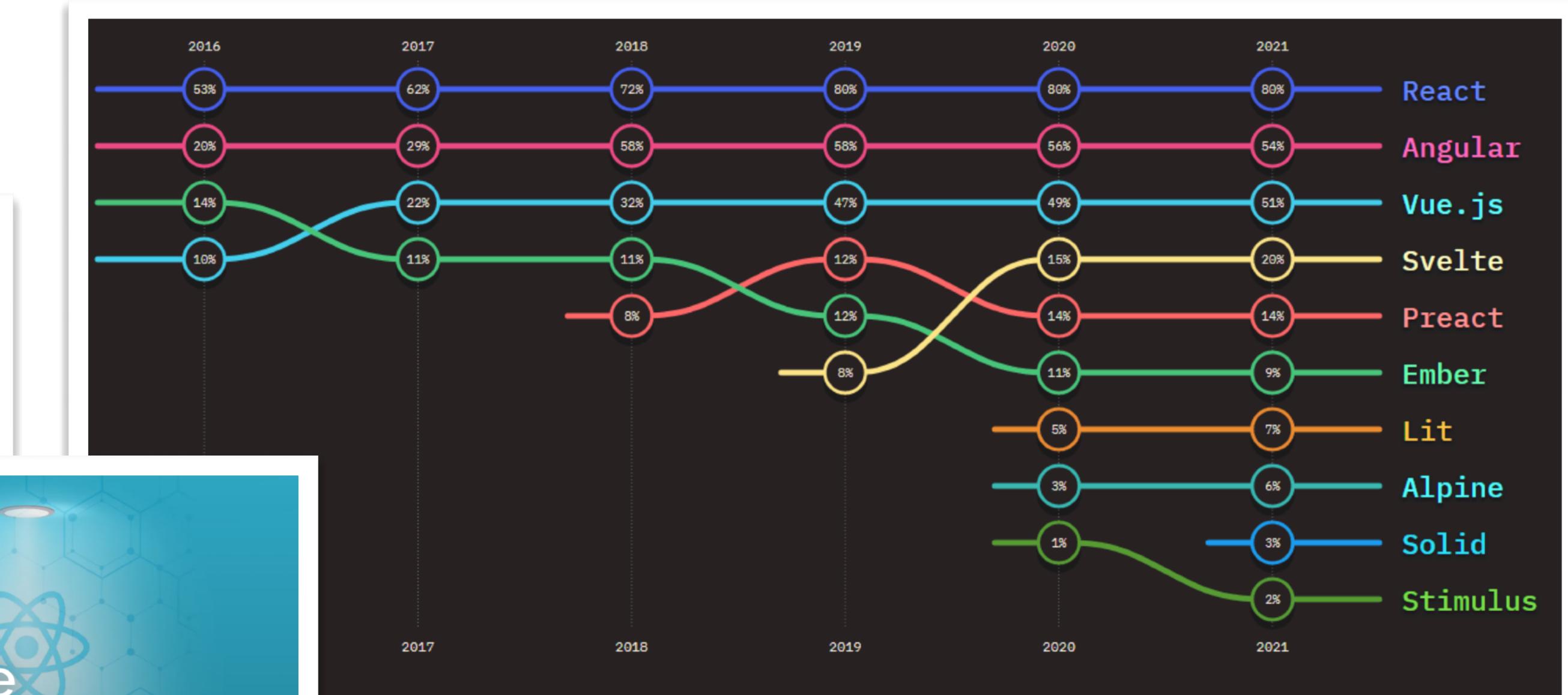
By Praveen Mishra May 6, 2021 □ 1

Reading Time: 8 minutes

Which JavaScript Framework/Library to choose for your business web app in 2021? In this React vs Angular vs Vue comparison, we will talk about the pros and cons of each and much more.

JavaScript, hands down, is the best language to choose for frontend development, and rightfully so! It provides a plethora of functionalities that let you create the UI of your web app exactly how you want.

Like everything, the world of JavaScript has evolved to make it easier to quickly create intuitive user interfaces. You can now choose from a long list of JS frameworks and UI Libraries for your business web app in 2021.



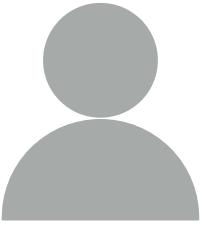
# Infinite amount of information available...

Our working memory **too limited** for the scattered evidence & tradeoffs.



Our working memory too limited for the scattered evidence & tradeoffs.

Need to **externalize our mental models** during sensemaking... into e.g., a structured table that **organizes all the evidence!**



	Fast?	Community	Documentation	Supported by
<b>React</b>	Yes	Really large	<a href="https://reactjs.org">https://reactjs.org</a>	Facebook
<b>Angular</b>	?	Also large	Not easy to understand <a href="https://angularjs.org/docs">https://angularjs.org/docs</a>	Google
<b>Vue</b>	Yes	?	Very detailed & intuitive <a href="https://vuejs.org/v2/guide">https://vuejs.org/v2/guide</a>	Alibaba

Actual table from formative study!

**Top Front-end Frameworks for 2022**

Let's take a closer look at the front-end frameworks dominating the landscape. We know who the big players are, but what about newcomers? Alpine, Lit, and Solid are all showing promising

## #1 – React

React makes it painless to create interactive UIs. Design simple views for each state in your application, and React will efficiently update and render just the right components when your data changes.

React continues to dominate the front-end space. The framework stands out with its own virtual DOM, ensuring persistent app performance at scale. Likewise, the component-based architecture means that development is more accessible across teams.

While the learning curve for React is moderately forgiving, the accessibility of tooling makes the process manageable. Namely, `create-react-app` automates the build process for an application boilerplate. And then there are [React DevTools](#), providing an accessible debugging experience from the browser.

Thanks to the mass adoption of React, front-end developers can enjoy getting their hands on

React.js Pros	React.js Cons
Easy to get started with thanks to troves of online tutorials, courses, etc.	Documentation can feel a bit lacking for beginners. E.g. JSX
Component structure makes it easy to define an element and then reuse it as needed.	Only used for UI development.
SEO-friendly for static and dynamic projects.	Not the best choice for small projects.
Version Control provides notices on outdated code structure.	Unopinionated – your call on deciding the structure and style guide.

### React Developer Tools

Use React Developer Tools to inspect React components, edit props and state, and identify performance problems.

You will learn

Elements Performance Components Profiler

Search (text or /re)

App List ListItem key="1" ListItem key="2" ListItem key="3"

props item: {id: 2, isComplete: t... removeItem: f () {} toggleItem: f () {} new entry: ...}

hooks Callback(handleDelete): f () {} Callback(handleToggle): f () {}

rendered by List App react-dom@16.14.0

Safari and other browsers

For other browsers (for example, Safari), install the `react-devtools` npm package:

**Vue.js Is Good, But Is It Better Than Angular Or React?**

by Mantra Ma

**Best Frontend Frameworks of 2021 for Web Development**

If you are looking for the best frontend frameworks, this software comparison will help you choose what to use based on user reviews and popularity.

**According to stars of Vue.js**

A few years ago, the main argument for React was that it was the best framework for building large-scale web applications. Now, the software market has shifted, and many people are talking about the benefits of Vue.js. Vue.js is a popular framework that has gained a lot of traction in recent years. It is known for its simplicity and ease of use, making it a great choice for both beginners and experienced developers.

**React vs Angular vs Vue 2021: Which to Choose for Your Web App?**

By Praveen Mishra | May 6, 2021

Reading Time: 8 minutes

With the rise of the JavaScript framework market, it's hard to decide which one to use for your next web application. In this React vs Angular vs Vue comparison, we will talk about the pros and cons of each and much more.

JavaSript, hands down, is the best language to choose for frontend development, and rightly so! It provides a plethora of functionalities that let you create the UI of your web app exactly how you want.

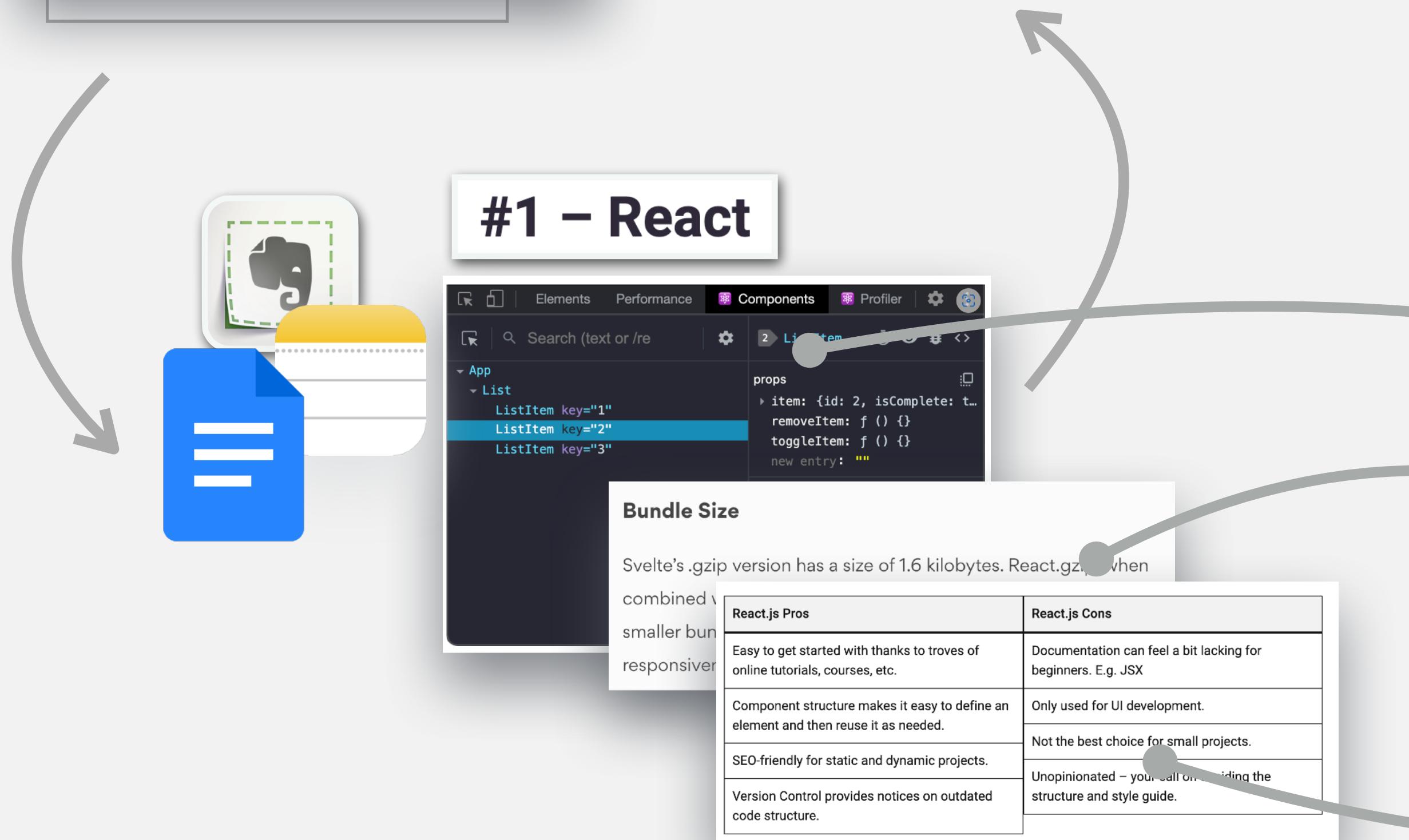
Like everything else, the world of JavaScript has evolved to make it easier to quickly create intuitive user interfaces. You can now choose from a long list of JS frameworks and UI libraries for your business web app in 2021.

In this article, I will be talking about 2 JS frameworks and 1 JS library.

Technologies surveyed: React, Angular, Vue.js, Preact, Svelte, Ember, Alpine, Solid, Stimulus.

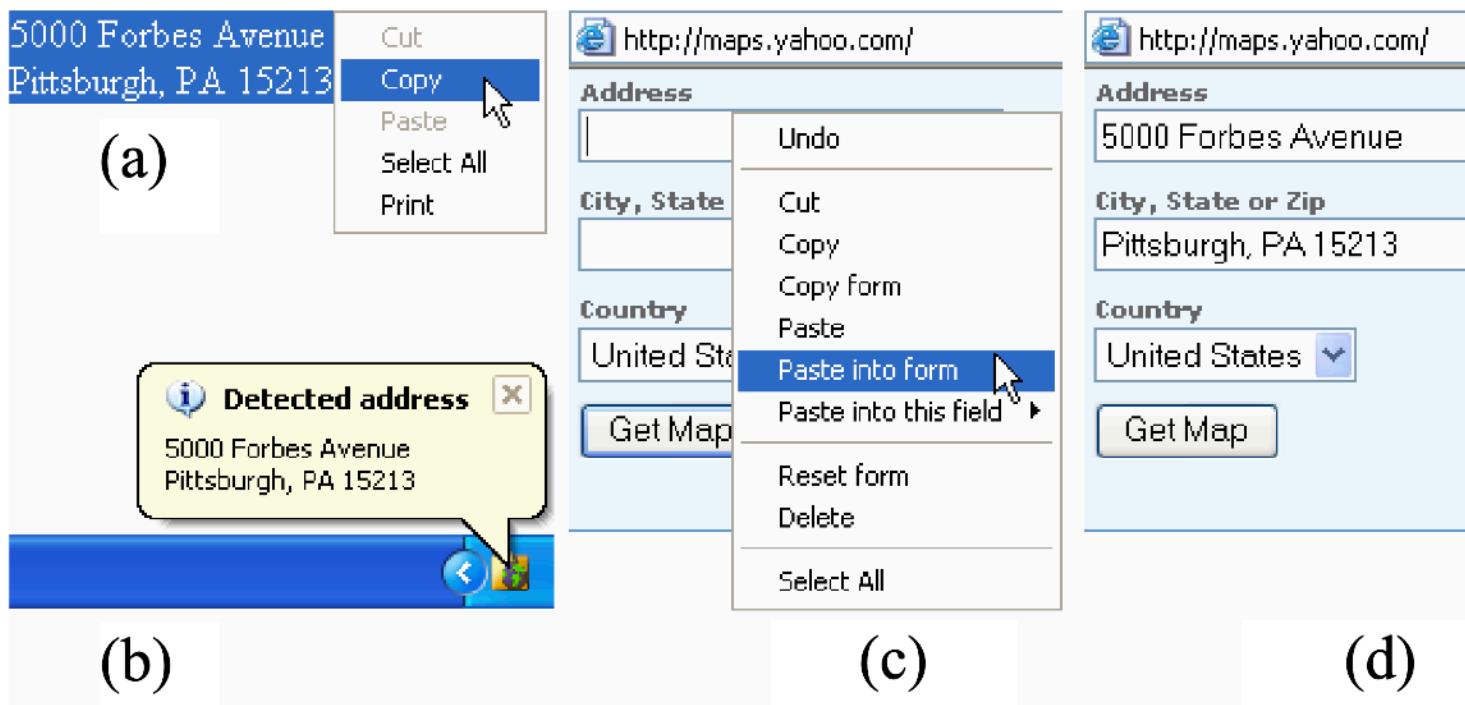
Technology	I've USED it before, and would use it again	I've HEARD of it, and would like to learn it	I've NEVER heard of it
Vue.js	40.0%	21.0%	38.0%
Angular	35.0%	23.0%	42.0%
Preact	22.0%	37.0%	41.0%
Svelte	14.0%	44.0%	42.0%
Ember	8.0%	31.0%	61.0%
Alpine	4.0%	22.0%	74.0%
Solid	2.0%	14.0%	84.0%

# Organizing is hard!

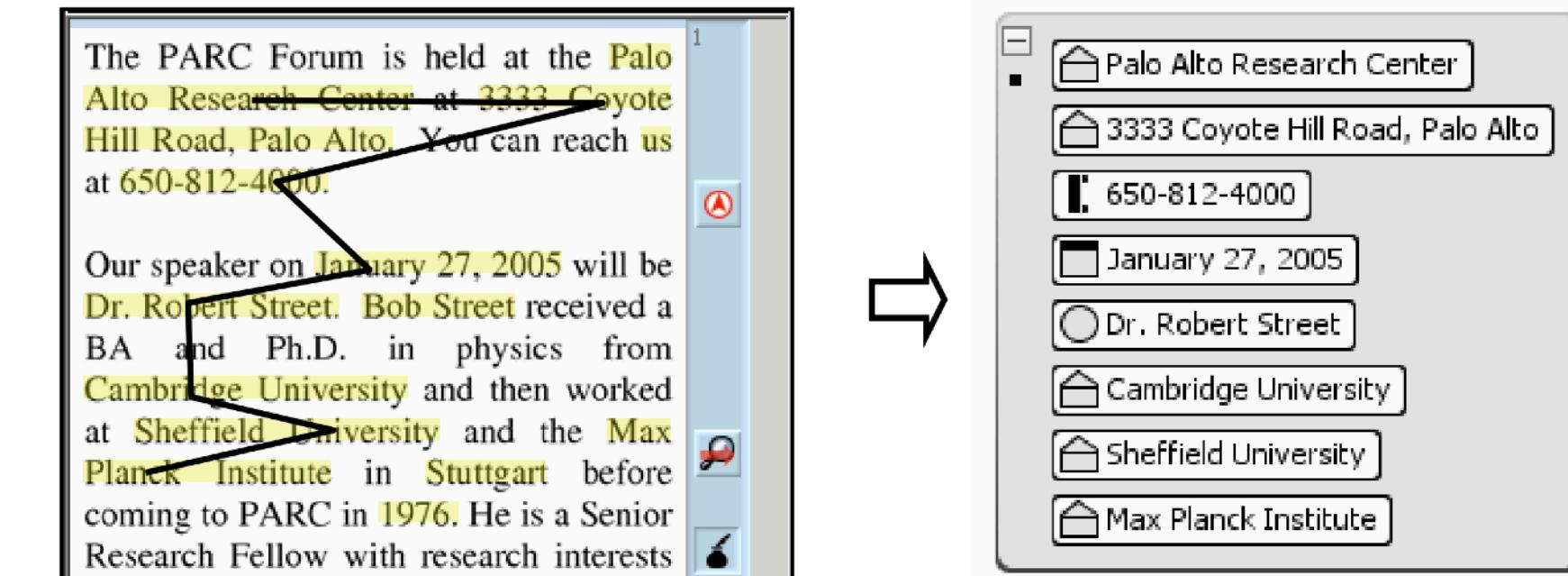


	Fast:	Community	Documentation	Supported by
<b>React</b>	Yes	Really large	<a href="https://reactjs.org">https://reactjs.org</a>	Facebook
<b>Angular</b>	?	Also large	Not easy to understand <a href="https://angularjs.org/docs">https://angularjs.org/docs</a>	Google
<b>Vue</b>	Yes	?	Very detailed & intuitive <a href="https://vuejs.org/v2/guide">https://vuejs.org/v2/guide</a>	Alibaba

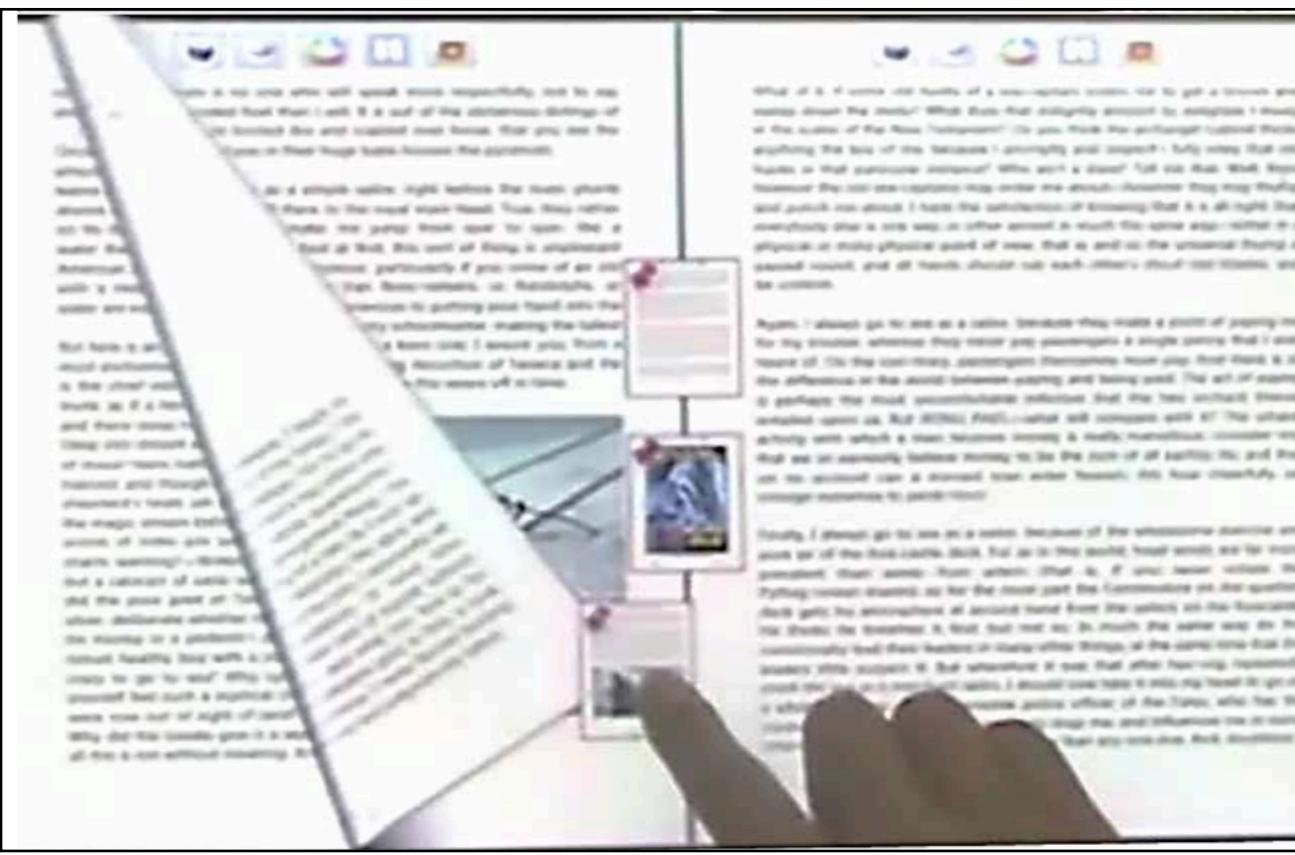
# Prior research – saving information



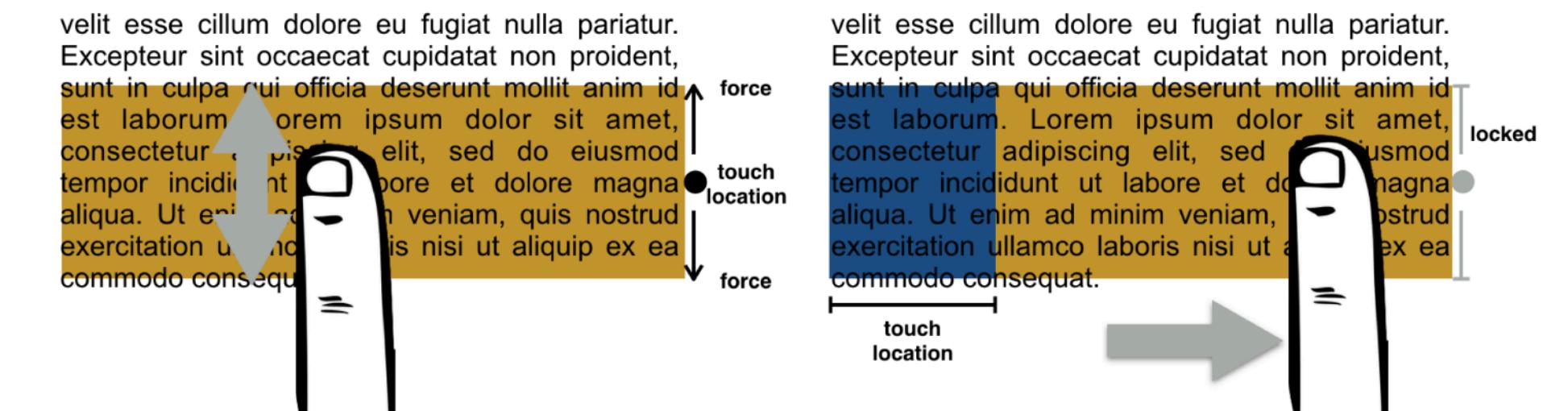
Citrine: providing intelligent copy-and-paste  
Stylos et al. (UIST 2004)



Entity quick click: rapid text copying based on automatic entity extraction  
Bier et al. (CHI 2006)



GatherReader: gathering information while active reading  
Hinckley et al. (CHI 2012)

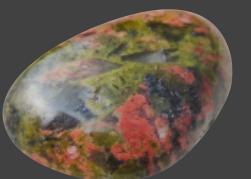


Supporting Mobile Sensemaking Through Intentionally Uncertain Highlighting Changes al. (UIST 2016)

# Externalizing is challenging...

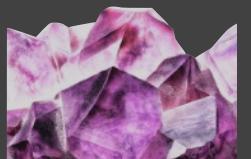
Too much cost & interruptions

Lack tool support



Unakite (UIST 2019)

Honorable Mention (top-6)



Crystalline (CHI 2022)



Wigglite (UIST 2022)

Minimize cognitive & physical cost,  
through **lightweight interactions**



	Intuitiveness	Popularity	Used by
React	👍	👍	Facebook
Angular	👍	👍	Google
Vue	👍	👎	Alibaba
EmberJS	👍	👎	Heroku

# Externalizing is challenging...

Too much cost & interruptions

Lack of tool support

I build and study **human-centered**  
**interactive tools** that facilitate &  
accelerate sensemaking.

