Experimental design and analysis

Experiment programming

https://www.lri.fr/~appert/eval/

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Project: hypotheses to test

Pick two visual variables of your choice (e.g., color, size, shape, shadow, etc.). Let's call them VV_1 and VV_2.

- Research hypotheses:
  - H_1: VV_1 is preattentive
  - H_2: VV_2 is preattentive
  - H_3: VV1 and VV2 combined are less preattentive than VV1 or VV2 in isolation

Operationalization

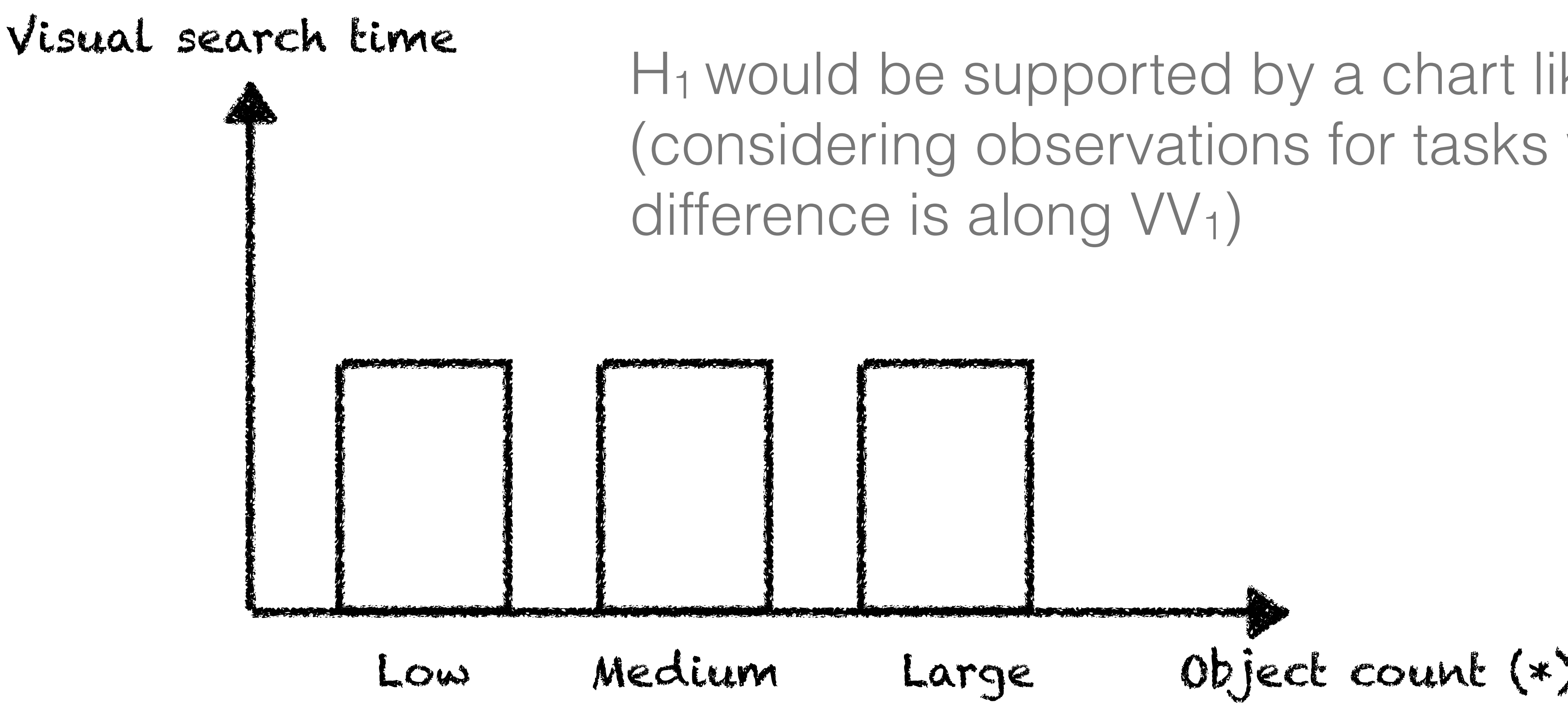
We refine what *preattentive* means:

A visual variable is preattentive when the **visual search time** for the only object that differs from a collection because of this visual variable **is not affected by the number of objects in the collection**.