Minimize cognitive & physical cost,  
through **lightweight interactions**



	Intuitiveness	Popularity	Used by
React	👍	👍	Facebook
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# Externalizing is challenging...

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## Externalizing



**Unakite** (UIST 2019)  
🥇 Honorable Mention (top-6)

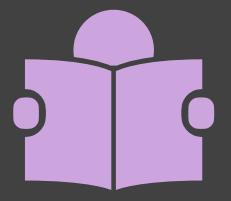


**Crystalline** (CHI 2022)



**Wigglite** (UIST 2022)

Minimize cognitive & physical cost,  
through **lightweight interactions**



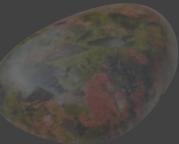
## Reading



Selenite (2023)



## Externalizing



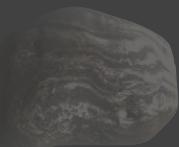
Unakite (UIST 2019)



Honorable Mention (top-6)



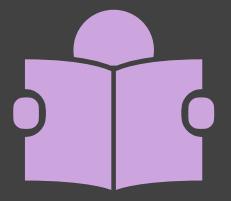
Crystalline (CHI 2022)



Wigglite (UIST 2022)

*Lack global perspective of key points  
Difficulty in selective reading*

Minimize cognitive & physical cost,  
through **lightweight interactions**



## Reading



Selenite (2023)



## Externalizing



Unakite (UIST 2019)



Honorable Mention (top-6)



Crystalline (CHI 2022)



Wigglite (UIST 2022)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

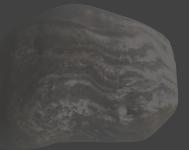
Minimize cognitive & physical cost,  
through **lightweight interactions**



## Reusing



**Strata** (CSCW 2021)  
🏆 Best paper (top 1%)



**Wigglite** (UIST 2022)



**Crystalline** (CHI 2022)



**Unakite** (UIST 2019)  
🏅 Honorable Mention (top-6)

## Externalizing

## Reading



**Selenite** (2023)

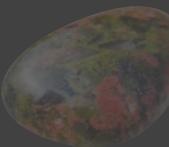
Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**

*Lost access to original decision context  
Unable to judge trustworthiness*



Selenite (2023)



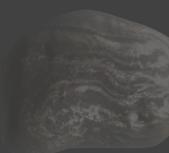
Unakite (UIST 2019)



Honorable Mention (top-6)



Crystalline (CHI 2022)



Wigglite (UIST 2022)



Strata (CSCW 2021)

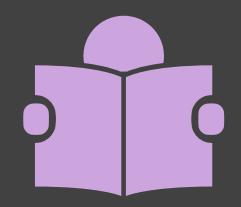


Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**

Guide knowledge reuse evaluations,  
with **systematic framework + tools**



## Reading



Selenite (2023)



## Externalizing



Unakite (UIST 2019)  
🥇 Honorable Mention (top-6)



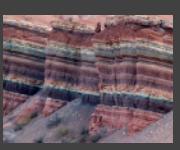
Crystalline (CHI 2022)



Wigglite (UIST 2022)



## Reusing

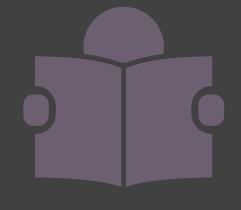


Strata (CSCW 2021)  
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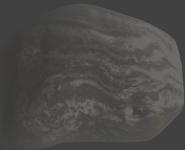
## Reusing



**Strata** (CSCW 2021)

🏆 Best paper (top 1%)

## Externalizing



**Wigglite** (UIST 2022)



**Crystalline** (CHI 2022)



**Unakite** (UIST 2019)

🥇 Honorable Mention (top-6)



**Selenite** (2023)

Minimize cognitive & physical cost,  
through **lightweight interactions**

Unakite: Scaffolding Developers' Decision-Making Using the Web

*Michael Xieyang Liu, Jane Hsieh, Nathan Hahn, Angelina Zhou, Emily Deng, Shaun Burley, Cynthia Taylor, Aniket Kittur, Brad A. Myers*

UIST 2019

*Users **n**eeds **a**ccelerators for **k**nowledge for **i**mplementations in **t**echnology **e**nvironments*

# Trade-offs



# Unakite



A chrome extension that helps developer  
**collect** and **organize** information while  
searching and browsing



# Design Goals (based on formative studies + prior work)

**[D1] Scaffolding:** *helping developers form systematic models when approaching decision making problems with tradeoffs.*

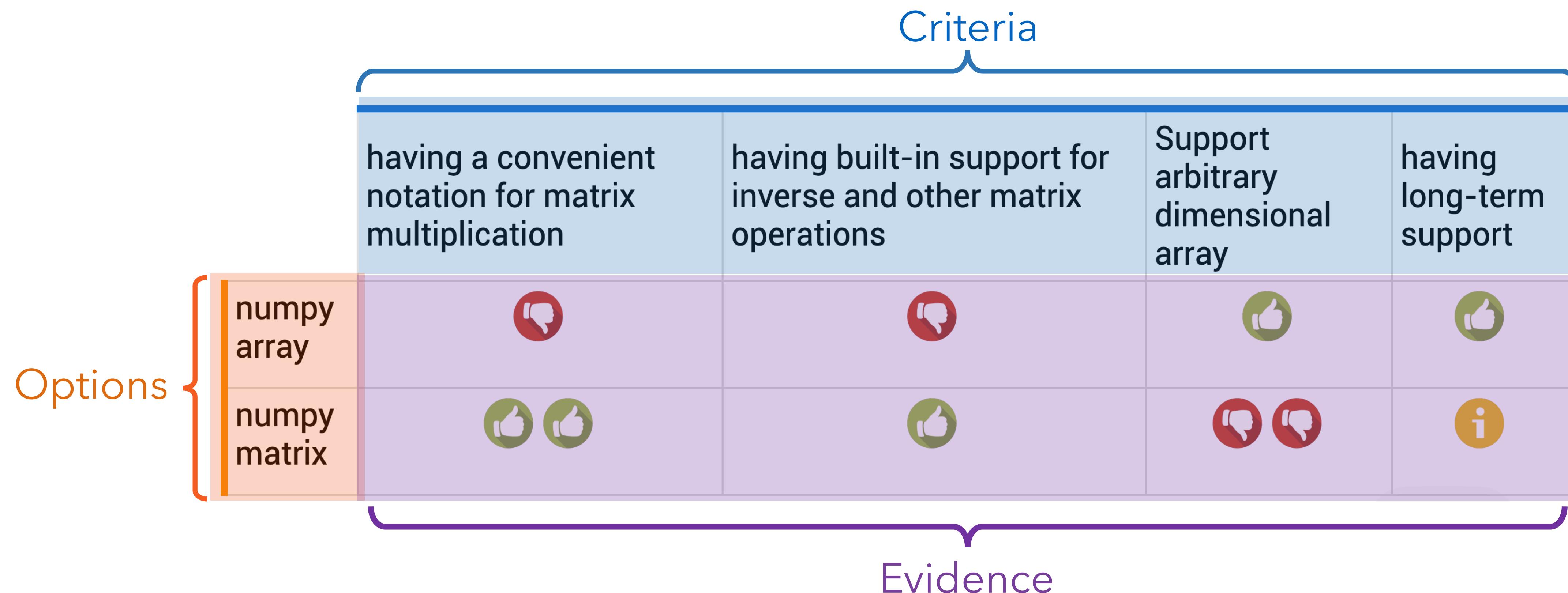
**[D2] Lightweight interactions:** *reducing the cost of collecting and organizing content so that the entry barriers to use the tool are low.*

**[D3] Summarization:** *helping developers synthesize and summarize different pieces of content together and manage them.*

**[D4] Contextualization:** *enabling developers to recreate the context from which information snippets were collected and copied.*

# [D1] Scaffolding: Option-Criterion-Evidence framework

Helping developers form **systematic models** when approaching decision making problems with **tradeoffs**.



# [D2] Lightweight interactions

Reducing the cost of collecting and organizing content so that **the entry barriers to use the tool are low**

The screenshot shows the Unakite v2.3.0 application interface. At the top, there's a search bar with the text "how to represent matrices in python" and a user profile for Michael. Below the search bar is a table titled "Table (Created 0...)" with three columns: "convenient notation for matrix multiplication", "have long term support", and "support N-dimensions". The table compares three items: "Numpy matrices", "python list", and "numpy ndarrays". "Numpy matrices" is highlighted with an orange border. The "Criteria" column contains icons: a green thumbs up for multiplication, a red thumbs down for long-term support, and a red thumbs down with an info icon for N-dimensions. The "Snippets" column contains icons: a green thumbs up for Numpy matrices and a green thumbs up for numpy ndarrays. At the bottom, there are tabs for "Uncategorized", "Options", "Criteria", "Snippets" (which is selected), "All", and "Trashed". Below the tabs, there are two snippets: "no!!!" and "Matrix objects are a subclass of ndarray, so they inherit all...". The "no!!!" snippet was created a month ago. The "Matrix objects are a subclass of ndarray..." snippet is from stackoverflow.com and was also created a month ago.

Comparison table

Snippet repository

# [D3] Summarization

Helping developers **synthesize** and **summarize** different pieces of content together and manage them.

	having a convenient notation for matrix multiplication	having built-in support for inverse and other matrix operations	Support arbitrary dimensional array	having long-term support
numpy array			 	
numpy matrix	  I can basically do a*b		 	

Uncategorized Options Criteria Snippets All Trashed

Python 3.5 NumPy supports infix (@) operator for matrix multiplication

stackoverflow.com 7 months ago

I tried the infix operator and it worked like a charm!

matrix will be deprecated in the future

docs.scipy.org 7 months ago

I thought numpy matrix can't do high dimensional vector manipulations

Created 7 months ago

## Comparison table:

*high-level summary of the decision-making space*

## Ratings:

*Summary of developer utilization of collected evidence*

## Concrete evidence:

*Detailed text snippet of corresponding evidence*

# [D4] Contextualization

enabling developers to **recreate the context** from which information snippets were collected and copied.

**Ease-of-recognize:** Snippets use original HTML with styling.

**Ease-of-back-tracking:** They involve metadata (e.g., information source & track time)

The main advantage of numpy matrices is that they provide a convenient notation for

 stackoverflow.com an hour ago

Showing HTML snapshot

The main advantage of numpy matrices is that they provide a convenient notation for matrix multiplication: if a and b are matrices, then  $a*b$  is their matrix product.

```
import numpy as np  
  
a=np.mat('4 3; 2 1')  
b=np.mat('1 2; 3 4')  
print(a)  
# [[4 3]  
# [2 1]]  
print(b)  
# [[1 2]  
# [3 4]]  
print(a*b)  
# [[13 20]  
# [ 5  8]]
```

Add a comment



# Study 1: Unakite for **authoring**

**Task:** Collect information from Stack Overflow pages and organize them into comparison tables.

**Condition & measurement:** **Overhead cost** – % of the time spent on directly using tool features

Unakite: selecting (snapshot), drag & drop, etc.

vs. Google Doc: copy-pasting, formatting, maintaining table, etc

**Between-subject:** 20 participants, each completed 3 tasks in the same condition  
(2 pre-defined, 1 self-proposed)

Unakite (**25%**) v.s. Google Doc (**44%**) ( $p < 0.01$ )

Unakite reduces the **overhead** of context switch and copy pasting!

# Study 2: Unakite for understanding trade-offs

**Task:** Explain code decisions made by a previous developer.

**Within-subject:** 16 participants, each completed one task in each condition

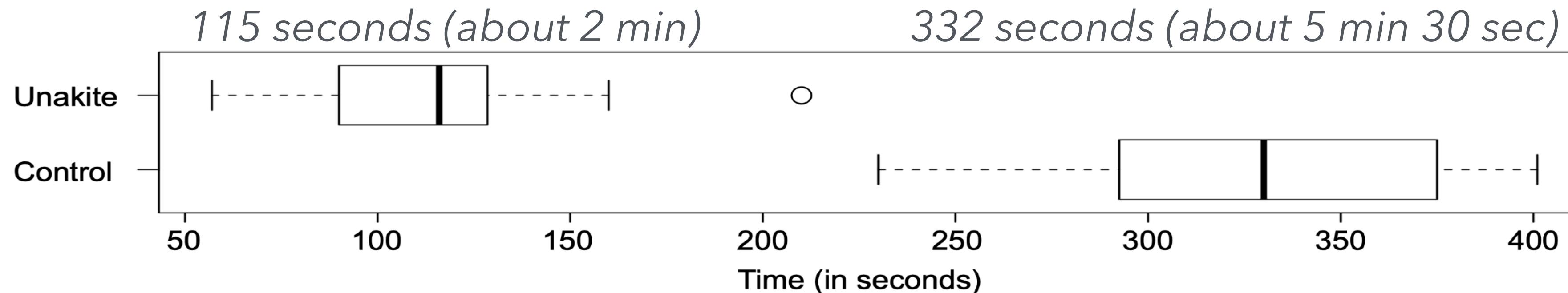
The screenshot shows a web-based application window titled "how to represent matrices in python". On the left, there's a sidebar with a list of snippets and a note about numpy matrices. The main area displays a table with two rows. The first row has three columns: "support N-dimensions", "convenient notation for matrix multiplication", and "have lots of methods". The second row has three columns: "numpy ndarrays", "Numpy matrices", and another "Numpy matrices" entry. Each row has a green thumbs-up icon and a blue thumbs-down icon. A note at the bottom states: "The main advantage of numpy matrices is that they provide a convenient notation for matrix multiplication: if a and b are matrices, then a\*b is their matrix product."

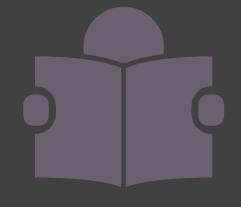
Unakite condition:  
explore pre-made comparison table

The screenshot shows a web browser window with multiple tabs open. The tabs include "python", "SciPy.org", "Stackoverflow", and "NumPy". The content area displays text from SciPy.org and StackOverflow. The text from SciPy.org states: "Numpy matrices are strictly 2-dimensional, while numpy arrays (ndarrays) are N-dimensional. Matrix objects are a subclass of ndarray, so they inherit all the attributes and methods of ndarrays." The text from StackOverflow states: "The main advantage of numpy matrices is that they provide a convenient notation for matrix multiplication: if a and b are matrices, then a\*b is their matrix product."

Control condition:  
read the same set of web resources

Synthesized table in  
Unakite speeds up  
understanding  
decisions!





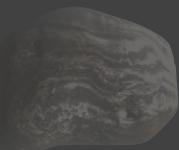
## Reusing



**Strata** (CSCW 2021)

🏆 Best paper (top 1%)

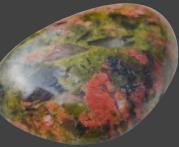
## Externalizing



**Wigglite** (UIST 2022)



**Crystalline** (CHI 2022)



**Unakite** (UIST 2019)



Honorable Mention (top-6)



**Selenite** (2023)

Minimize cognitive & physical cost,  
through **lightweight interactions**

Unakite: Scaffolding Developers' Decision-Making Using the Web

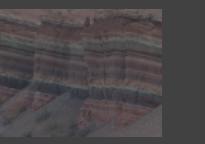
*Michael Xieyang Liu, Jane Hsieh, Nathan Hahn, Angelina Zhou, Emily Deng, Shaun Burley, Cynthia Taylor, Aniket Kittur, Brad A. Myers*

UIST 2019

*Users **n**eeds **a**ccelerators for **k**nowledge for **i**mplementations in **t**echnology **e**nvironments*



## Reusing



**Strata** (CSCW 2021)



*Best paper (top 1%)*



## Externalizing



**Crystalline** (CHI 2022)



**Wigglite** (UIST 2022)



## Reading



**Selenite** (2023)

Minimize cognitive & physical cost,  
through **lightweight interactions**

Can we **automate** everything?

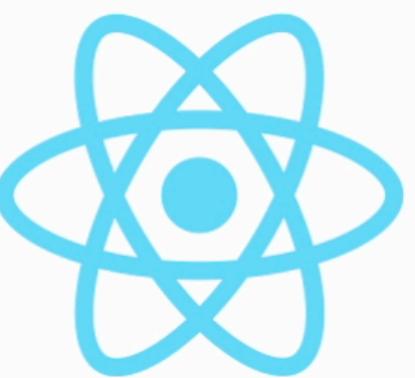
& what do we automate?

# Implicit behaviors while browsing...



[Vue](#), also known as Vue.js, is the youngest member of the group. It was developed by ex-Google employee Evan You in 2014. Over the last several years, Vue has seen a substantial shift in popularity, even though it doesn't have the backing of a large company. The most current version is always announced on the official Vue website on their [releases page](#). Contributors for Vue are [supported by Patreon](#). It should be noted that Vue also has its own [GitHub repo](#), and [functions using TypeScript](#).

Further reading: [Vue.js Tutorial for Beginner Developers](#)



[React](#), developed by Facebook, was initially released in 2013. Facebook uses React extensively in their products (Facebook, Instagram, and WhatsApp). Similar to Vue, the React developers also announce their newest version on the blog section of the React website.

Here's a short summary of Angular vs React vs Vue, in terms of their status and history:

The history of Angular vs React vs Vue

	Angular	React	Vue
Initial release	2010	2013	2014
Official site	<a href="https://angular.io">angular.io</a>	<a href="https://reactjs.org">reactjs.org</a>	<a href="https://vuejs.org">vuejs.org</a>
Current version	13.x	17.x	3.x

# Implicit behaviors while browsing...

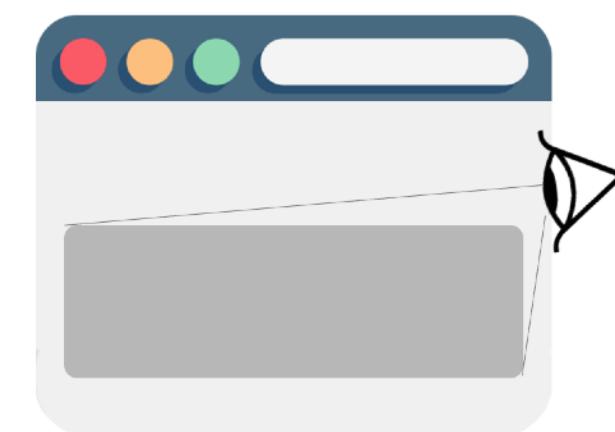


[Vue](#), also known as Vue.js, is the youngest member of the group. It was developed by ex-Google employee Evan You in 2014. Over

Here's a short summary of Angular vs React vs Vue, in terms of their status and history:

The history of Angular vs React vs Vue

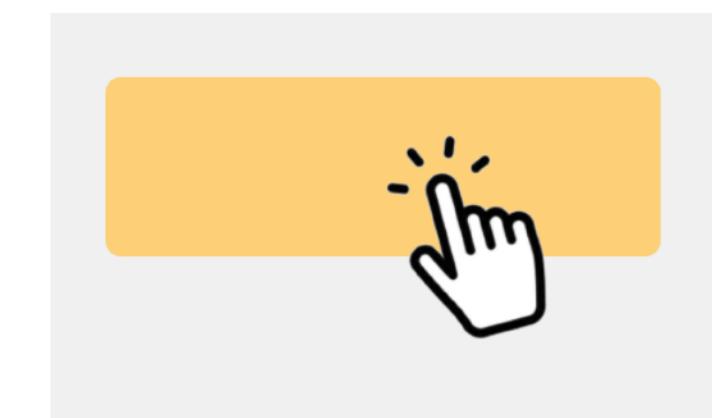
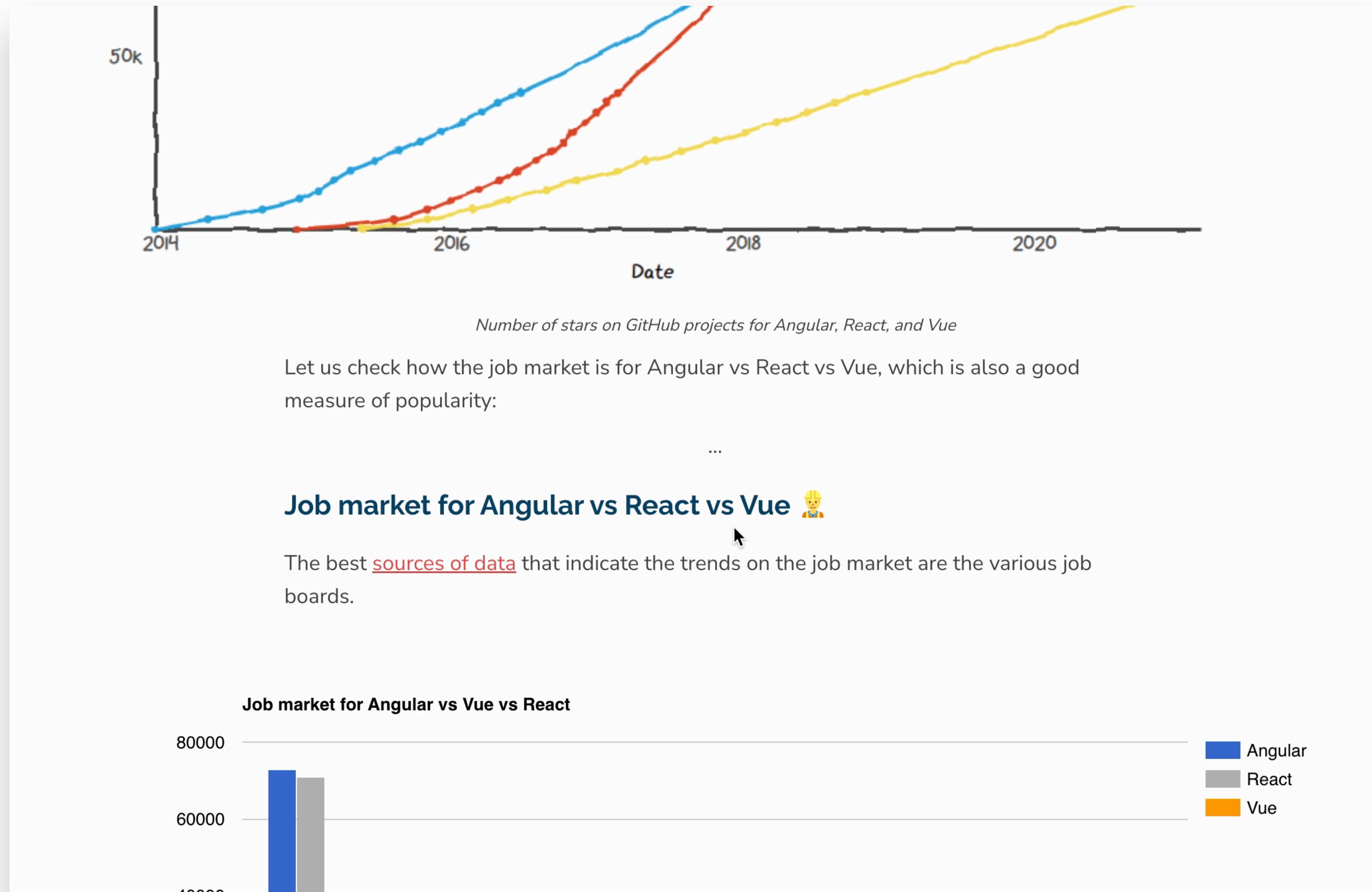
	Angular	React	Vue
Initial release	2010	2013	2014
Official site	<a href="https://angular.io">angular.io</a>	<a href="https://reactjs.org">reactjs.org</a>	<a href="https://vuejs.org">vuejs.org</a>
Current version	13.x	17.x	3.x
Used by	Google, Wix	Facebook, Uber	Alibaba, GitLab



Content dwelling

Our existing behavior signals can already **reflect our attentions**.

# Implicit behaviors while browsing...



Clicking

# Implicit behaviors while browsing...

# Stars	78.4k	180k	218k
# Forks	20.6k	36.5k	35.7k
# Contributors	1,500+	1,500+	400+

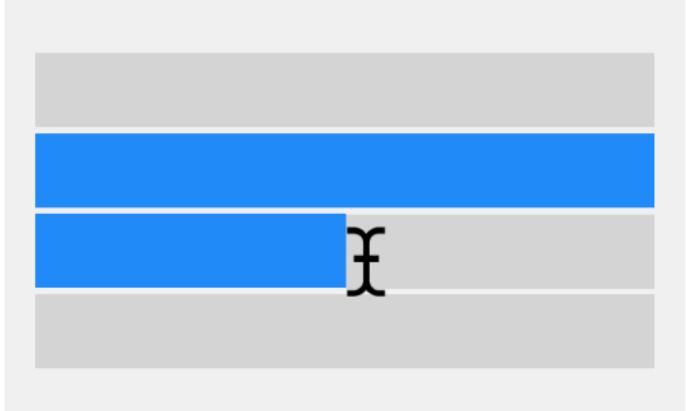
When comparing Vue vs React, Vue has a huge number of watchers, stars, and forks. This shows Vue's popularity among users and its value compared to React. However, the number of contributors for Vue are lower than Angular and React.

One possible explanation is that **Vue is driven entirely by the open source community, whereas Angular and React have a significant share of Google and Facebook employees contributing to the repositories.**

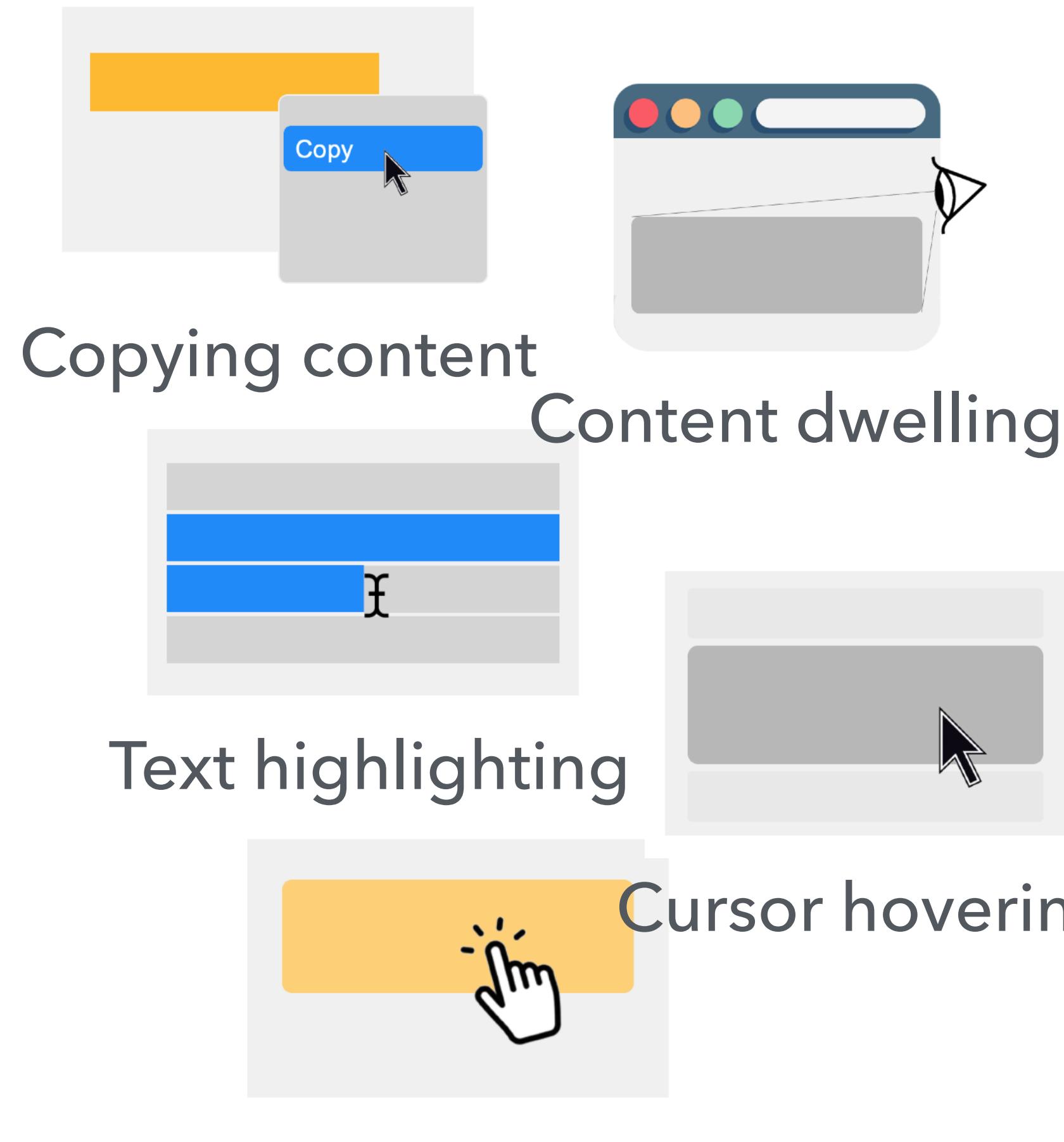
From the statistics, all three projects show significant development activity, and this is surely going to continue in the future — just these statistics cannot be the basis of not deciding to use either of them.

An additional metric that you'll want to consider is GitHub's ["Used By" badge](#), which needs to be enabled by the repository author. This shows how many other repositories on GitHub are dependent on that repository. Angular's GitHub repo shows 1.7 million, React currently shows almost 5.7 million users, while Vue shows over 167,000 for both of its repos combined. Quite a difference among the three frameworks, but this is largely due to Vue being the newer framework and doesn't tell the full picture on overall demand.

## Part 3: Migrations



## Text highlighting

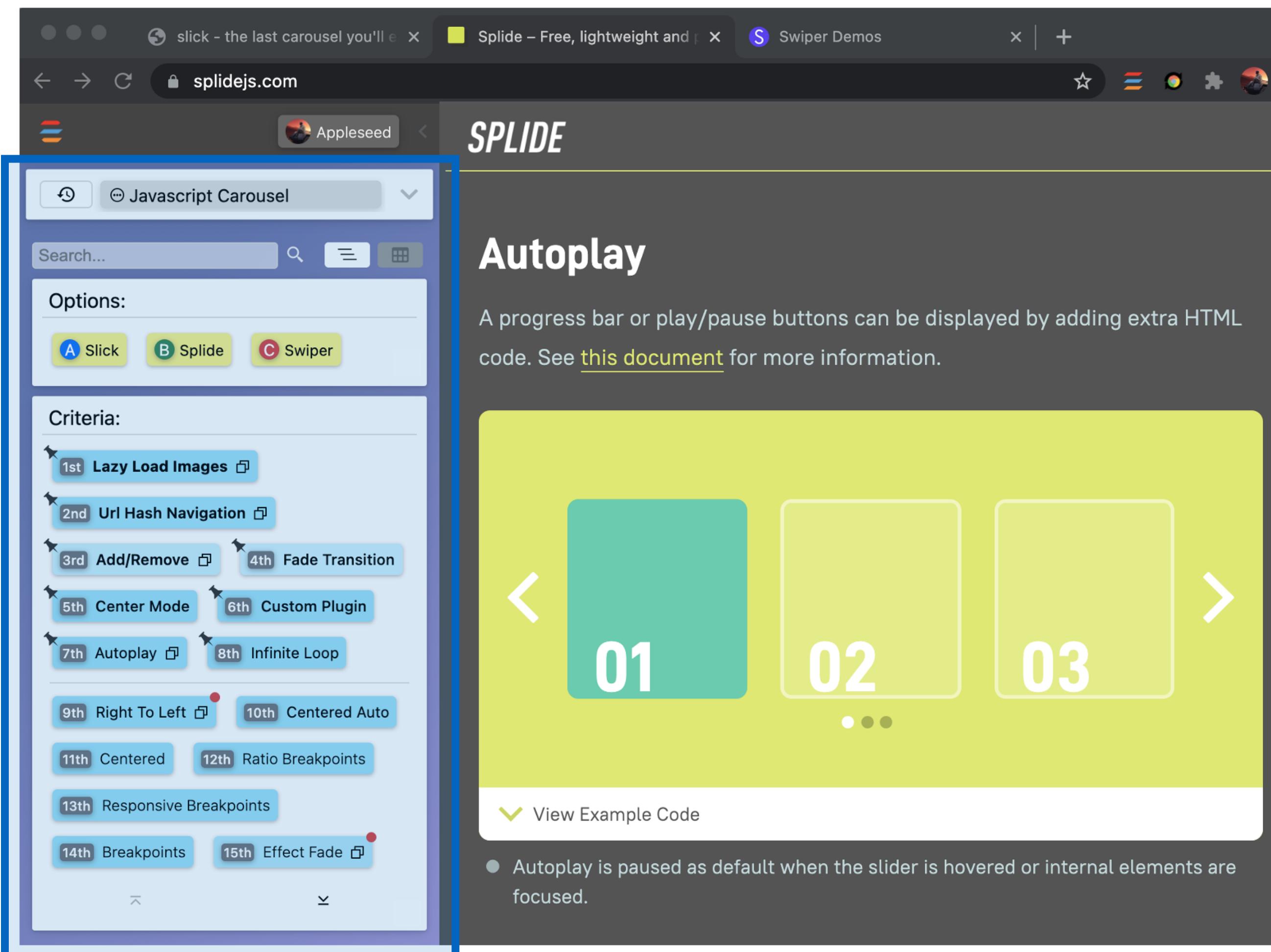


**Spontaneous** interactions contain **signals** relevant to mental model construction.

Crystalline: Lowering the Cost for Developers to Collect and Organize Information for Decision Making

*Michael Xieyang Liu, Aniket Kittur, Brad A. Myers*  
CHI 2022

*Clipping resulting in your structure as tables and lists linked to implicit notetaking easily*



As a browser extension sidebar!

**Spontaneous** interactions contain **signals** relevant to mental model construction.

**Crystalline: Lowering the Cost for Developers to Collect and Organize Information for Decision Making**

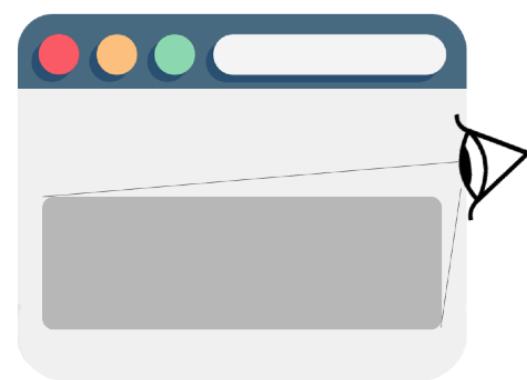
Michael Xieyang Liu, Aniket Kittur, Brad A. Myers

CHI 2022

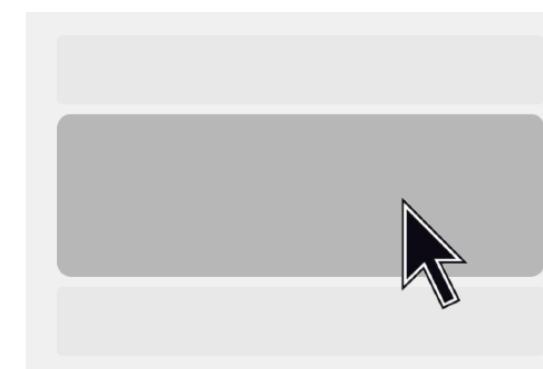
Clipping resulting in your structure as tables and lists linked to implicit notetaking easily

# Automation by tracking implicit behavior signals

**Capture** implicit interaction relevant to mental model building.



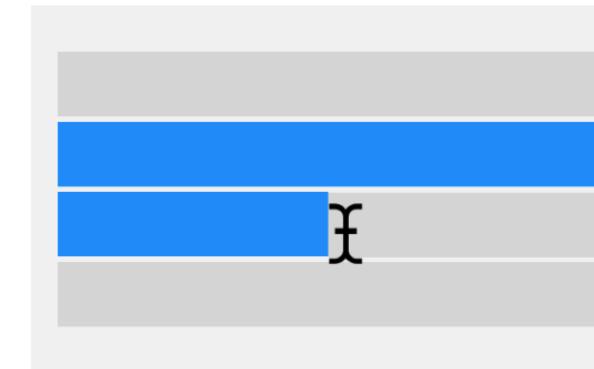
Content dwell



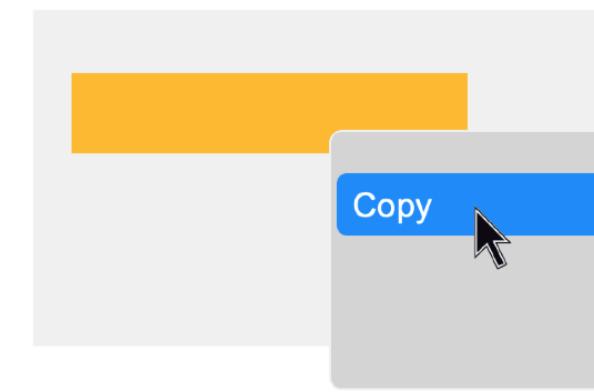
Cursor hover



Click



Text highlight



Copy content

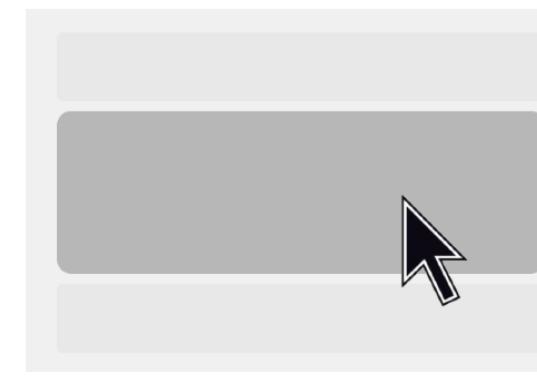
But not all behavioral signals are equally informative.

# Automation by tracking implicit behavior signals

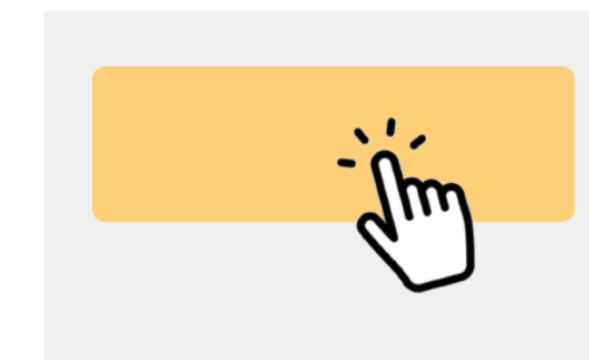
**Capture** implicit interaction that **might be** relevant to mental model building.



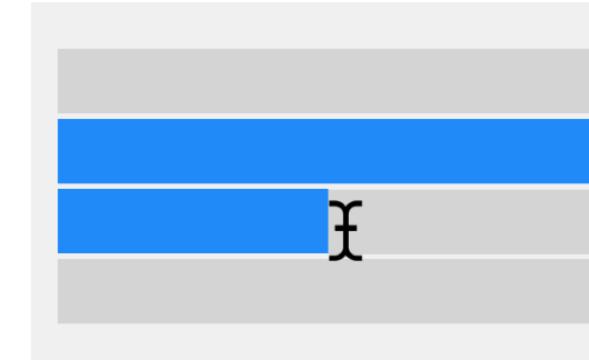
Content dwell



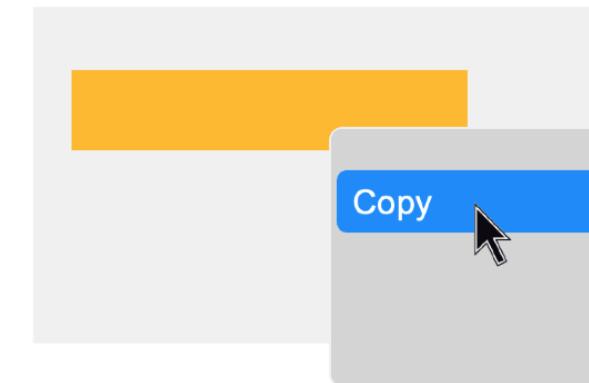
Cursor hover



Click



Text highlight



Copy content

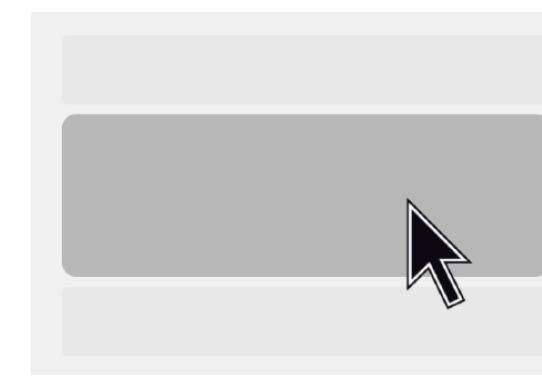
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# Automation by tracking implicit behavior signals

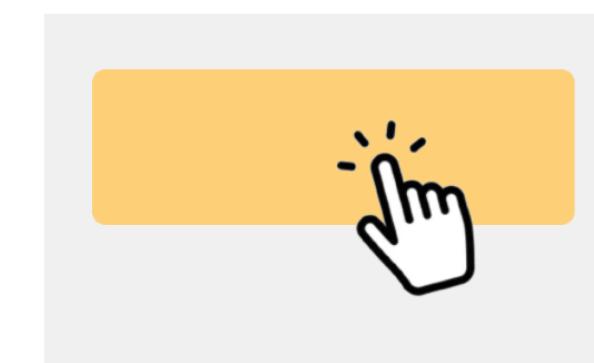
**Capture** implicit interaction that **might be** relevant to mental model building.