Operationalization

We identify factors and measures

Sketching the charts you would like to report helps a lot

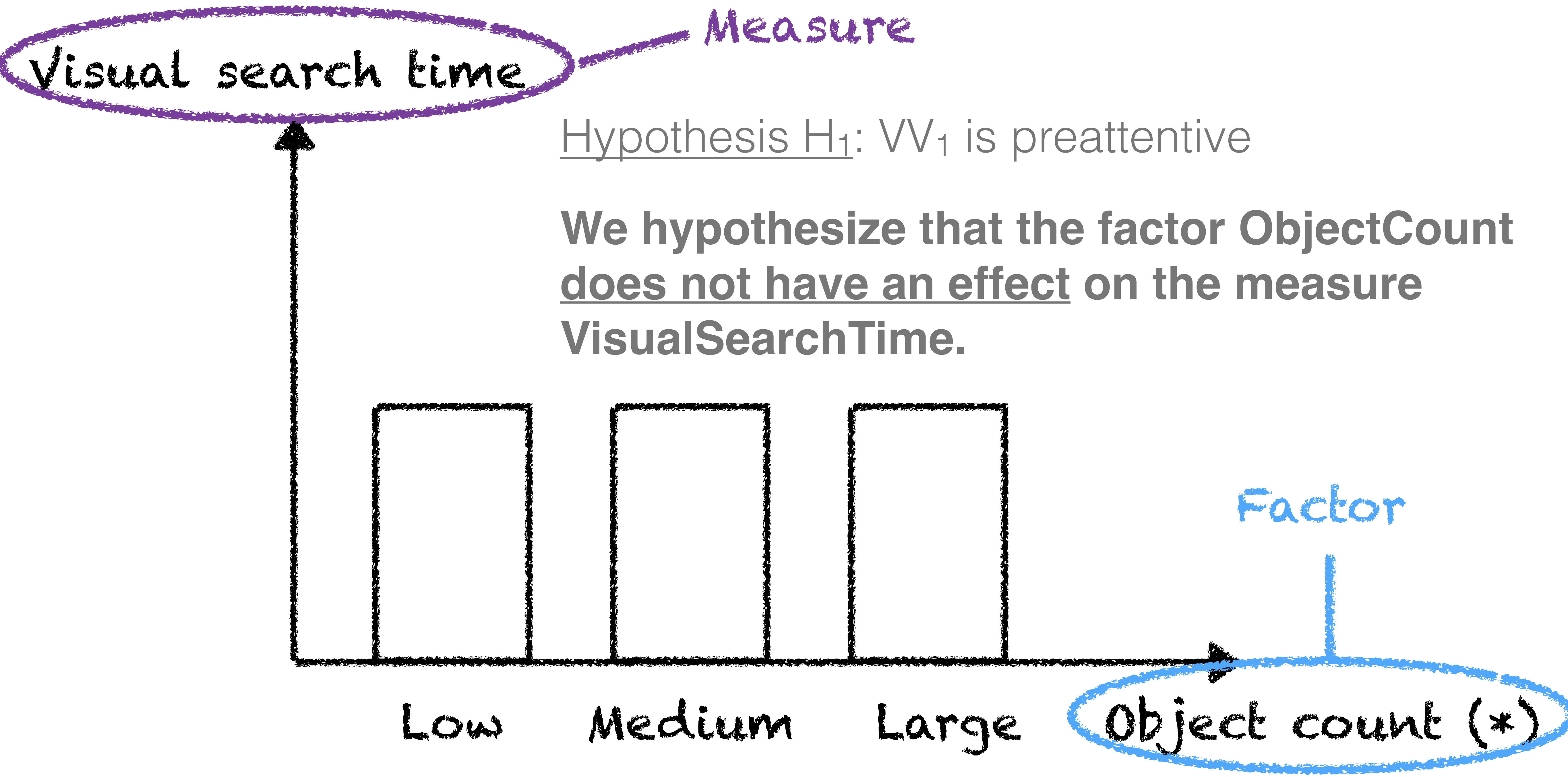


Hypothesis H_1: VV_1 is preattentive

H_1 would be supported by a chart like this one (considering observations for tasks where the difference is along VV_1)

(*) Number of objects in the collection

Operationalization



Hypothesis H_1: VV_1 is preattentive

We hypothesize that the factor ObjectCount does not have an effect on the measure VisualSearchTime.