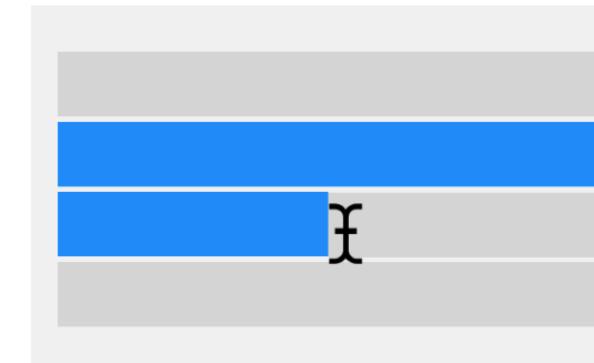
Content dwell



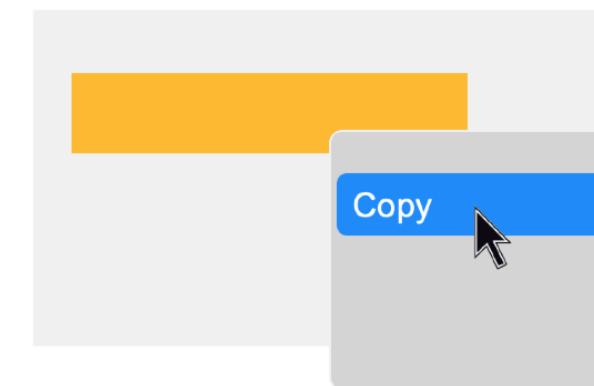
Cursor hover



Click



Text highlight



Copy content

**Extract** information that **actually** reflects users' mental model.

Rank by signal strength

Filter out interaction noises

Filter out noise in context

# Automation by tracking implicit behavior signals

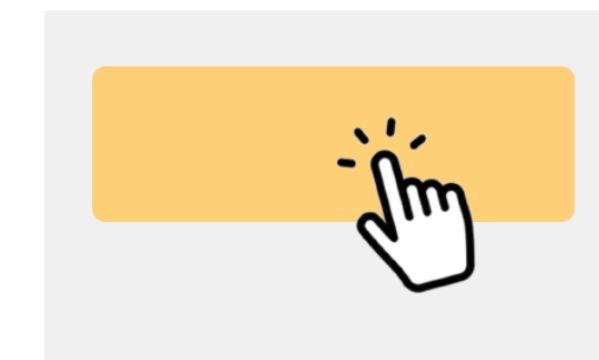
**Capture** implicit interaction that **might be** relevant to mental model building.



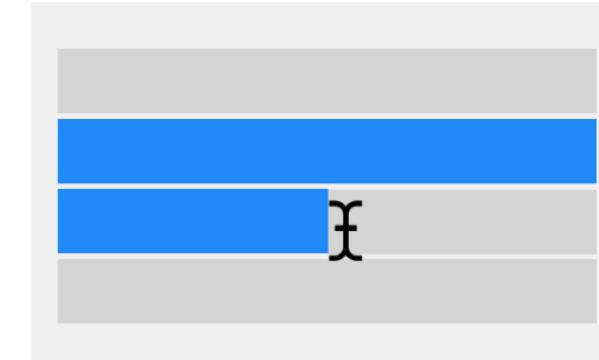
Content dwell



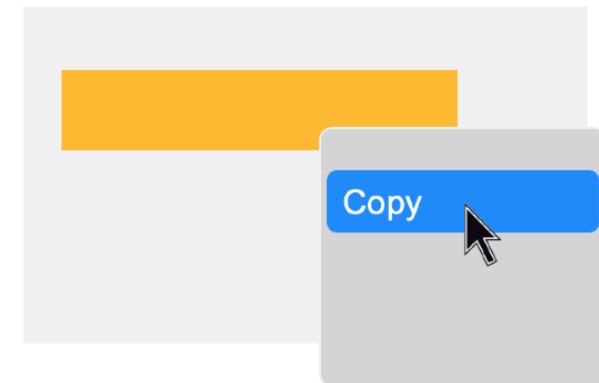
Cursor hover



Click



Text highlight



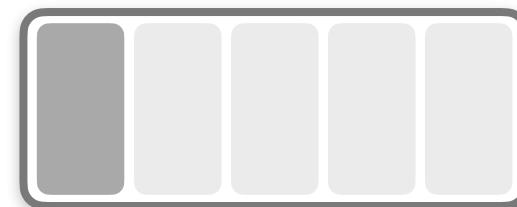
Copy content

**Extract** information that **actually** reflects users' mental model.

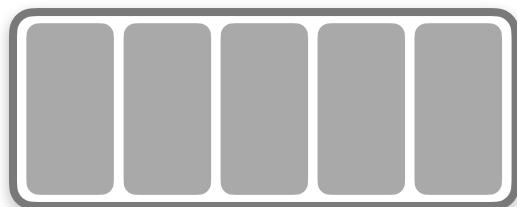
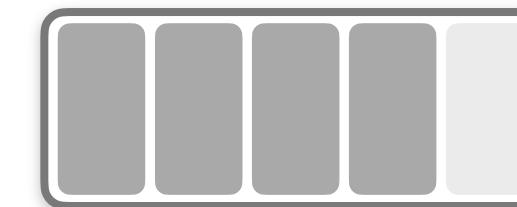
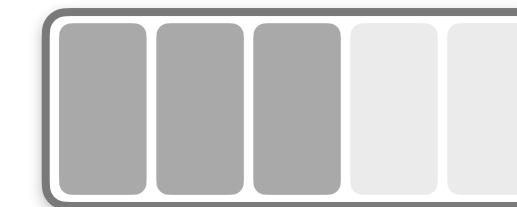
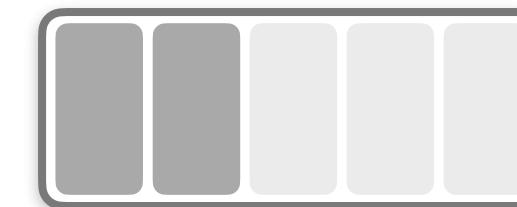
Rank by signal strength

Filter out interaction noises

Filter out noise in context



Weakest



Strongest

Javascript Carousels

Search...

Options:

A Swiper   B Slick   C Splide

Criteria:

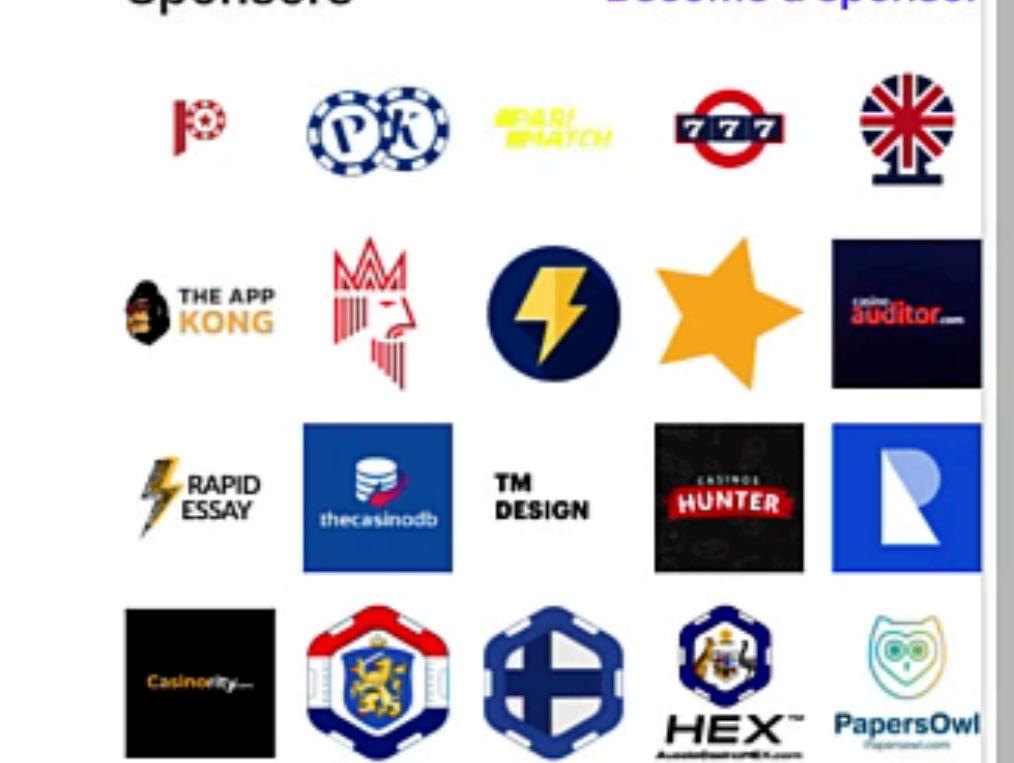
1st Focus Center   2nd Multiple Slides  
3rd Grab Cursor   4th Nested   
5th Slides Grid  
6th Custom Pagination   
7th Scroll Container   8th Centered Auto  
9th Filtering   10th Freemode  
11th Drag Free   12th Slides   
13th Virtual Slides   14th Slides Per View  
15th Watch Slides Visibility

History:

G javascript carousel

- Splide - The lightweight, flexible and accessible slider/carousel
- slick - the last carousel you'll ever need

S Swiper Demos



Slide 1   Slide 2

Default

Navigation

Pagination

Pagination dynamic

Pagination progress

Pagination fraction

Pagination custom

Scrollbar

Vertical

Space between

Slides per view

Slides per view auto

Centered

Centered auto

CSS mode

Freemode

Scroll container

Slides Grid

## Infinite loop

[Open in new window](#)

Slide 1

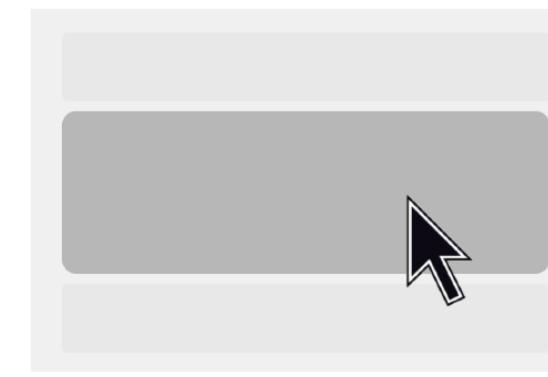
<

# Automation by tracking implicit behavior signals

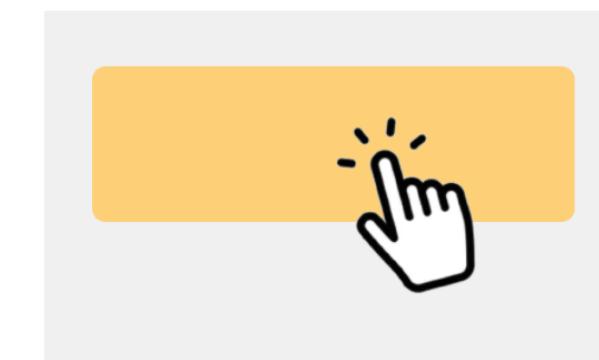
**Capture** implicit interaction that **might be** relevant to mental model building.



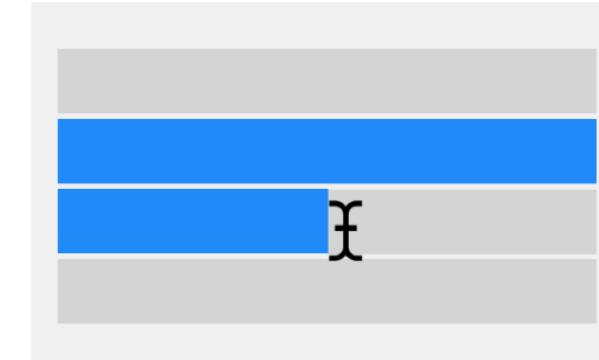
Content dwell



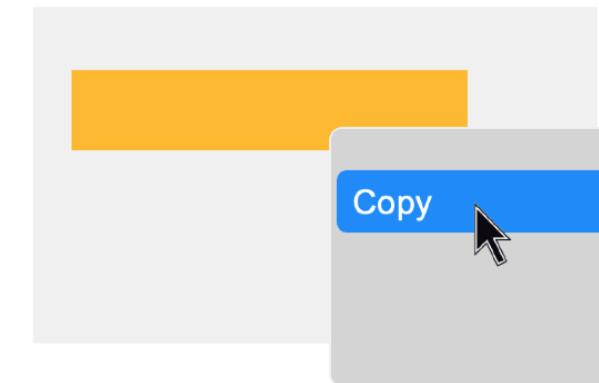
Cursor hover



Click



Text highlight



Copy content

**Extract** information that **actually** reflects users' mental model.

Rank by signal strength

Filter out interaction noises

Filter out unintentional interactions  
through time, length, etc. signals.

# Automation by tracking implicit behavior signals

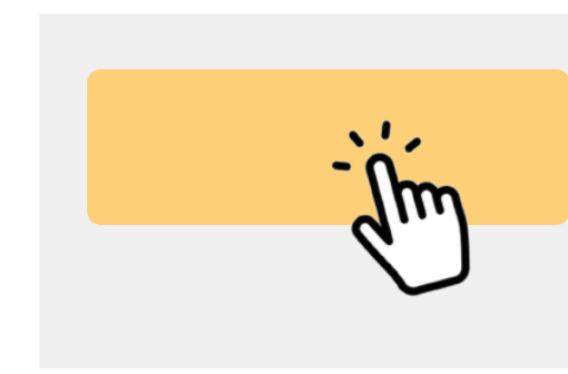
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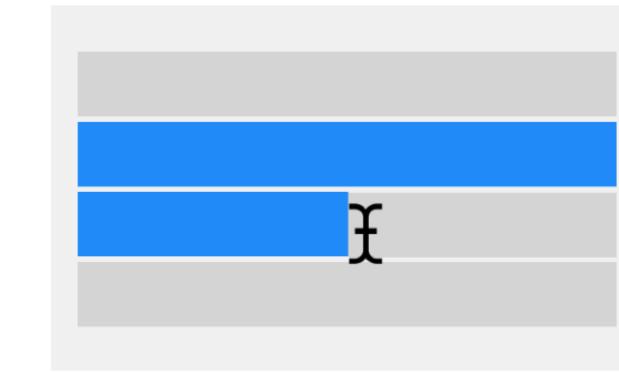
Content dwell



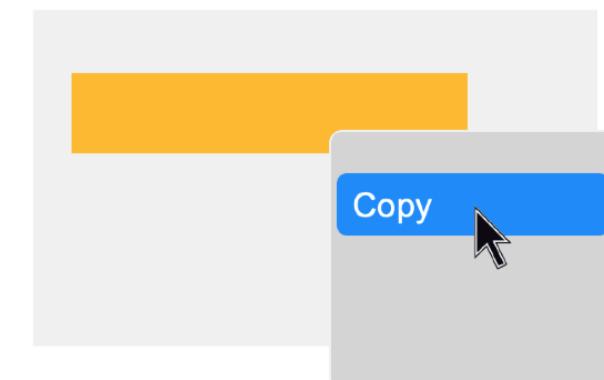
Cursor hover



Click



Text highlight



Copy content

**Extract** information that **actually** reflects users' mental model.

Rank by signal strength

Filter out interaction noises

Filter out unintentional interactions through time, length, etc. signals.

A Started guide that should help one set up React. The creation is thorough and complete, with solutions to many present problems. Rejected since the highlight is likely the result of an accidental double click.

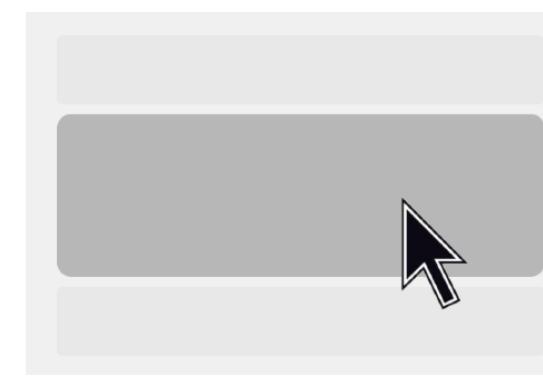
framework and advanced features require the use of third-party libraries. This makes the learning curve of the core framework not so steep but depends on the path you take with additional functionality. However, learning to use React

# Automation by tracking implicit behavior signals

**Capture** implicit interaction that **might be** relevant to mental model building.



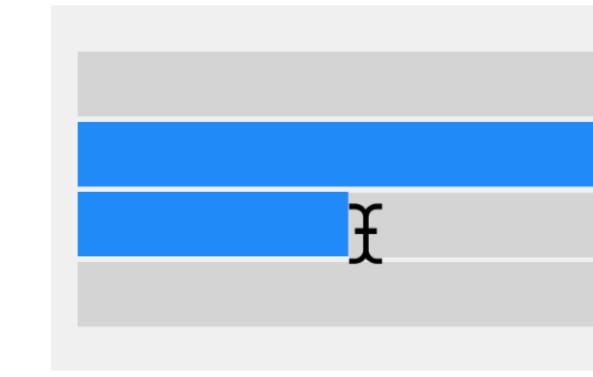
Content dwell



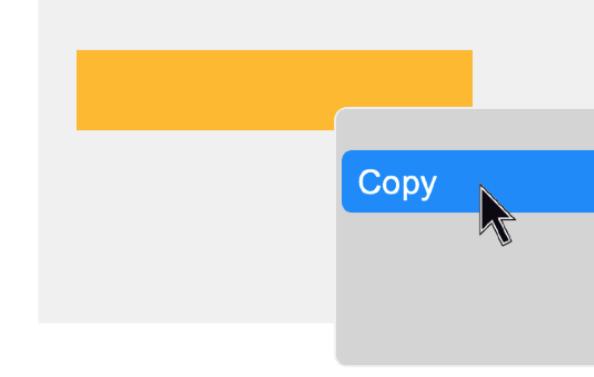
Cursor hover



Click



Text highlight



Copy content

**Extract** information that **actually** reflects users' mental model.

Rank by signal strength

Filter out interaction noises

Filter out noise in context

Use key **entities** as  
**criteria** and **options**.

Named entity extraction +  
Noun chunk extraction

**Size** and **load times** 

The sizes of the libraries won't be as big of a factor since caching and minification are pretty standard nowadays. Although there can be a significant difference between the sizes of the frameworks (e.g. Angular is the largest), they are still small as compared to the average webpage size (about 2MB according to the most [recent data](#)). Additionally,

Compact mode

**A Swiper**

**B Slick**

**C Splide**

**1st Grab Cursor**

**2nd Fade Transition**

**3rd Nested**

**4th Add/Remove**

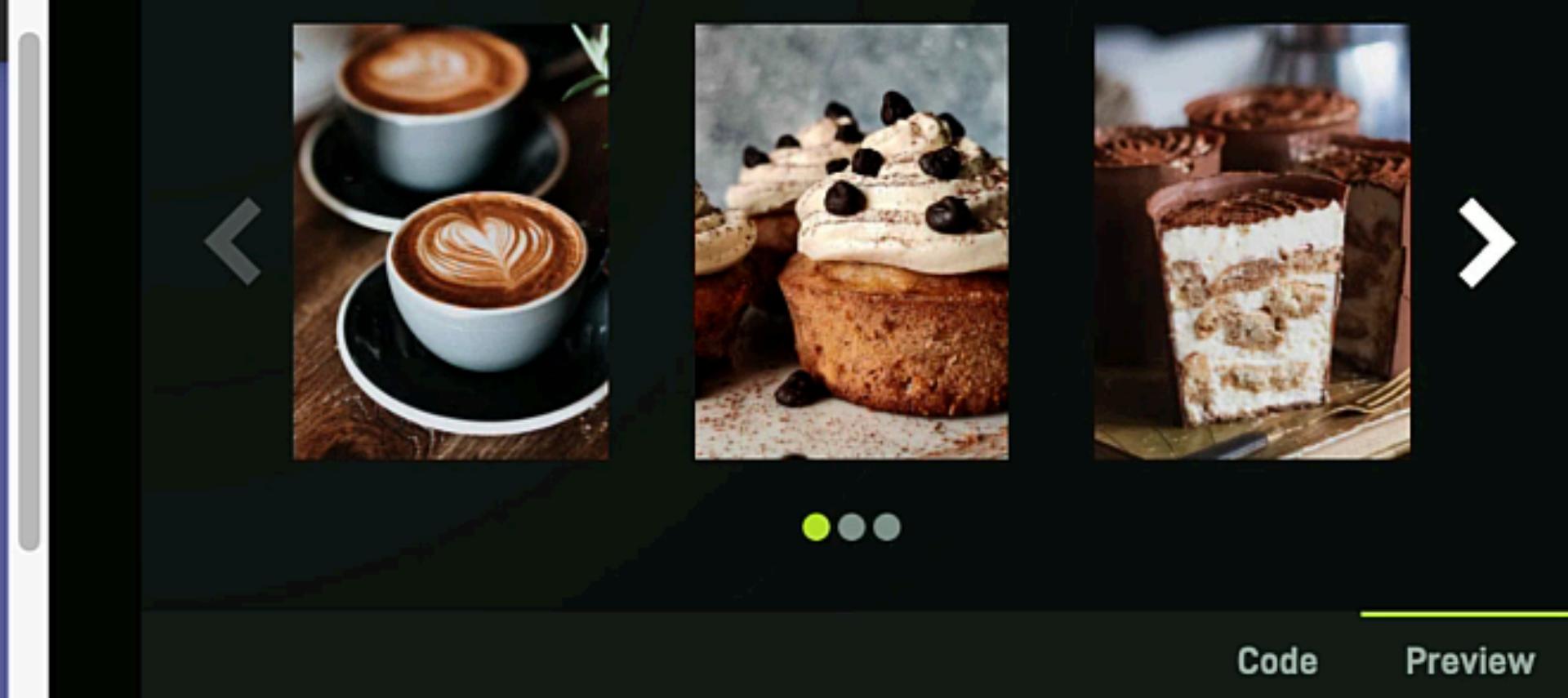
**5th Thumbnails**

**6th Slides Grid**

**7th Custom Pagination**

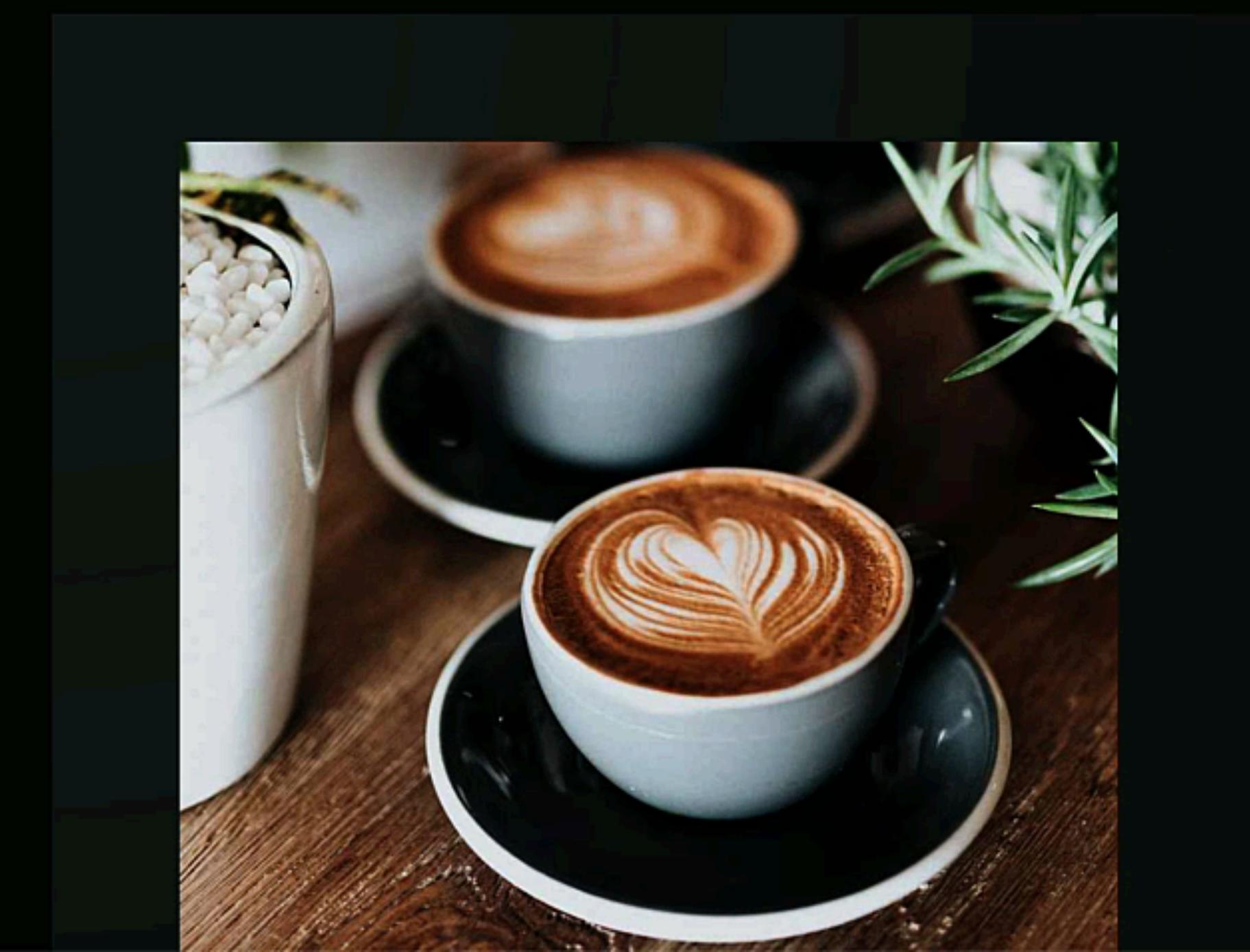
This section displays seven examples of slider components:

- 1st Grab Cursor:** Shows a grid of images with a cursor icon.
- 2nd Fade Transition:** Shows a grid of images with a fade transition effect.
- 3rd Nested:** Shows a nested slider structure.
- 4th Add/Remove:** Shows a slider with an "Add/Remove" button.
- 5th Thumbnails:** Shows a slider with a thumbnail navigation.
- 6th Slides Grid:** Shows a grid-based slider layout.
- 7th Custom Pagination:** Shows a slider with a custom pagination bar.



## Thumbnails

Splide sliders can be synchronized with one another. By utilizing this, you can make a gallery with thumbnails navigation.



# Crystalline is useful!

N=12, within-subjects, Unakite as baseline

With Crystalline, participants built comparison tables...

in **20%\* less** time

time spent having to  
use tool features

with **60%\* less** overhead cost.

Crystalline-style automation is **significantly faster** and more **efficient**  
because users shift from **manual collecting & organizing → monitoring**

\* denotes statistically significant differences ( $p < 0.05$ )

# However, automation can make errors...

N=12, within-subjects

Manual collecting & organizing → monitoring **& error fixing**

*"[I needed to] occasionally peeking into what it's been doing and fixing whatever that's not correct."*

Crystalline-style automation is significantly faster and more efficient.

\* denotes statistically significant differences ( $p < 0.05$ )

# In fact, users do expect to take some initiatives.

**Despite automation, participants wanted and tried to exercise more control over system behavior.**

*"it looks like if I spend a little bit more time on a particular place, the corresponding thing (criterion) can get picked up and bubble up quickly... the same thing with clicking or maybe selecting some text... so, at some point, I think I just started taking advantage of that and tried to bump what I really cared about up to the top..."*

# What if we shift error fixing to **lightweight control**?

**Despite automation, participants wanted and tried to exercise more control over system behavior.**

*"it looks like if I spend a little bit more time on a particular place, the corresponding thing (criterion) can get picked up and bubble up quickly... the same thing with clicking or maybe selecting some text... so, at some point, I think I just started taking advantage of that and tried to bump what I really cared about up to the top..."*

# What if we shift error fixing to **lightweight control**?

In addition to automation, how can we offer users **lightweight** interactions that promises **direct control**?

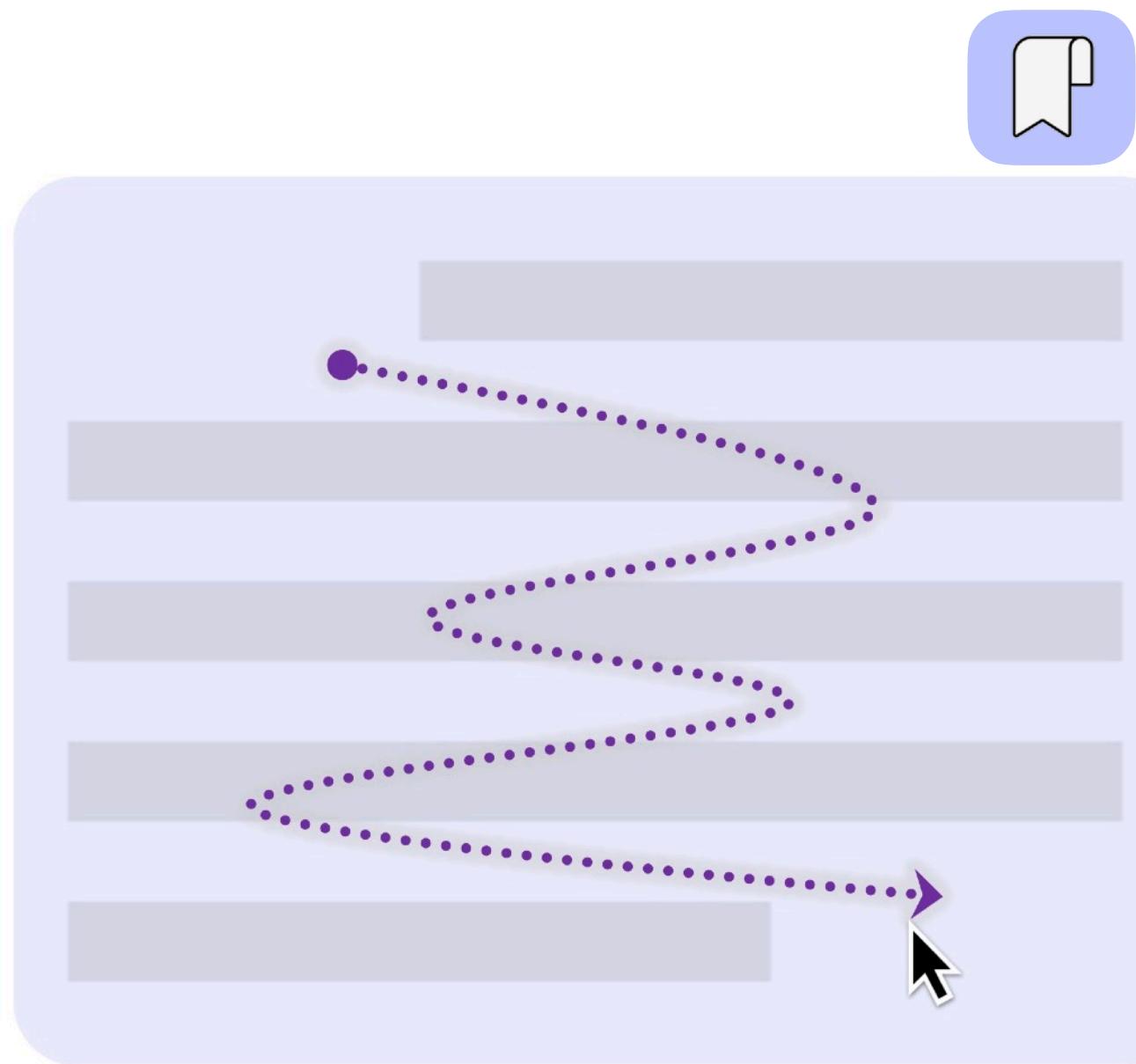
**Wigglite:** **streamlines** information collection and triage via a wiggle-based mouse gesture (or finger gesture on mobile devices).

Wigglite: Low-cost Information Collection and Triage

*Michael Xieyang Liu, Andrew Kuznetsov, Yongsung Kim,  
Joseph Chee Chang, Aniket Kittur, Brad A. Myers.*

UIST 2022

# Collecting content using wiggling.



**Wiggle** the cursor back-and-forth over the content of interest to collect it.

```
npm install @vue/cli-plugin-unit-jest @vue/test-utils
```

The next step is to create a test file, naming it **browserstack.test.js**. Jest can catch any file named **\*.test.js** or **\*.spec.js**.

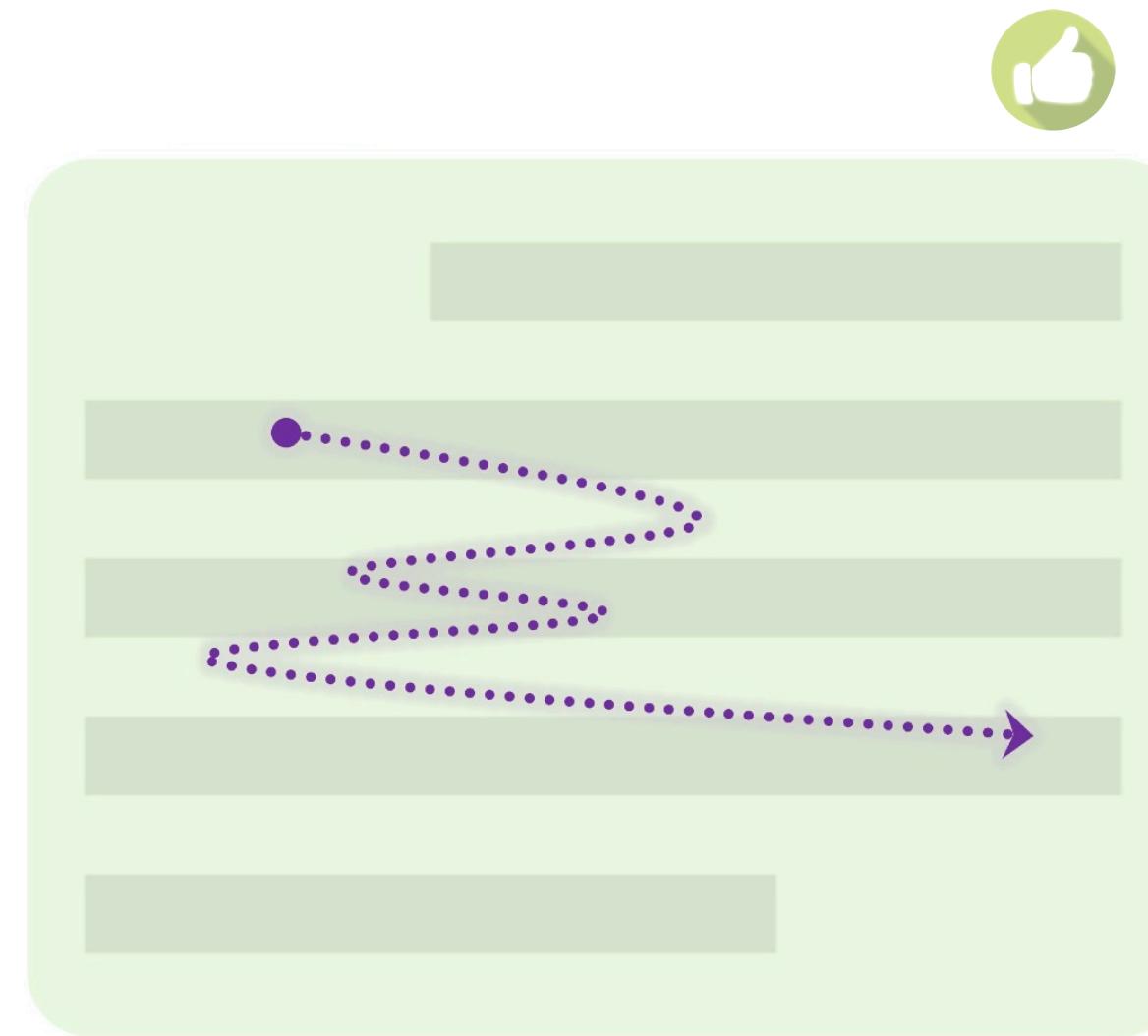
```
import { mount } from '@vue/test-utils'  
import Browserstack from './.../browserstack.js';  
  
it("testing a vue app", ()=>{  
  expect(wrapper.find('button').exists()).toBe(true)  
})
```

**Lightweight:** No explicit clip, drag, drop!

**Lightweight:** Cursor available!

**Explicit & non-intrusive:** People don't do this otherwise!

# Classifying content with wiggling.



Classifying content  
as “**positive**”, or “**pro**”.

Naturally extend wiggling to  
e.g. content judgements!

React is often the most popular choice among developers. However, before choosing React, let's study the benefits and drawbacks of using React.

## Advantages of using React

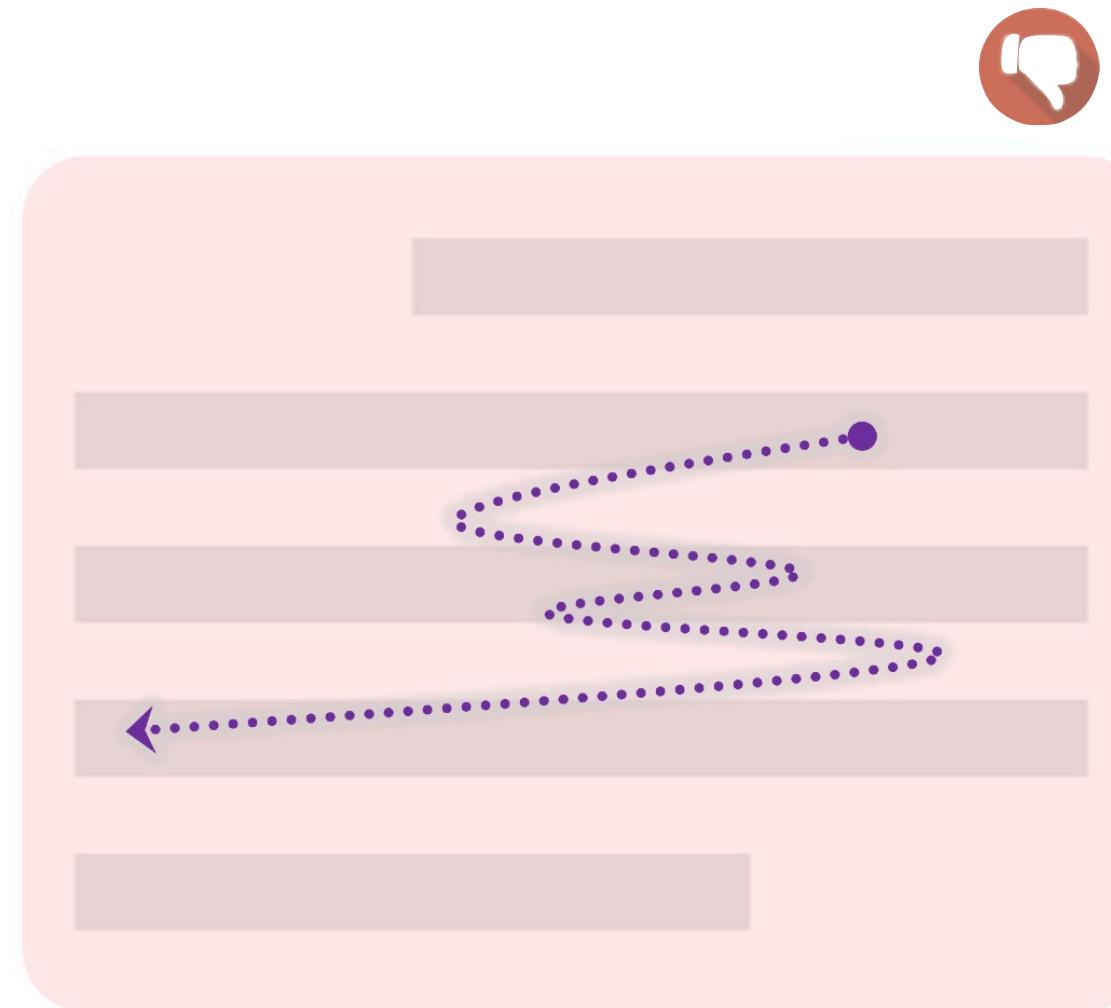
- **Reusable Components:** While developing React applications, the amount of complexity and coding is less because of the reusable components in React. It brought more functionality and a clear codebase, which is also easy to maintain.
- **Performance:** React does not depend upon the conventional DOM and uses a JavaScript structure, virtual DOM. Using virtual DOM enhances the performance and increases the speed of the programs.
- **Learning Curve:** React is way ahead of its competitors due to its easy learning curve. Moreover, it is easy for web developers who have just finished their concepts in HTML and JavaScript to learn React.

Read More: [Browser Compatibility for ReactJS Web Apps](#)

## Limitations of using React

- **Development Pace:** Since React is the most widely used JavaScript library, React is

# Classifying content with wiggling.



Classifying content as  
“negative”, or “con”.

Read More: [Browser Compatibility for VueJS Web Apps](#)

## Limitations of using Vue.Js

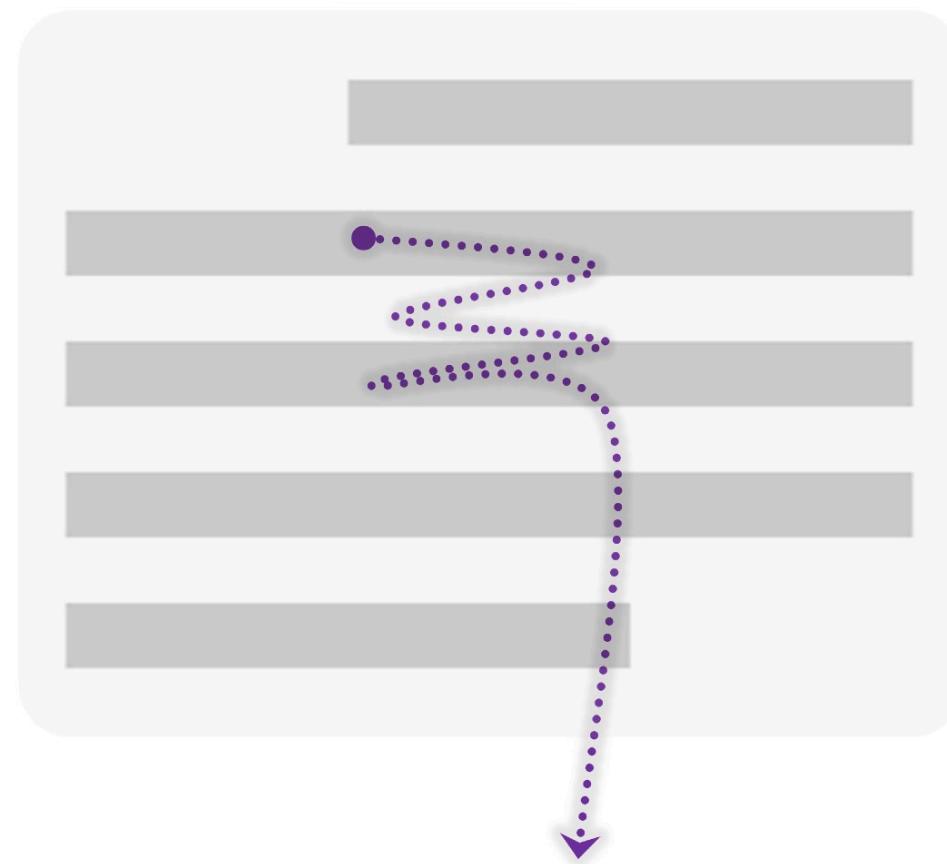
- **Ecosystem:** The ecosystem plays a vital role in applications to adapt to several browsers and operating systems. Vue has a very narrow ecosystem, therefore, does not render in older versions of operating systems and web browsers.
- **Developers:** Other frameworks such as Angular and React are backed by Google and Facebook, which automatically build trust among the people, however, Vue is generally not trustworthy among the audiences.

## Core Differences: Angular vs React vs Vue

Here are some of the core differences between Angular, React, and Vue to make it easy to decide which is the best web development framework for your project.

Parameter	Angular	React	Vue
Initial Release	2016	2011	2014

# More expressive power with directions + Intensity!

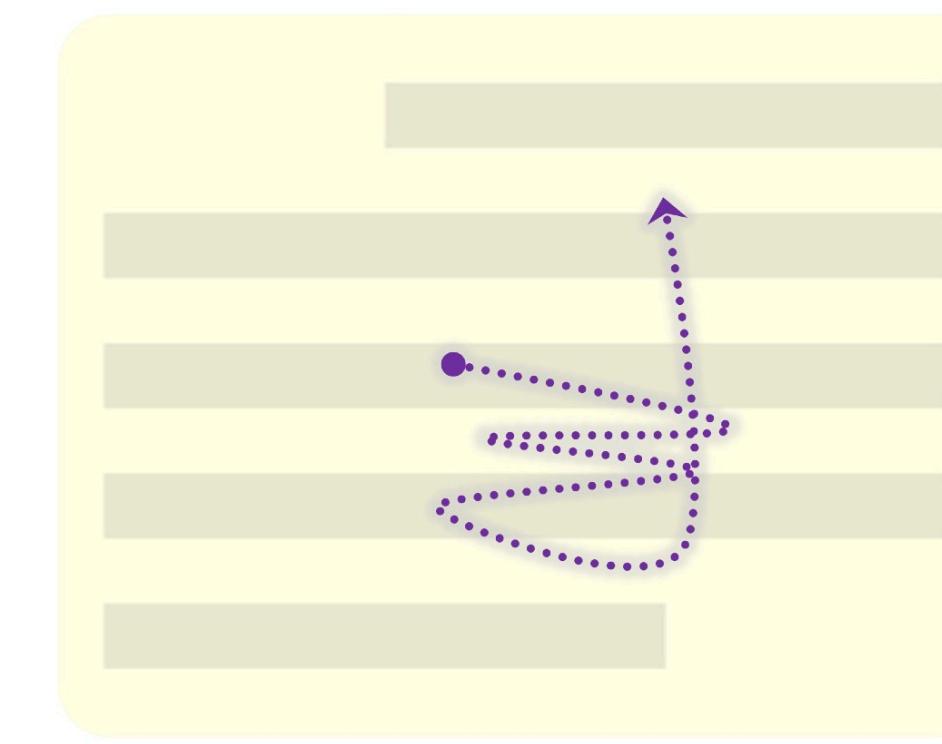


Low

Medium

High

Critical



# Evaluating wiggling efficiency

N=12, within-subjects

With wiggling, participants collected and organized clips...

in **24%\* less** time

with **58%\* less** overhead cost.