(*) Number of objects in the collection

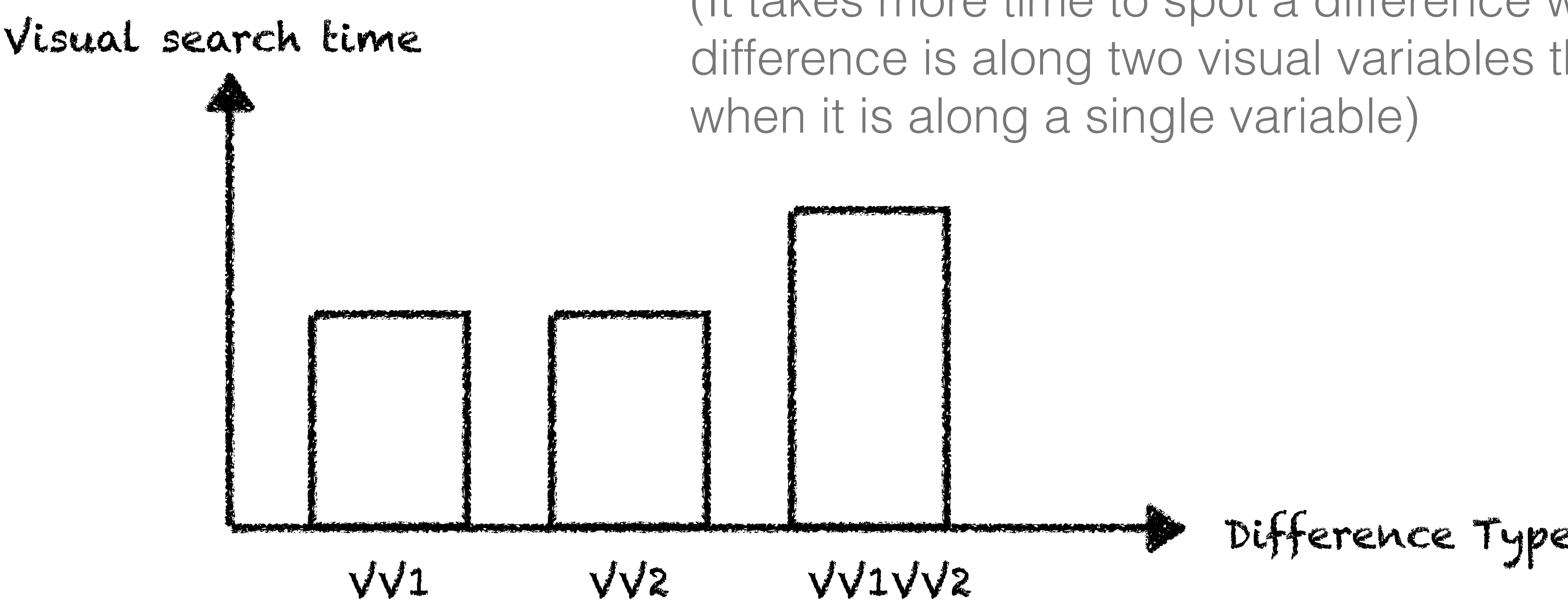
Operationalization

We identify factors and measures

Sketching the charts you would like to report helps a lot

Hypothesis H_3: VV_1 and VV_2 combined are less preattentive than VV_1 or VV_2 in isolation