*"I just wiggle and move on, in fact, when I am wiggling on something, my eyes are already onto the next paragraph, no more stopping to do the regular clipping thing any more."*

\* denotes statistically significant differences ( $p < 0.05$ )

# Evaluating wiggling accuracy & integration

True positives

**3.53%** false negative (FN)

With the current implementation, 2.01% did not activate, 1.48% activated on the wrong content

**0** false positive (FP)

Suggesting that normal mouse movements would not trigger a wiggle activation

True negatives

Robust against false negatives!

Does not interfere with existing interactions!



## Reusing

## Externalizing

## Reading



**Strata** (CSCW 2021)

*Best paper (top 1%)*



**Wigglite** (UIST 2022)



**Crystalline** (CHI 2022)



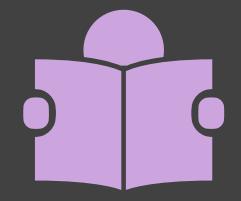
**Unakite** (UIST 2019)

*Honorable Mention (top-6)*



**Selenite** (2023)

Minimize cognitive & physical cost,  
through **lightweight interactions**



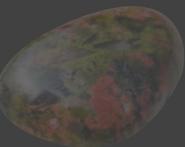
## Reading



Selenite (2023)



## Externalizing



Unakite (UIST 2019)



Honorable Mention (top-6)



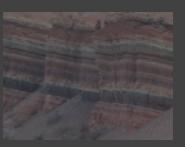
Crystalline (CHI 2022)



Wigglite (UIST 2022)



## Reusing



Strata (CSCW 2021)



Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**

# The Best Washing Machines (and Their Matching Dryers)

By Winnie Yang, Sarah Bogdan and Liam McCabe Updated May 26, 2023

## Top 8 Deep Learning Frameworks in 2023

Lesson 6 of 32

Last updated on Feb 23, 2023

In today's world, more and more organizations are turning to **Artificial Intelligence (AI)** to improve their business processes.

The growth of machine learning and AI has led to increased demand for AI-powered and predictive personalizations to their customer experience. Companies are looking to implement machine learning and AI for their business needs.

## TensorFlow

Google's Brain team developed a Deep Learning framework called TensorFlow. It uses languages like Python and R, and uses data structures like tensors to represent data. Because as you build these neural networks, you can reuse them across different parts of your neural network.

TensorFlow's machine learning models are designed to be used in production environments, making it easier to bring machine learning into your organization's workflow.

With TensorFlow, you also get TensorBoard, which is a visualization tool that allows you to see what's happening during training. This makes it easier to understand how your model is learning and what it's doing. TensorBoard is often used by data scientists and engineers when working with your shareholders. You can use it to show them what's happening with your model's performance over time.

## 6 of the Best Frameworks for Hybrid App Development

If you want the biggest audience for your app, check out these cross-platform frameworks to avoid costly, drawn-out development.

### 1. React Native



Create native apps for Android and iOS  
Compatibility

React Native is a JavaScript framework used to develop cross-platform mobile apps. This framework has a unique language called JSX for developing user interfaces that allow you to write HTML and CSS through React. Its user interface components are also designed to create a fast and enjoyable experience for end users. End-user experience

Dev speed

React Native has the attractive ability to instantly reflect the changes you make to your application. This is unlike most other development applications that require you to recompile code or relaunch the app. Real-time compilation

Many pages prioritize Options (used as headers), but embed and intertwine multiple **criteria** in paragraphs

But both prior observations and a formative study with 8 participants suggested that this format is **suboptimal** for people's reading & sensemaking!

# Formative Study

*"This looks like a promising stroller, let me read..."*

## Best less-expensive full-featured four-wheeler: **Evenflo Pivot Xpand Modular Stroller**

Our pick

### [Evenflo Pivot Xpand Modular Stroller](#)

A four-wheeled stroller that offers bang for the buck



\$282\* from Amazon

\$350 from Evenflo

\*At the time of publishing, the price was \$350.

**Best for:** Families who want the features of an Uppababy, but want or need to spend much less.

**Why we like it:** The [Evenflo Pivot Xpand Modular Stroller](#) is a solid stroller that ticks the essential boxes, with adjustable handlebar height, a reversible toddler seat, and an accessible storage basket. It doesn't feel as thoughtfully designed or streamlined as our other four-wheeled pick, the Uppababy Cruz, but it's more than half as good for less than half the cost.

**Notable features:** The Pivot Xpand's handlebar has four height settings—38.5 inches, 39.5 inches, 40.5 inches, and 41 inches—and it is adjusted like

# Formative Study

Option-oriented reading is **overwhelming**: too many criteria to capture, digest, and formalize.

*"This looks like a promising stroller, let me read..."*

*"Wow this review is so long and time-consuming, if I were reading on my own I'd give up already..."*



Strap the two buckles under the bassinet to quickly turn it into a toddler seat. Gif: Marki Williams

The toddler seat reclines smoothly via a handle on the back. The recline angle goes back to around 30 degrees, inviting enough for naps. The toddler seat also has an “infant mode” for children under 6 months old; by unbuckling a strap under the seat, the seat becomes almost flat, creating a suitable position for small babies (and making the stroller particularly cost efficient since you don’t have to purchase a separate bassinet, as you do with the Uppababy Cruz).

The Pivot Xpand’s belly bar, though, is one area where it feels particularly cheap. Most strollers’ belly bars unlock on either side and pivot away from the child to open. But the belly bar on the Pivot Xpand is designed to be fully detached from the stroller in order to get the child in and out. In practice, I found that I could easily get my son in and out of the stroller without removing the belly bar, but that might be more challenging with larger kids—or a mid-tantrum toddler.

# Formative Study

Option-oriented reading is **overwhelming**: too many criteria to capture, digest, and formalize.

People **prefer selective reading**, but: “laundry list” of criteria forces unnecessary linear information digestion.

*“This is my dealbreaker, but of course they make the cons hard to find. Some simple metadata of what’s covered in a paragraph would be helpful; if I got to see this first I could have jumped to read the next stroller.”*

cheap. Most strollers’ belly bars unlock on either side and pivot away from the child to open. But the belly bar on the Pivot Xpand is designed to be fully detached from the stroller in order to get the child in and out. In practice, I found that I could easily get my son in and out of the stroller without removing the belly bar, but that might be more challenging with larger kids—or a mid-tantrum toddler.

At 24 inches, the canopy on the Pivot Xpand was one of the shortest that we tested; the canopy on the Uppababy Cruz extends to a full 32 inches. On the plus side, the canopy does have a mesh peekaboo window and can be adjusted to three different heights on the toddler seat, a nice option for taller and kids with longer torsos. Unlike most canopies, which are zipped or clipped to the frame of the stroller on the side and the top, the Pivot Xpand attaches to the toddler seat on the sides only. This makes it easy to adjust the height, but it also means that if you pull the canopy out quickly, it can pull away from the top—a potential hassle in a rainy and windy situation.

The Pivot Xpand can be converted from a single to a double stroller, with the purchase of a **second toddler seat**. (We did not test this stroller as a double; read more on convertible strollers [here](#).) It is the only one of our main stroller picks that converts.

Refreshingly, the Pivot Xpand actually comes with a cupholder—the only one of our picks that does; this is an especially welcome bonus, given the price.

Evenflo offers a [90-day warranty](#) for manufacturer defects, which is an unusually short warranty period. This does not cover normal wear and tear or accidental damage.

**Cleaning:** The Pivot Xpand’s polyester fabric cannot be removed from the stroller frame, so spot-cleaning it is the only option. (Ditto for the storage basket.)

# Formative Study

Option-oriented reading is **overwhelming**: too many criteria to capture, digest, and formalize.

People **prefer selective reading**, but: “laundry list” of criteria forces unnecessary linear information digestion.

Dealing with **unknown-unknown**: no “intuition or guidance” on what to care about.

*“Hmm so this page didn’t talk about traveling or umbrella... I wonder what else is missing. What can’t there be some guidance or intuition of what I should care about?”*

## Meet your guide



Elise Czajkowski

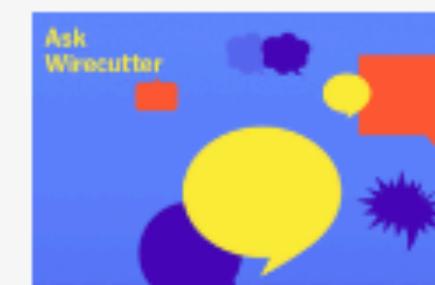
Elise Czajkowski is a freelance writer and editor covering strollers for Wirecutter.

## Further reading



### The Best Travel Strollers

We logged over 130 miles testing nine strollers and took four on five flights, and we found that the best travel stroller is the Uppababy Minu.



### Ask Wirecutter: The Best Stroller for the City

If you live in a city and walk a lot, here’s what our parenting editor suggests you buy for your first stroller.



### The Things You Need Before You Bring Your Baby Home

We’ve tested dozens of car seats, strollers, and diapers to narrow down the list of things you really need before you bring your baby home.



### The Best Umbrella Strollers

We tested eight umbrella strollers for 86 hours and found that the Summer Infant 3D Lite is the best for most people.

# Formative Study ➔ Design Rationale

Reading is not a process we can take for granted – People need help...

Developing **well-rounded knowledge** about what might be important for a topic;  
Reading more **targetedly** about what they care.

**Selenite**: AI-assisted, grounded reading and information discovery!

[D1] **Global grounding for overview** upon entering a page, using common criteria and the options encountered.

[D2] **Local grounding for guided reading**, using page/paragraph-level summaries and annotations.

[D3] **Suggestions on next steps** upon finishing, based on criteria already covered.

# The Best Baby Strollers of 2023, According to Our Testing

Lightweight, affordable and luxury picks for newborns, toddlers and first-time parents.

BY JAMIE SPAIN AND JESSICA HARTSHORN | UPDATED: APR 24, 2023

REVIEWED BY RACHEL ROTHMAN  
CHIEF TECHNOLOGIST & EXECUTIVE TECHNICAL DIRECTOR

 **SAVE ARTICLE**



BOB GEAR

**FYI:** We've updated this guide and swapped in the [Chicco Corso LE Modular Travel System](#) and [Colugo The Compact Stroller](#) for out-of-stock products.

💡 Topic: **Best strollers of 2023**

☰ Options encountered so far:

Thule Spring Nuna TAVO Next Evenflo Pivot Xplore Wagon  
Doona Car Seat Stroller UPPAbaby Vista v2  
Bugaboo Butterfly Baby Jogger City Mini GT2 Double Stroller  
Zoe Traveler Thule Urban Glide 2 UPPAbaby Cruz v2  
Joovy Twin Roo+

☒ Criteria that people consider regarding the topic:

Safety<sup>11</sup> Comfort<sup>5</sup> Maneuverability<sup>21</sup> Durability<sup>1</sup> Foldability<sup>14</sup>  
Weight and Size<sup>17</sup> Storage<sup>4</sup> Versatility<sup>40</sup> Price<sup>8</sup> User Reviews<sup>3</sup>  
Safety Features<sup>4</sup> Comfort for the Child<sup>6</sup> Ease of Use<sup>8</sup>  
Storage Space<sup>7</sup> Weight Capacity<sup>2</sup> Cleaning and Maintenance  
Style and Design<sup>2</sup> Brand Reputation  
Accessories and Add-ons Longevity<sup>1</sup>

 Request more criteria  + Add a criterion

## Criteria that people consider regarding the topic:



Request more criteria

+ Add a criterion

BOB GEAR

*FYI: We've updated this guide and swapped in the [Graco Carseat Modular Travel System](#) and [Colugo The Compact Stroller](#) for out-of-stock products.*

# Global overview w/ criteria

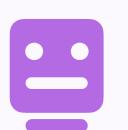
XI

What are some criteria that people consider regarding the topic of "best baby strollers" that are most relevant to the topic, frequently considered, and can cover a broad range of perspectives?

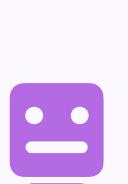


*Using GPT-4 as a **knowledge retriever***

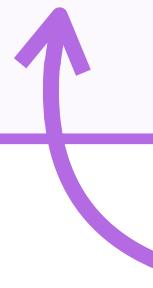
What are some criteria that people consider regarding the topic of "best baby strollers" that are **most relevant to the topic, frequently considered, and can cover a broad range of perspectives?**



+



Please give me 5 more that are **different, more diverse, and more important.**



Iterative Self-refine technique

Madaan et al. 2023

## In-context criteria annotations

Versatility Storage Space Price Weight and Size

If you like the Uppababy Cruz V2 but want a larger stroller with even more storage space (and the ability to convert it to carry two kids): The Uppababy Vista V2 is basically a supersized version of the Uppababy Cruz V2, our four-wheeled pick for daily urban use. The Vista V2's frame is bigger than that of the Cruz V2 (it's 3.5 inches wider and 2 inches longer), and it expands on an already generous storage basket by another 3 inches in width. As for the handling, we thought the Vista V2 maneuvered slightly better than the Cruz V2, since its larger frame distributed weight differently across the stroller, but we also found it harder to navigate tight spaces with a stroller that had a bigger footprint. Neither the Cruz V2 nor the Vista V2 is ideal for folding and carrying, and the Vista V2's additional heft—it weighs 28 pounds versus the Cruz V2's 25 pounds—makes it that much more cumbersome to lift. Another key difference is that the Vista V2 can convert from a single stroller to a double stroller with the purchase of an additional seat; we named the earlier-generation Vista model the upgrade pick in our guide to the best double strollers. And unlike the Cruz V2, the Vista V2 comes with an infant bassinet attachment. Still, considering the price and weight differences—and the fact that it can be hard to predict when (or if) you'll need a convertible stroller and what type you may want—we've concluded that the Cruz V2 is a better choice for most people looking for a full-size stroller for one child.

🏁 Criteria that people consider regarding the topic:

Safety 9 Comfort 21 Maneuverability 20 Foldability 5 Durability 5  
Weight and Size 16 Storage Space 19 Versatility 36 Price 26  
User-Friendliness 15 Weight capacity 4 Canopy Brake System  
Suspension Reversible Handlebar 5 Adjustable Handlebar 2  
Easy Cleaning 4 Travel-Friendly 26 Accessories  
Brand Reputation 2 Warranty Folding Mechanism 2  
Adjustability 29 Style and Design 4

Analyze paragraphs with  
**natural language inference (NLI):**

“ [paragraph content] **discusses** [criterion] ”



bart-large-mnli

(an NLI model)

Yes

No

# In-context criteria annotations

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Foldability Folding Mechanism Travel-Friendly Versatility Weight and Size Maneuverability

**Why we like it:** The [Baby Jogger City Mini GT2 All-Terrain Stroller](#) is a three-wheeled stroller that's excellent at taking on tricky terrain like grass and gravel. (Despite the brand name, however, it's not designed for running.) It is sturdy and wide, but also very light, and it has a quick, ridiculously simple one-handed fold—the best of any stroller we tested—making it easy to pop into the back of your car before you head off on an adventure.

Durability Maneuverability Comfort Adjustability Versatility

The City Mini GT2 doesn't put on airs: It delivers rugged functionality. The stroller's rubberized handlebar is comfortable for long-term pushing and gripping as you go over bumps and curbs, and its large canopy and deeply reclining, nap-friendly toddler seat lend themselves well to extended day trips. (Hello, theme parks.)

Adjustability Adjustable Handlebar

This stroller has the longest toddler seat of any of our picks, and its adjustable handlebar can go up the highest, 44 inches, making this stroller a potentially great fit for particularly tall families.

Foldability Versatility Travel-Friendly Maneuverability

Note that the City Mini GT2 shares some similarities, including its quick fold, with the [Baby Jogger City Mini 2](#), our top pick in the original version of this guide. At this writing, Baby Jogger is in the process of phasing out the City Mini 2.

Durability Storage Space

**Size and storage:** At 25.5 inches wide and 33 inches long, the City Mini GT2

Versatility Storage Space Price Weight and Size

If you like the Uppababy Cruz V2 but want a larger stroller with even more

Versatility Storage Space Price Weight and Size

If you like the Uppababy Cruz V2 but want a larger stroller with even more storage space (and the ability to convert it to carry two kids): The

Uppababy Vista V2 is basically a supersized version of the Uppababy Cruz V2, our four-wheeled pick for daily urban use.

Storage Space Weight and Size The

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Weight and Size we also found it harder to navigate tight spaces with a stroller that had a bigger footprint.

Weight and Size Neither the Cruz V2 nor the Vista V2 is ideal for folding and carrying, and the Vista V2's additional heft—it weighs 28 pounds versus the Cruz V2's 25 pounds—makes it that much more

cumbersome to lift.

Versatility Another key difference is that the Vista V2 can convert from a single stroller to a double stroller with the purchase of an additional seat ; we named the earlier-generation Vista model the upgrade

pick in our guide to the best double strollers.

Versatility And unlike the Cruz V2,

the Vista V2 comes with an infant bassinet attachment.

Price Still,

considering the price and weight differences—and the fact that it can be hard to predict when (or if) you'll need a convertible stroller and what type you may want—we've concluded that the Cruz V2 is a better choice for most people looking for a full-size stroller for one child.

Analyze

## Analyze hard-to-read content with GPT-4

Given the following content and a list of criteria:

Content: [content]

Criteria: [criteria]

For each criterion:



1) extract \*\*every possible\*\* utterance that \*\*mentions\*\* or \*\*explicitly describes\*\* that criterion from the content

2) perform **sentiment analysis** to determine if the utterance is "positive", "neutral", or "negative" with respect to that criterion.

Remember to use the \*\*exact same words\*\* from the content. Do not paraphrase!

# After reading...

## Status report

Criteria that you looked at:

Safety      Comfort      Price      Weight and size      Foldability

Ease of cleaning      Durability

Criteria that you ignored:

Maneuverability      Storage space      Design

You might be interested in further searching for “Best baby strollers” based on:

Ease of assembly      Brake & locking system

## Suggesting new searches



“Best baby stroller +  
**ease of assembly**”



**“Brake and locking system**  
of baby strollers”

# Study 1: Performance Evaluation

How well can Selenite:

- 1) accurately report **options** that are present on a web page;
- 2) comprehensively report critical **criteria** people commonly consider

*by testing on a diverse set of 10 topics:*

5 reported in **formative study** + 5 most popular from **Wirecutter**

*each compared to:*

**top 5 SERPs** → **hand-annotated groundtruth**   **options** + **criteria**

**100%!**

# Groundtruth



# v.s. Selenite



e.g., "best air purifier"



Ease of use

Noise

Room size suitability

Price

Smart features



User-friendly control

Noise level

Coverage

Price

Smart features

Speed settings

Air quality indicator

Portability

Warranty

Customer reviews

Fan speed settings

Additional features

Portability

Warranty

Customer reviews

Design

Customer support

Filter type

Sleep mode

Power consumption

Design

Customer support

Filter type

Sleep mode

Power consumption

Smell removal

Performance

Ozone safe

Filter replacement indicator

Odor elimination

Effectiveness

Ozone emissions

Filter indicator



Child lock

Certifications

Size

CADR (Clean Air Delivery Rate)

# Are the **global** criteria set any good?

**Precision:** % of criteria retrieved by Selenite that were in the groundtruth

**Recall:** % of groundtruth criteria that are retrieved by Selenite

	#Groundtruth	#Selenite	Precision	Recall	F1
Best washing machines	19	24	0.88	1.0	
Birthday gift ideas	11	21	0.57	0.91	
Best hybrid app frameworks	15	21	0.86	0.93	
Best time tracking tools	21	21	0.81	0.95	
Deep learning frameworks	25	20	0.80	0.84	
Best sleeping bags	19	21	0.81	0.89	
Best air purifiers	20	24	0.83	1.0	
Best robot vacuums	23	28	0.82	1.0	
Best baby strollers	22	24	0.92	1.0	0.96
Best tropical vacation spots	15	19	0.74	0.93	0.82
<b>Mean</b>	19.0	22.3	0.80	0.95	0.87

**High recall:** criteria retrieved by Selenite can cover most of the criteria relevant to a topic.

# Are the **global** criteria set any good?

**Precision:** % of criteria retrieved by Selenite that were in the groundtruth

**Recall:** % of groundtruth criteria that are retrieved by Selenite

	#Groundtruth	#Selenite	Precision	Recall
Birthday gift ideas	19	24	0.88	0.95
Best hybrid app frameworks	11	21	0.57	0.88
Best time tracking tools	15	21	0.86	
Deep learning frameworks	21	21	0.81	
Best sleeping bags	25	20	0.80	
Best air purifiers	19	21	0.81	
Best robot vacuums	20	24	0.83	
Best baby strollers	23	28	0.82	
Best tropical vacation spots	22	24	0.92	
	15	19	0.74	
Mean	19.0	22.3	0.80	0.95 0.87

**Birthday gift ideas**

Best hybrid app frameworks

Best time tracking tools

Deep learning frameworks

Best sleeping bags

Best air purifiers

Best robot vacuums

Best baby strollers

Best tropical vacation spots

Mean

Lower-than-avg precision on some topics – **not necessarily bad!**

What **Selenite** suggests: "Practicality", "Sentimental value", "Durability", etc.

What **webpages** talks about: "Fun", "Cool", etc. — **hard for comparison**

# How good is the local grounding?

**Precision:** % of criteria recognized by Selenite that were indeed discussed in paragraph

**Recall:** % of criteria discussed in paragraph that were indeed recognized by Selenite

	Precision	Recall	F1
Best washing machines	0.91	1.0	0.95
Birthday gift ideas	0.57	0.96	0.72
Best hybrid app frameworks	0.83	1.0	0.91
Best time tracking tools	0.88	0.98	0.93
Deep learning frameworks	0.87	0.95	0.91
Best sleeping bags	0.95	1.0	0.97
Best air purifiers	0.83	0.98	0.90
Best robot vacuums	0.95	1.0	0.97
Best baby strollers	0.81	1.0	0.90
Best tropical vacation spots	0.92	1.0	0.96
<b>Mean</b>	0.85	0.98	0.91

**Higher recall than precision:**  
prioritize coverage!

# Study 2: Case Study

How well can Selenite support users' reading and understanding?

*8 participants, each performed...*

**2 pre-defined tasks:** use Selenite to read about an **unfamiliar topic**

*Selected from the 28 topics in formative study, based on screening survey*

**1 self-selected task:** Read a 3rd topic that **they intend to explore in real-life**

*Can revisit previous topics of interest and potentially uncover fresh perspectives*



**Weight:** 14.3 lbs | **Folded Size:** 3.534 cubic inches

#### REASONS TO BUY

- + High-quality
- + Sleek design
- + Easy to push

#### REASONS TO AVOID

- Expensive for an umbrella
- Harder to nap in

Foldability | Travel-Friendly | Price | **Versatility** | Weight and Size | Style and Design | Maneuverability | User-Friendliness | · Analyze

The [BabyZen Yoyo2](#) is a lightweight umbrella stroller with a compact fold. This high-end, lighter product has many features parents want in a small package that is good for travel. While the Yoyo2 is more expensive than most secondary travel-friendly competitors, it is also a high-quality choice with excellent materials that function well. The Yoyo2 is easy to push and turn (a rarity in the umbrella world); plus, it is stylish and sleek.

Price

· Analyze

While it is harder to push and a wee bit heavier than the smallest product, it is easier to use and earned a higher score for quality than most of the [best umbrella strollers](#) we tested. It is also more expensive than similar choices, so it isn't the best option for families on a tight budget or parents who only need a travel option for a single event. If budget isn't a concern, and you want the absolute best in a lightweight product, the BabyZen Yoyo2 stands out in its field.

**Read more:** [BabyZen Yoyo2 review](#)

# Selenite prioritizes users' reading needs

**8/8** participants immediately started with common criteria

**7/8** frequently jumped between criteria mentions for easy reading and comparison

*"just have to hunker down and read" (P7)*



*"you don't gotta stick to what the authors say anymore, ya know? Because, let's face it, their storylines can get all tangled and complicated sometimes." (P1)*

# Selenite helps save user time and effort

**8/8** participants appreciate the “bird-eye overview” (P4) & “expert opinion” (P1)

**8/8** used paragraph overview for grasping the key points

“the anxiety and guesswork of wondering what other folks would actually care about” (P7)  
“figuring out stuff that I’m not used to” (P6)



“felt like back in the day when my classmate would mark all the important stuff in the textbook after a class when I couldn’t make it.” (P1)

The screenshot shows a user interface for a product analysis tool. At the top, there's a navigation bar with tabs for 'Analyze' and 'Compare'. Below the navigation, there's a section for 'Versatility' which has 35 mentions. A hand cursor is hovering over the 'Versatility' title. To the right of the title, there's a list of features: 'Offering versatile features such as reversible seat, compatibility with car seats, and the ability to convert into a travel system.' Below this, there's a list of criteria with their respective counts: Price (25), User-Friendliness (14), Weight capacity (3), Canopy (5), Brake System (25), Suspension (5), Reversible Handlebar (2), Adjustable Handlebar (2), Easy Cleaning (3), Travel-Friendly (25), Accessories (1), Brand Reputation (1), Warranty (1), Folding Mechanism (2), Adjustability (28), Style and Design (4). At the bottom of the interface, there are two buttons: 'Request more criteria' and '+ Add a criterion'.

Maneuverability Price Storage Space User-Friendliness Travel-Friendly Weight and Size

The [Baby Trend Expedition](#) is an inexpensive jogging stroller easy to push and turn with pneumatic rubber tires and a locking swivel front wheel. This budget-friendly product is good on uneven terrain, has under-seat storage, and has a three-wheel design that is easy to turn in tight spaces. With a low list price, this jogger is less than half the price of most joggers, proving you can have an excellent moving product that is easy to push without the sticker shock. These features helped the Expedition win kudos for strong bang-for-your-buck in our Jogging Review.

This jogger lacks suspension and tracking adjustment, making it a poor choice for serious runners. It is also heavy and large if you hope to travel or have limited space. We would still recommend this product to a friend who wants a jogging look with large rubber tires (for

# Selenite helps capture easy-to-miss information

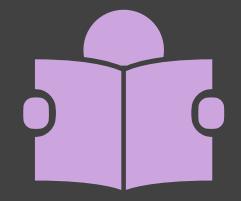
**3/8** participants used the zoom-in option and noticed additional logic flow

(Others thought the webpages were well-written, NLI label was enough, and zoom-in would take too long)

*"finding a needle in a haystack" (P8) → "it's more like following a well-lit path" (P5)*

the handlebar was uniquely uncomfortable. Safety When we pushed the empty stroller on uneven pavement, one of the front wheels popped up, which we found unsettling—we also heard stories about the entire stroller frame collapsing mid-push. Safety Following multiple reports of structural issues with the frame when the stroller was being used as a double, Mockingbird issued a voluntary recall on certain models and sent out frame-reinforcement kits. Our reservations extend to the Mockingbird Single Stroller, which is a similar stroller that has a slightly smaller frame and one fewer recline option but doesn't convert to a double. Safety Mockingbird's voluntary recall applies to some lot numbers of the Single model, as well. Safety Since we tested these strollers, Mockingbird says that "significant strength improvements" have been made to the construction of both the Single and Single-to-Double strollers, and as of May of 2023, all Mockingbird strollers for sale are not subject to the recall.

People early stop when they see one description on a criteria, vs. Selenite helps find *inline contrasts!*



## Reading



Selenite (2023)



## Externalizing



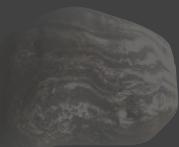
Unakite (UIST 2019)



Honorable Mention (top-6)



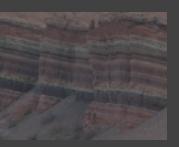
Crystalline (CHI 2022)



Wigglite (UIST 2022)



## Reusing



Strata (CSCW 2021)



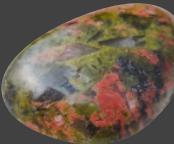
Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**



Selenite (2023)



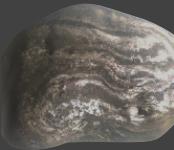
Unakite (UIST 2019)



Honorable Mention (top-6)



Crystalline (CHI 2022)



Wigglite (UIST 2022)



Strata (CSCW 2021)



Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**



Selenite (2023)



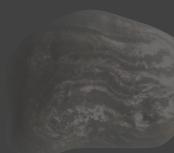
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Best paper (top 1%)

Assist reading & comprehension,  
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Minimize cognitive & physical cost,  
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Guide knowledge reuse evaluations,  
with **systematic framework + tools**

# Evaluating mental models is hard.

Author: Past me

	Intuitiveness	Popularity	Used by
React	👍	👍	Facebook
Angular	👍	👍	Google
Vue	👍	👎	Alibaba
EmberJS	👍	👎	Heroku

Reader: Current me...

Can I **trust** this table?



Is this **relevant** to what I want to do?



Is it **thorough**? Does it include everything?

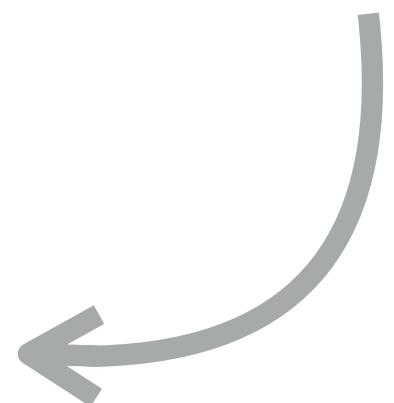
How can we help people evaluate **different aspects** of a mental model?

# Key observation:

Evidence in the table...

To compare performance, I did the following in iPython. It turns out that arrays are significantly faster.

	Faster	...
np.array	👍	...
np.matrix	👎	...
...		...



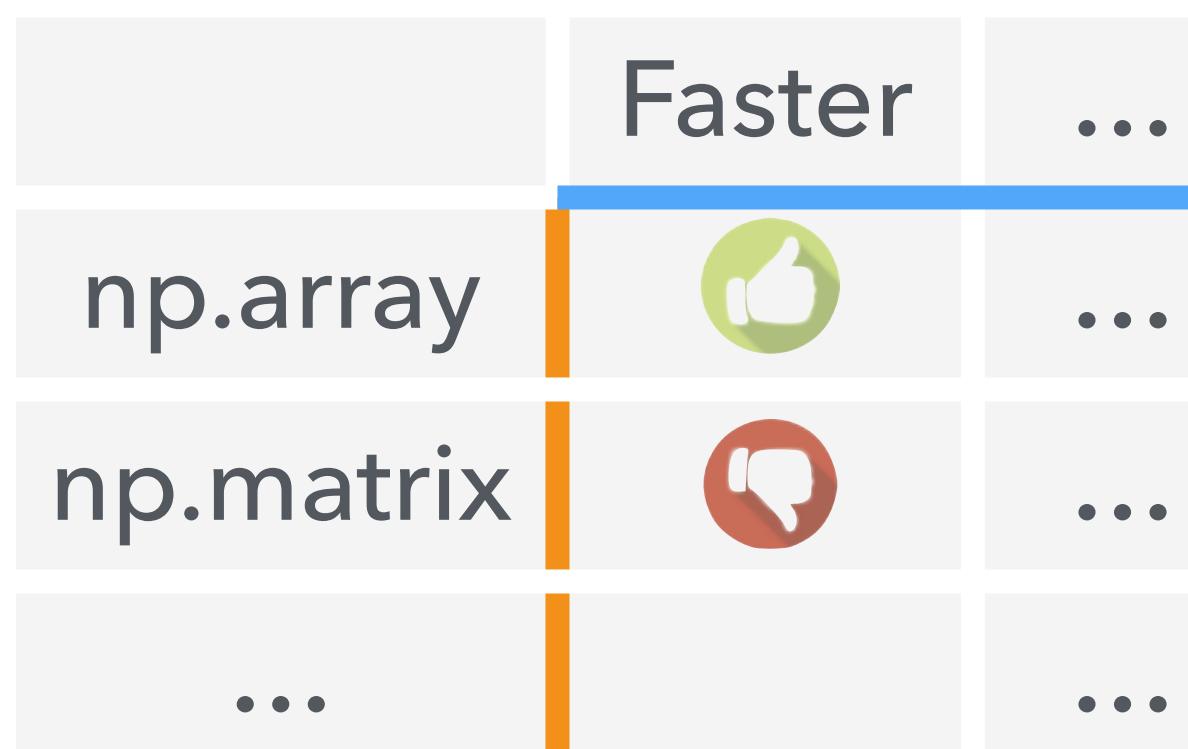
# Key observation:

## Evidence in the table...

Has richer context.

And the contexts are useful for evaluation!

*From interviews & prior work*



stack overflow About Products For Teams

## numpy np.array versus np.matrix (performance)

Asked 8 years, 4 months ago Active 1 year, 6 months ago Viewed 7k times

2 Answers

Active Oldest Votes

There is a general discussion on [SciPy.org](#) and on [this question](#).

To compare performance, I did the following in iPython. It turns out that arrays are significantly faster.

```
In [1]: import numpy as np
In [2]: %timeit
...: v = np.matrix([1, 2, 3, 4])
100000 loops, best of 3: 16.9 us per loop

In [3]: %timeit
...: w = np.array([1, 2, 3, 4])
100000 loops, best of 3: 7.54 us per loop
```

Therefore numpy arrays seem to have faster performance than numpy matrices.

*Versions used:*

Numpy: 1.7.1  
IPython: 0.13.2  
Python: 2.7

Share Improve this answer Follow edited May 23 '17 at 12:18 answered Jun 5 '13 at 8:46

Community Bot 1 ● 1 atomh33ls 24.1k • 20 ● 95 ● 149

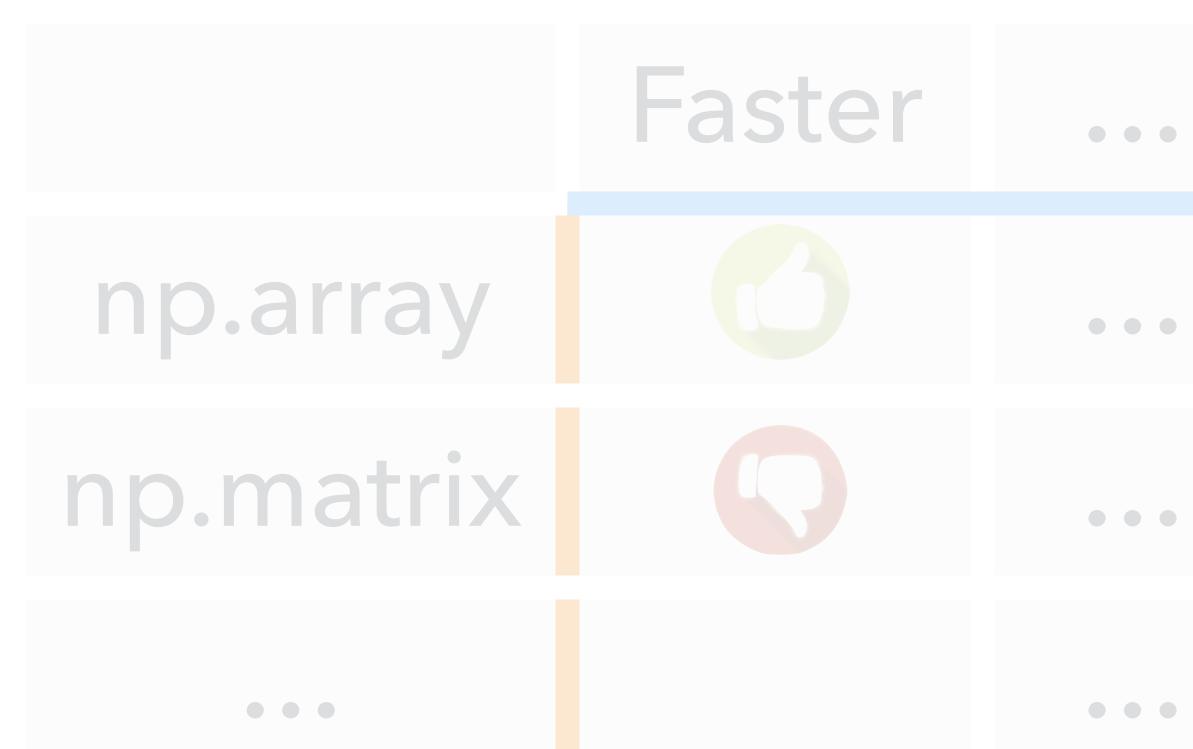
# Contexts are useful...



Is this **relevant** to what I want to do?

Title == search query?

Programming context?



stack overflow About Products For Teams

## np.array versus np.matrix (performance)

2 Answers Active Oldest Votes

There is a general discussion on [SciPy.org](#) and on [this question](#).