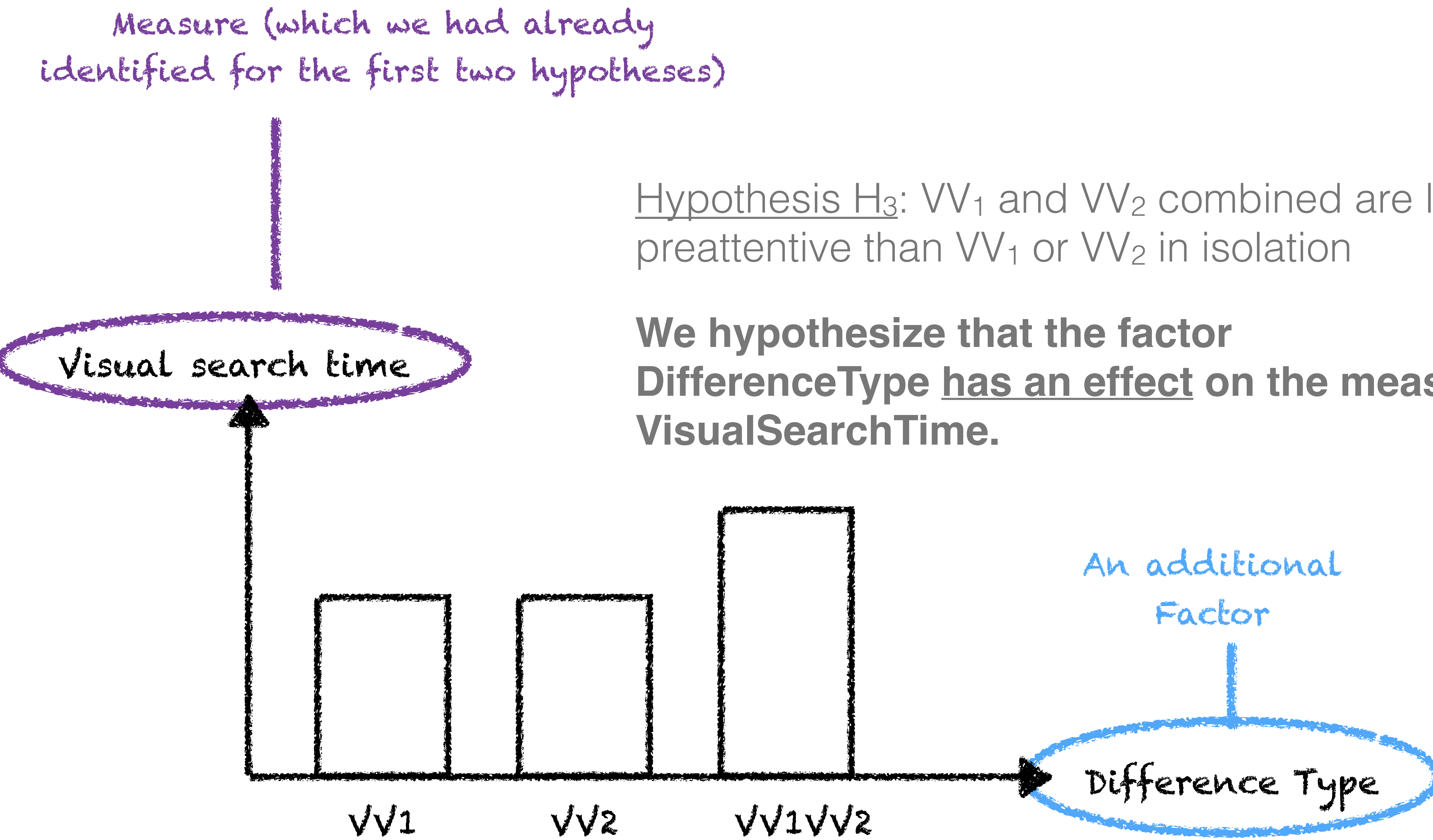
(It takes more time to spot a difference when the difference is along two visual variables than when it is along a single variable)



Operationalization

Hypothesis H_3: VV_1 and VV_2 combined are less preattentive than VV_1 or VV_2 in isolation

We hypothesize that the factor DifferenceType has an effect on the measure VisualSearchTime.



Operationalization

Factors:

OC: ObjectCount

{Low, Medium, Large}

DT: Difference Type

{VV1, VV2, VV1VV2}

Task?

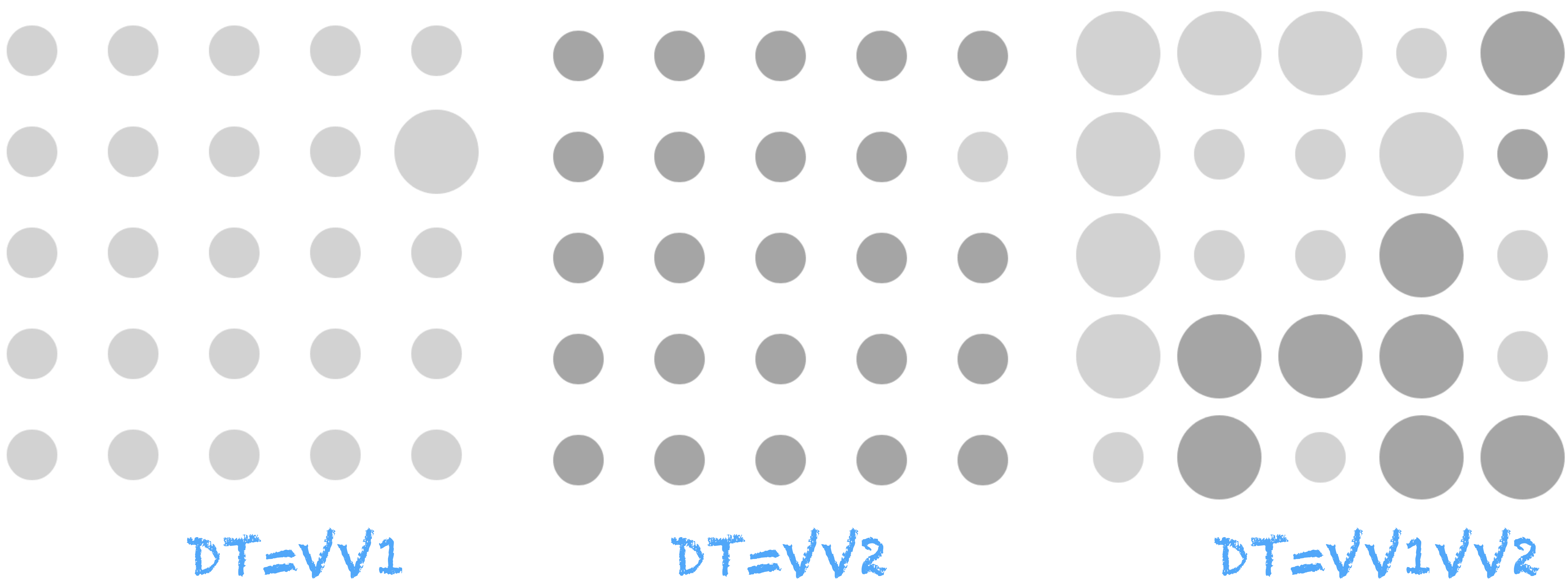
Measure:

Visual Search Time

Operationalization - task

Stimulus: present a collection of objects where only one object is different from all the other objects