5 To compare performance, I did the following in iPython. It turns out that arrays are significantly faster.

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1.54 us per loop
```

**Versions used:**

Numpy: 1.7.1

iPython: 0.13.2

Python: 2.7

Share Improve this answer Follow edited May 23 '17 at 12:18 by Community Bot 1 ● 1 answered Jun 5 '13 at 8:46 by atomh33ls 24.1k ● 20 ● 95 ● 149

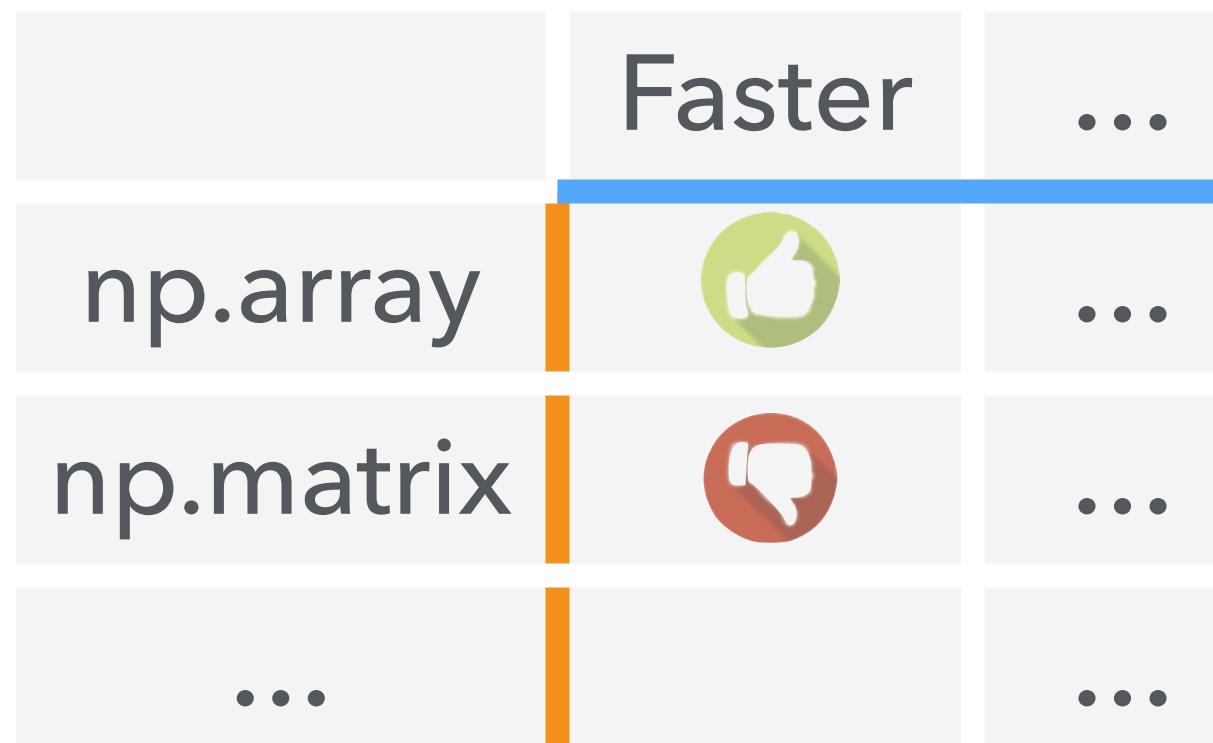
**Strata: A framework and a system** that systematically **extracts** and **visualizes** useful signals to help users evaluate mental models for reuse.

To Reuse or Not To Reuse? A Framework and System for Evaluating Summarized Knowledge

Michael Xieyang Liu, Aniket Kittur, Brad A. Myers.

CSCW 2021

🏆 Best Paper (top 1%)



stack overflow About Products For Teams

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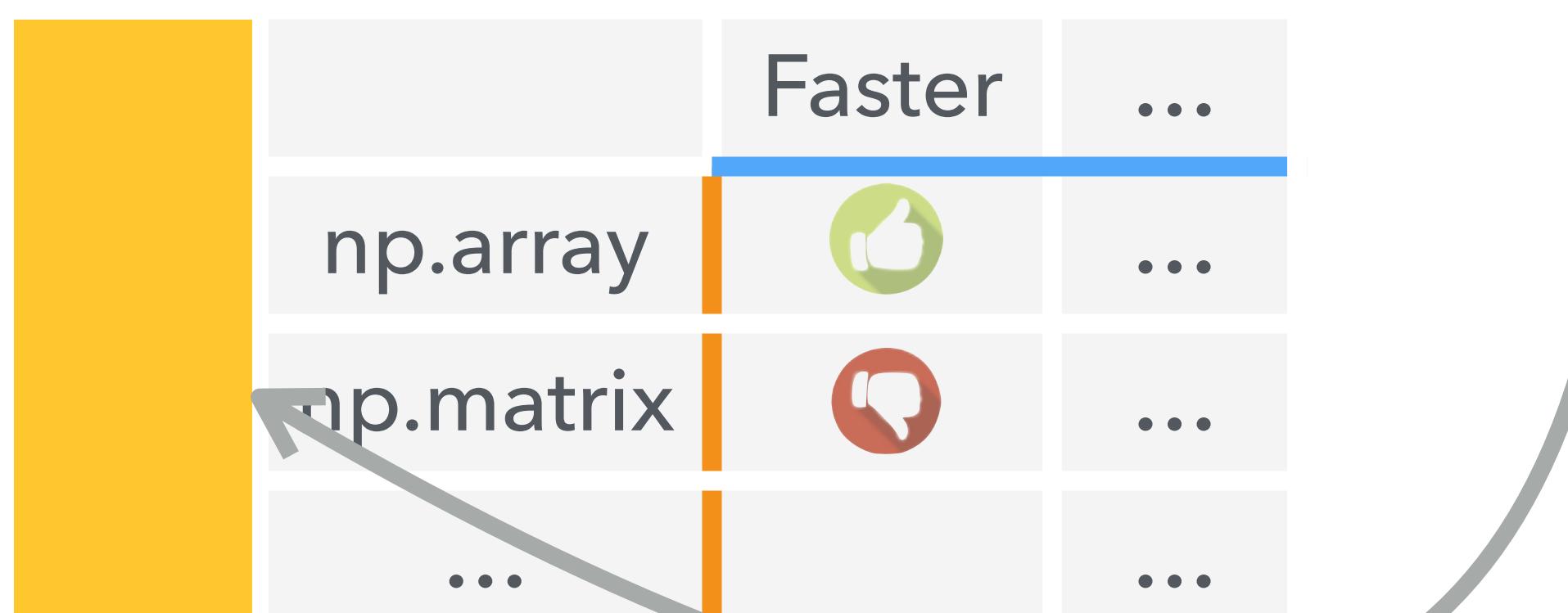
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stack overflow About Products For Teams

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Share Improve this answer Follow edited May 23 '17 at 12:18 by Community Bot 1 ● 1 answered Jun 5 '13 at 8:46 by atomh33ls 24.1k ● 20 ● 95 ● 149

**Search Queries**

Sort by: Timestamp Duration # of clips saved

G numpy.array vs numpy.matrix	5 clips
G numpy.array vs python.list	3 clips
G python.matrix data structure advantages and disadvantages	2 clips
G python.matrix data structure	2 clips
G numpy.matrix memory usage	0 clips
G numpy.array and python.list	0 clips

**Research process** No issues

**Time spent:** The author spent a total of about an hour on the task.  
The task was updated 19 days ago.

**Information collected:** The author went through 10 pages, and collected 12 snippets, of which 3 are options, 3 are criteria, and 6 are evidence clips.

**Timeline**

G numpy.array vs numpy.matrix	5 min
EE Python matrices - An Introduction	2 min
EE numpy.ndarray	
Matrix - how to represent matrices in python - Stack Overflow	1 min
EE python.list	

### More convenient

**NumPy ndarray**

**The advantage of matrix...**

[stackoverflow.com](#) 20 up votes updated 4 years ago

### Faster

**Arrays are faster than matrix**

[stackoverflow.com](#) 5 up votes accepted answer updated 3 months ago

### More efficient

**Consumes less memory**

[www.geeksforgeeks.org](#) updated 17 days ago

**Probable memory shortage**

[www.quora.com](#) updated a year ago

### NumPy matrix

**The advantage of matrix...**

[stackoverflow.com](#) 20 up votes updated 4 years ago

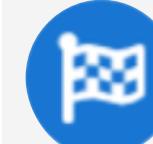
### List

**Array is convenient to use.**

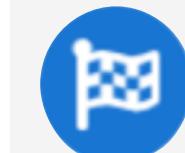
[www.geeksforgeeks.org](#) updated 17 days ago

### Consumes more memory

[www.geeksforgeeks.org](#) updated 17 days ago

	 <b>More convenient</b>	 <b>Faster</b>	 <b>More efficient</b>
<b>NumPy ndarray</b>	 The advantage of matrix...	 Arrays are faster than matrix	 Consumes less memory  Probable memory shortage
<b>NumPy matrix</b>	 The advantage of matrix...	 Arrays are faster than matrix	
<b>List</b>	 Array is convenient to use.		 Consumes more memory

## NumPy ndarray



### More convenient

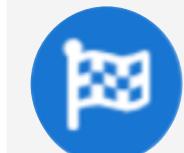


The advantage of matrix...

stackoverflow.com

20 up votes

updated 4 years ago



### Faster



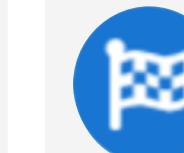
Arrays are faster than matrix

stackoverflow.com

5 up votes

accepted answer

updated 3 months ago



### More efficient



Consumes less memory

www.geeksforgeeks.org

updated 17 days ago



Probable memory shortage

www.quora.com

updated a year ago

## NumPy matrix



The advantage of matrix...

stackoverflow.com

20 up votes

updated 4 years ago



Arrays are faster than matrix

stackoverflow.com

5 up votes

updated 3 years ago

## List



Array is convenient to use.

www.geeksforgeeks.org

updated 17 days ago



Consumes more memory

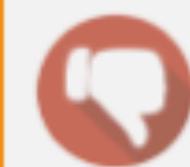
www.geeksforgeeks.org

updated 17 days ago

## NumPy ndarray



### More convenient



The advantage of matrix...

stackoverflow.com

20 up votes

updated 4 years ago

## NumPy matrix



The advantage of matrix...

stackoverflow.com

20 up votes

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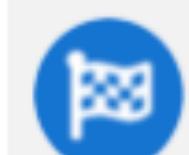
## List



Array is convenient to use.

www.geeksforgeeks.org

updated 17 days ago



### Faster



Arrays are faster than matrix

stackoverflow.com

5 up votes

accepted answer

updated 3 months ago



### More efficient



Consumes less memory

www.geeksforgeeks.org

updated 17 days ago



Probable memory shortage

www.quora.com

updated a year ago

# Also, a side panel for more summaries...

Search Queries

Sort by: Timestamp Duration # of clips saved

- G numpy array vs numpy matrix 5 clips
- G numpy array vs python list 3 clips
- G python matrix data structure advantages and disadvantages 2 clips
- G python matrix data structure 2 clips
- G numpy matrix memory usage 0 clips
- G numpy array and python list 0 clips

Research process

No issues

Time spent: The author spent a total of about an hour on the task.  
The task was updated 19 days ago.

Information collected: The author went through 10 pages, and collected 12 snippets, of which 3 are options, 3 are criteria, and 6 are evidence clips.

Timeline

- G numpy array vs numpy matrix 5 min
- Python matrices - An Introduction 2 min
  - G numpy ndarray
- Matrix - how to represent matrices in python - Stack Overflow 1 min
  - G python list

### More convenient

NumPy ndarray

The advantage of matrix... stackoverflow.com 20 up votes updated 4 years ago

### Faster

Arrays are faster than matrix stackoverflow.com 5 up votes accepted answer updated 3 months ago

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Arrays are faster than matrix stackoverflow.com 5 up votes updated 3 years ago

### More efficient

Consumes more memory www.geeksforgeeks.org updated 17 days ago

### More convenient

List

Array is convenient to use. www.geeksforgeeks.org updated 17 days ago

Guide users interpret the trustworthiness, relevance, and thoroughness of a Unakite table!

# Evaluating Mental Model Trustworthiness

S

G n  
G n  
G p a  
G p  
G n  
G n  
F  
Ti Ti  
In cc 6  
Timeli  
G nur  
ee  
use.

## Domains

1 issue

**Credibility** - 1 of the domains is not on the trusted whitelist:  
- [www.techgeekbuzz.com](http://www.techgeekbuzz.com) *add as trusted*

[whitelist of trusted domains]

**Diversity** - Information are from 4 different domains, the most-used one being [stackoverflow.com](http://stackoverflow.com), which is where 58% of the snippets are collected from.

List of source domains

<a href="http://stackoverflow.com">stackoverflow.com</a>	7 snippets
<a href="http://www.geeksforgeeks.org">www.geeksforgeeks.org</a>	2 snippets
<a href="http://www.quora.com">www.quora.com</a>	2 snippets
<a href="http://www.techgeekbuzz.com">www.techgeekbuzz.com</a>	1 snippets

Faster More efficient

Arrays are faster than matrix Consumes less memory

Can I **trust** this table?

Summarize various sources information are gathered from for readers' overview.

Consumes more memory

updated 17 days ago

# Evaluating Mental Model Trustworthiness

ient

NumPy  
ndarray

Matrix

The advantage of matrix

stackoverflow.com

20 up votes

updated 4 years ago

Arrays are faster than matrix

stackoverflow.com

5 up votes

accepted answer

updated 3 months ago

Consumes less memory

www.geeksforgeeks.org

updated 17 days ago

Probable memory shortage

www.quora.com

updated a year ago



Can I **trust** this table?

Link evidence with its **popularity** and **up-to-dateness**.

# Evaluating Mental Model Trustworthiness

NumPy  
ndarray

The advantages of NumPy ndarray:

- consumes less memory.
- fast as compared to the python List.
- convenient to use.

NumPy  
matrix

The advantages of NumPy matrix:

- The list can be homogeneous or heterogeneous.
- Element wise operation is not possible in list.
- Python list are by default 1 dimensional. But we can create a n Dimensional list .But then to it will be 1 D

Example 1:

- consumes less memory.

## Example 1:

- consumes less memory.
- fast as compared to the python List.
- convenient to use.

- The list can be homogeneous or heterogeneous.
- Element wise operation is not possible in list.
- Python list are by default 1 dimensional. But we can create a n Dimensional list .But then to it will be 1 D

Showing:  snippet  surroundings

Consumes less memory

www.geeksforgeeks.org

updated 2 years ago

stackoverflow.com

20 up votes

updated 4 years ago

www.geeksforgeeks.org

updated 17 days ago

www.quora.com

updated a year ago



Can I **trust** this table?

Link evidence with its **original context**.

# Evaluating Mental Model Trustworthiness

**Domains** [1 issue]

Credibility - 1 of the domains is not on the trusted whitelist:  
- [www.techgeekbuzz.com](http://www.techgeekbuzz.com) *add as trusted*

[whitelist of trusted domains]

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Domain	Upvotes	Accepted Answer	Last Update
<a href="http://stackoverflow.com">stackoverflow.com</a>	7 s		updated 4 years ago
<a href="http://www.geeksforgeeks.org">www.geeksforgeeks.org</a>	2 s		updated a year ago
<a href="http://www.quora.com">www.quora.com</a>	2 s		
<a href="http://www.techgeekbuzz.com">www.techgeekbuzz.com</a>	1 snippets		

**Arrays are faster than matrix**

[stackoverflow.com](http://stackoverflow.com)  
5 up votes  
accepted answer  
updated 3 months ago

**Consumes less memory**

[www.geeksforgeeks.org](http://www.geeksforgeeks.org)  
updated 17 days ago



Can I **trust** this table?

Core support: Reconstruct the information source!

# Evaluating Mental Model Thoroughness

## ✓ Research process

No issues

✓ **Time spent:** The author spent a total of about an hour on the task.  
The task was updated 19 days ago.

✓ **Information collected:** The author went through 10 pages, and collected 12 snippets, of which 3 are options, 3 are criteria, and 6 are evidence clips.

## Timeline

G numpy array vs numpy matrix

5 min

ee Python matrices - An Introduction

2 min

numpy ndarray

Matrix - how to represent matrices in python -  
Stack Overflow

1 min

python list

P Python Matrix and Introduction to NumPy -  
Program

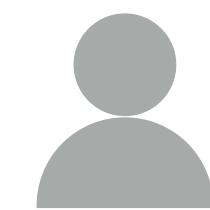
1 min

Fast

More efficient

matrix... Arrays are faster than matrix

Consumes less memory



Is it **thorough**? Does it include everything?

Visualize the **research trajectory** and **spent effort**.

Consumes more memory

www.geeksforgeeks.org

updated 17 days ago

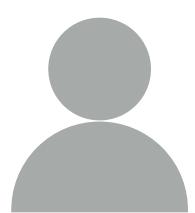
# Evaluating Mental Model Thoroughness

The screenshot shows a digital interface for evaluating mental models. At the top left is a search bar with the query "numpy array vs numpy matrix". Below it is a section titled "Evidence Snippets" with a red header. This section contains three items:

- More convenient**: A blue icon with a flag. Description: "The advantage of matrix...". Status: 2 issues.
- Faster**: A blue icon with a flag. Description: "Arrays are faster than lists because they are...". Status: 1 up vote, updated 17 days ago.
- Consumes less memory**: A green icon with a thumbs up. Description: "arrays consume less memory than lists because they share the same memory space...". Status: DG [www.geeksforgeeks.org](http://www.geeksforgeeks.org), updated 17 days ago.

The "Evidence Snippets" section also includes a summary of its own metrics:

- Evidence popularity**: 3 evidence snippets received at least 5 up-votes on Stack Overflow.
- Up-to-dateness**: The oldest snippet was updated 4 years ago.
- Evidence consistency**: There is 1 cell with conflicting evidence.



Is it **thorough**? Does it include everything?

Alert evidence **inconsistency**

# Evaluating Mental Model Thoroughness

The screenshot shows a search interface with a sidebar of search history and a main search results area. The search bar contains 'numpy array vs'. The results are categorized into three columns:

- More convenient**: Shows a snippet from 'The advantages of matrix' comparing numpy arrays and matrices.
- Faster**: Shows a snippet from 'Arrows are faster than matrix' comparing numpy arrays and matrices.
- More efficient**: Shows snippets from 'Consumes less memory' (geeksforgeeks.org) and 'Probable memory shortage' (quora.com).

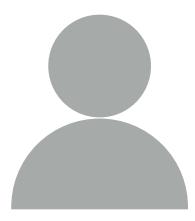
The main result for 'numpy array vs' is highlighted and expanded:

**numpy matrix**

Commonly searched for alternatives: **pandas dataframe**, **numpy ndarray**, **python lists**, **set**, **tuple**

20 up votes, updated 4 years ago

5 up votes, updated 3 years ago



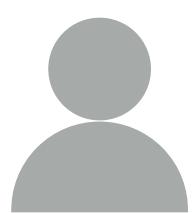
Is it **thorough**? Does it include everything?

Suggest **alternative** search

# Evaluating Mental Model Thoroughness

The screenshot shows a digital workspace interface with several cards:

- Research process:** A green card under "Search C..." showing "Time spent" (19 days ago) and "Information collected" (12 snippets, 3 options, 6 evidence clips). It also lists "numpy array vs numpy matrix" and "Python matrices - An Introduction" in the timeline.
- Evidence Snippets:** A red card with "No issues" and "Evidence Snippets". It includes "Evidence popularity" (3 snippets with at least 5 up-votes), "Up-to-dateness" (oldest snippet updated 4 years ago), and "Evidence consistency" (1 consistent evidence snippet).
- numpy matrix:** A white card with "2 issues". It features an orange icon, the text "numpy matrix", and a list of commonly searched alternatives: "pandas dataframe", "numpy ndarray", "python lists", "set", and "tuple". It also shows "5 up votes" and was last updated 3 years ago.



Is it **thorough**? Does it include everything?

Core support: reflect & alert  
conflicts & potentials for extension.

# Evaluating Mental Model Relevance

The screenshot shows a search interface with the following sections:

- Search Queries**:
  - Sort by: Timestamp Duration # of clips saved
  - G numpy array vs numpy matrix 5 clips
  - G numpy array vs python list 3 clips
  - G python matrix data structure advantages and disadvantages 2 clips
  - G python matrix data structure 2 clips
  - G ... 2 clips
  - G ... 2 clips
- Languages, frameworks, & platforms**:
  - Languages**: Python v2.7
  - Libraries & frameworks**: Numpy v1.7.1
  - Platforms**: No platform information is detected for now.

The screenshot shows a comparison interface with the following sections:

- More convenient**:
  - Faster
  - Arrays are faster than matrix
- More efficient**:
  - Consumes less memory

A speech bubble icon with the text: "Is this **relevant** to what I want to do?" is overlaid on the interface.

Core support: Reconstruct the information foraging trajectory!

# Study: evaluating if to reuse mental models

N=20, between-subjects, Unakite as baseline

With Strata, users explained their rationale for reuse...

in **33%\* less** time

with **126%\* more** valid & high-quality reasons.

\* denotes statistically significant differences ( $p < 0.05$ )

# Study: evaluating if to reuse mental models

N=20, between-subjects, Unakite as baseline

Strata provides **guidance** for verification.

*"It serve(d) as a comprehensive guidance for things that I should pay attention to..."*

in 33%\* less time

with 126

Strata **reminds** users of important signals to check that they would otherwise overlook.

*"I realize that I'm more of a grab-and-go kinda person and I don't usually remember to check how many up-votes a Stack Overflow answer gets or when it was last updated..."*

\* denotes statistically significant differences ( $p < 0.05$ )



Selenite (2023)



Unakite (UIST 2019)



Honorable Mention (top-6)



Crystalline (CHI 2022)



Wigglite (UIST 2022)



Strata (CSCW 2021)



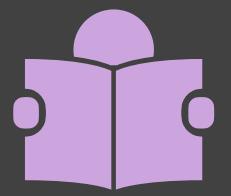
Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
through **lightweight interactions**

Guide knowledge reuse evaluations,  
with **systematic framework + tools**

# Summary of Contributions



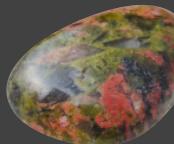
## Reading



Selenite (2023)



## Externalizing



Unakite (UIST 2019)



Honorable Mention (top-6)



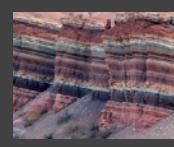
Crystalline (CHI 2022)



Wigglite (UIST 2022)



## Reusing



Strata (CSCW 2021)



Best paper (top 1%)

Assist reading & comprehension,  
via **AI-retrieved global perspectives**

Minimize cognitive & physical cost,  
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Guide knowledge reuse evaluations,  
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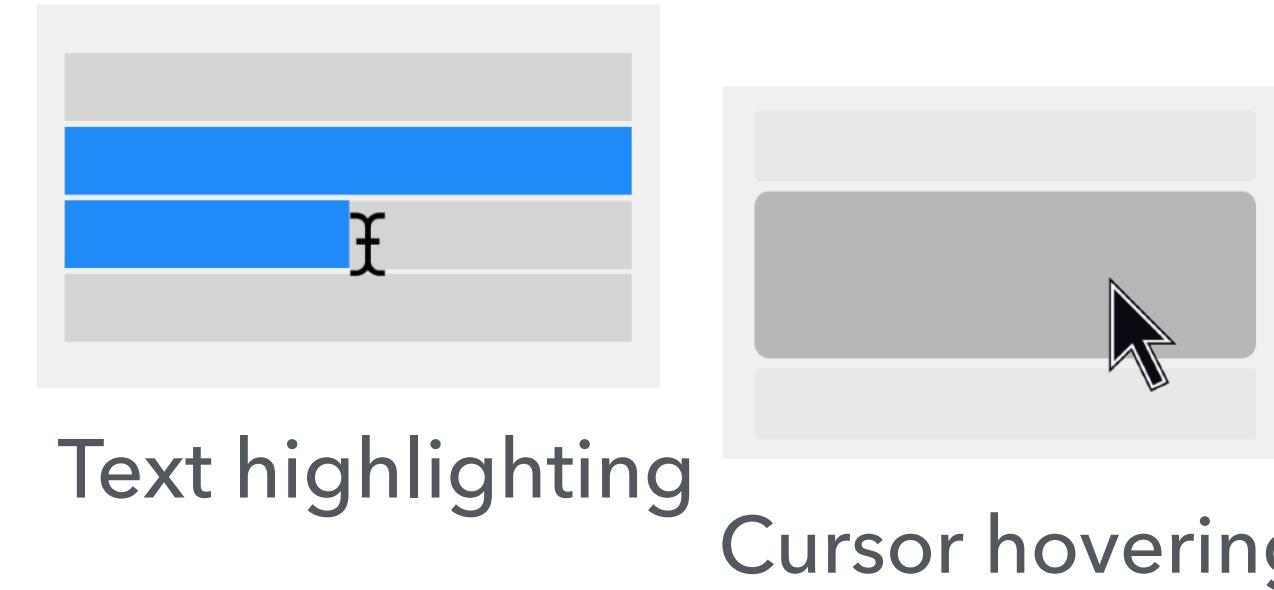
# Overall Takeaways

**Lightweightness:** Minimize the overhead of externalizing through interaction design

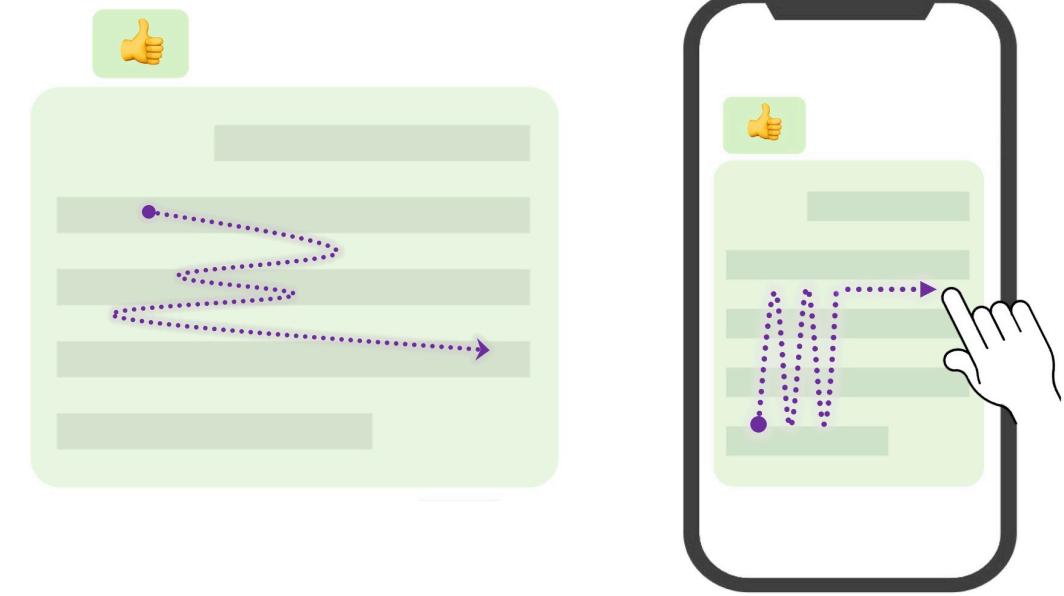
Reduce context switch

	Fast?	Community
React	Yes	Really large
Angular	?	Also large
Vue	Yes	?

Harvest implicit human behavior



Utilize intuitive gestures



**Augmentation:** Help people comprehend existing info. by providing context

Guide reading for deeper comprehension

Cleaning performance <sup>31</sup> Navigation and mapping <sup>28</sup>  
Battery life and runtime <sup>10</sup> Dustbin capacity Noise level  
**Smart features and connectivity** 28 mentions < 3rd > ↑ ⊗  
*the availability of advanced features such as app control, voice control, scheduling, and integration with*

Guide evidence eval. for knowledge reuse

Domains 1 issue  
**Credibility** - 1 of the domains is not on the trusted whitelist:  
- [www.techgeekbuzz.com](http://www.techgeekbuzz.com)  
[whitelist of trusted domains]  
**Diversity** - Information are from 4 different domains, the most-used one being [stackoverflow.com](http://stackoverflow.com), which is where 58% of the snippets are collected from.  
**Consumes less memory**  
[www.geeksforgeeks.org](http://www.geeksforgeeks.org)  
updated 17 days ago

# Future Work

**Lightweightness:** lightweight interactions



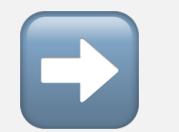
**lightweight & flexible structures?**

	Intuitiveness	Popularity	Used by
React	👍	👍	Facebook
Angular	👍	👍	Google
Vue	👍	👎	Alibaba
EmberJS	👍	👎	Hercules

Existing table structure can be **too rigid** for some use cases, especially in early sensemaking stages.

Can we support **multiple different structures** (e.g., lists, trees, maps, etc.) , as well as **fluid transition** between those structures?

**Augmentation:** augmented reading & understanding



**augmented searching?**

The screenshot shows a search interface with the query "compare google and microsoft". The results page displays a snippet from Google's official website, followed by a "People also ask" section and a "Latest from microsoft.com" section. A red arrow points from the Microsoft section to the right panel.

The screenshot shows an AI-generated comparison article titled "compare google and microsoft". The article discusses the similarities and differences between Google and Microsoft, mentioning search engine dominance, product offerings, and market capitalization. A yellow thinking emoji is overlaid on the left side of the article, and a red arrow points from the Microsoft search result in the previous panel to this article.

How do we integrate the AI data source into users' **natural search flow**, possible by leveraging **existing UI affordances and interactions**?

# Conclusion

I design and build **user interfaces, interactions, and computational scaffolds** that enable **initial users**  to more efficiently and effectively **read, comprehend, collect, and organize** information to make and justify decisions, while automatically capturing the sensemaking context to help **subsequent people**  **understand** and **evaluate** those decisions.

- Investigated this core thesis by designing and building five systems.
- Through lab and case studies, I demonstrated how users can benefit from sensemaking systems that minimize interaction costs as well as provide appropriate augmentation.



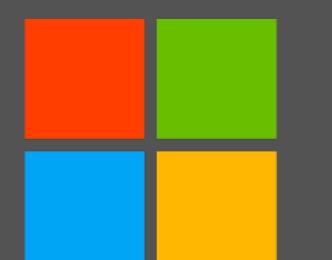
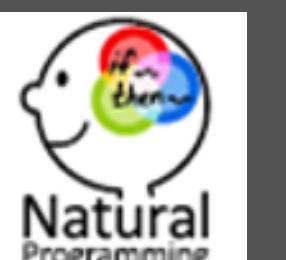
Committee



Thank you ❤️

Collaborators, friends,

R2, participants, & instant noodle



BOSCH

Sponsors

Tuesday, July 25, 2023



*Ph.D. thesis defense*

# Tool Support for Knowledge Foraging, Structuring, & Transfer During Online Sensemaking

**Michael Xieyang Liu**

@lxieyang(@hci.social) / xieyangl@cs.cmu.edu

**CMU HCII**

Committee  
Brad A. Myers  
Aniket Kittur  
Kenneth Holstein  
Daniel M. Russell