Example with VV1=Size and VV2=Color



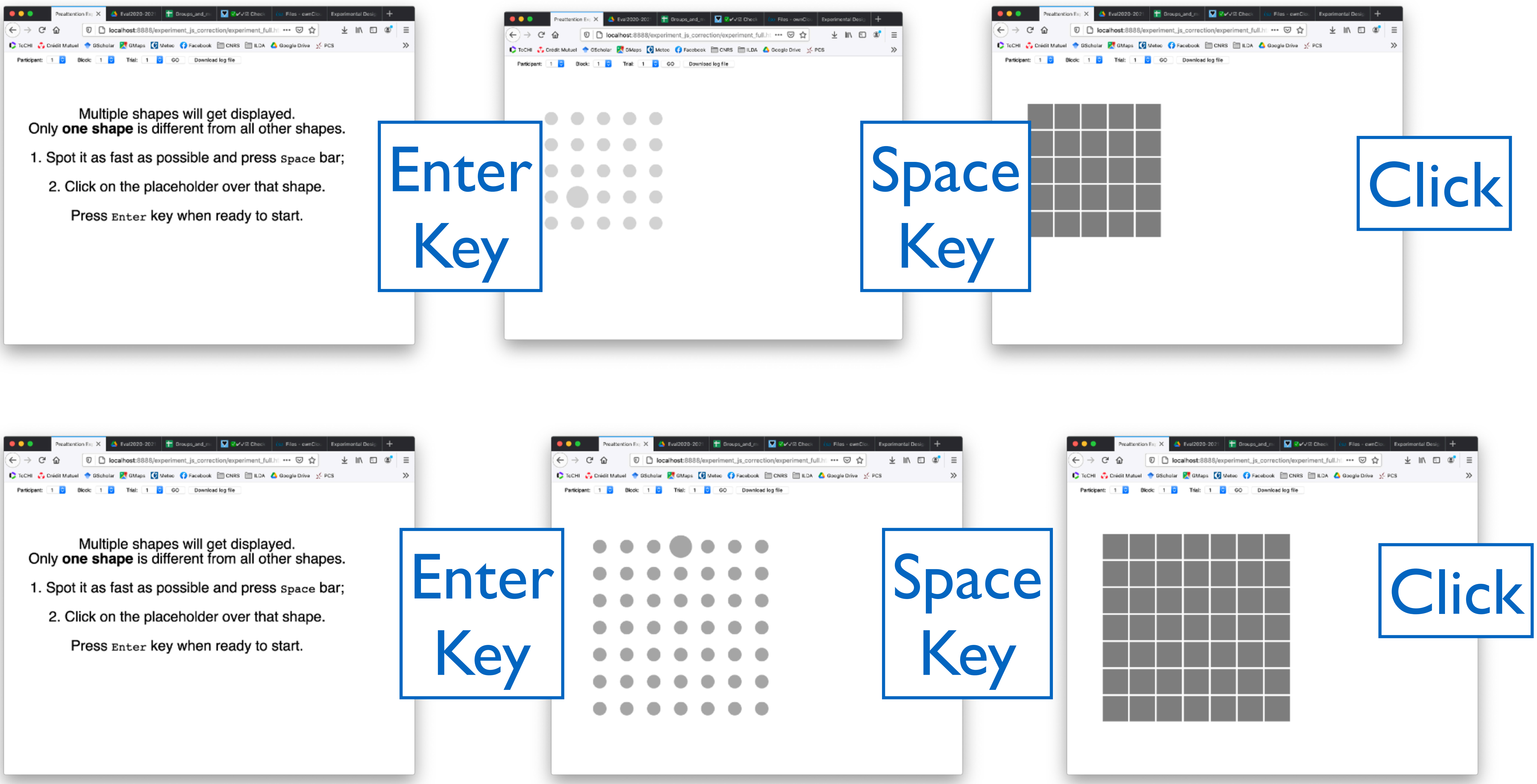
Operationalization - task

Response: the participant finds the different object

How to measure visual search time?

- Only visual search: stop timer at ~~pointing~~ (no!), stop timer at key press (yes!)
- Make sure the participant spots the right object: 2-step task with first key press then click on placeholders
- Avoid an "animation effect" by using placeholders that are clearly different from all objects in the collection

Experiment storyboard



…

Operationalization - task

Make sure that you give **all the necessary details** to ensure replicability of your experiment by others

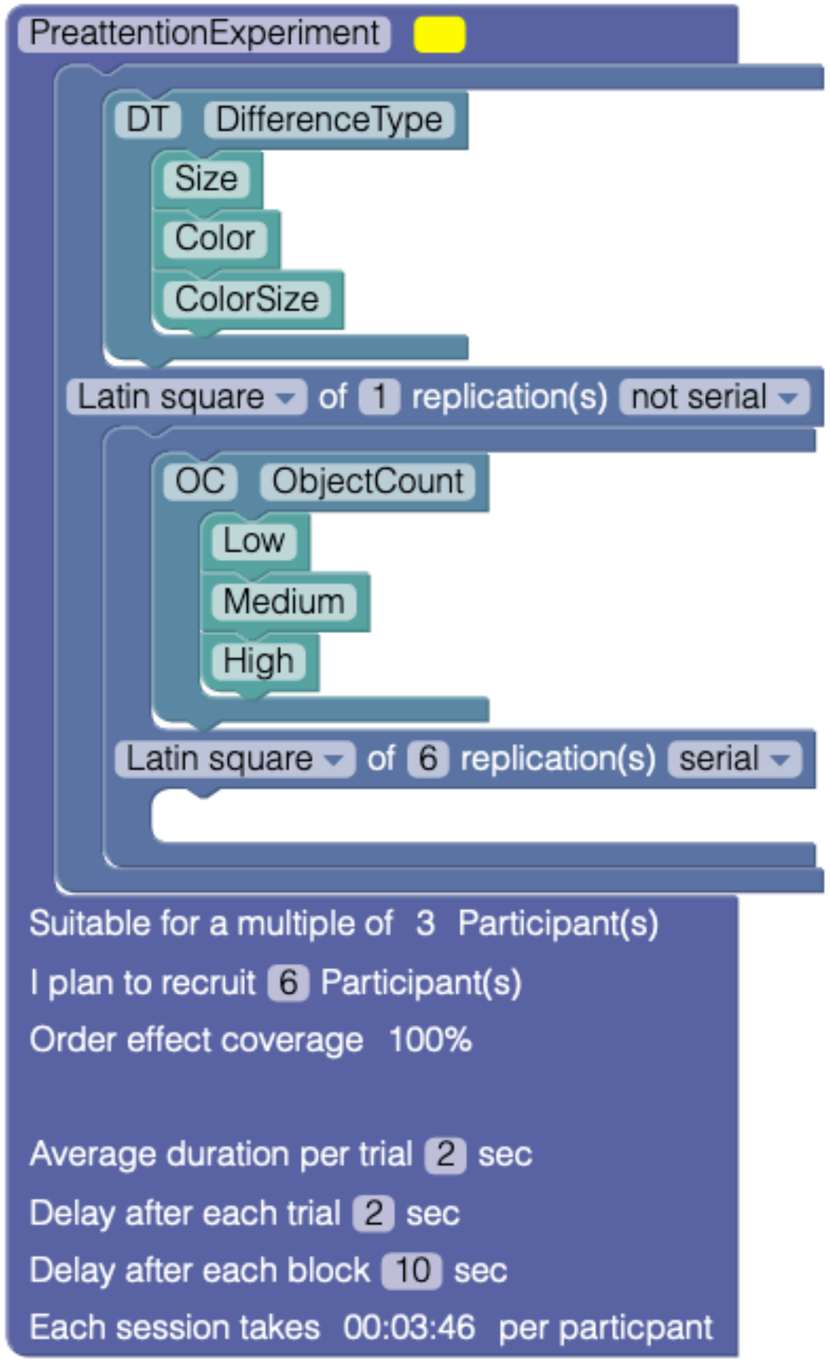
Participants must identify the object with a unique appearance as quickly as possible. They press 'Enter' when ready, and a scene with multiple shapes appears, starting the timer. As soon as they spot the distinct object, they press 'Space', stopping the timer. All objects are thus turned into generic square placeholders at their original locations... etc.

Make the design formal with TouchStone 2 (20')

Two constraints:

- You need at least 30 measures per condition overall to run inferential statistics
- You have access to 6 participants

TouchStone 2



Design description

Here again, make sure that you give **all the necessary details** to ensure replicability of your experiment.

The experiment tests two factors (DT and OC) according to a within-subject design.

Trials are blocked by DifferenceType (DT), and then by ObjectCount (OC). Presentation order of DT blocks and OC sub-blocks are counterbalanced using a LatinSquare. Each sub-block contains 6 replications of the task in the corresponding DTxOC condition.

In total, we collect:

6 participants x 3 DT x 3 OC x 6 replications = 324 trials

Experiment programming

Experiment programming I/O

experiment design (TouchStone csv output)

```
DesignName,ParticipantID,TrialID,Block1,Block2,DT,OC
PreattentionExperiment,1,1,1,1,Color,Medium
PreattentionExperiment,1,2,1,1,Color,Medium
PreattentionExperiment,1,3,1,1,Color,Medium
...
PreattentionExperiment,6,268,3,3,Color,Medium
PreattentionExperiment,6,269,3,3,Color,Medium
PreattentionExperiment,6,270,3,3,Color,Medium
```

`experiment_touchstone2.csv`

↓

experiment program

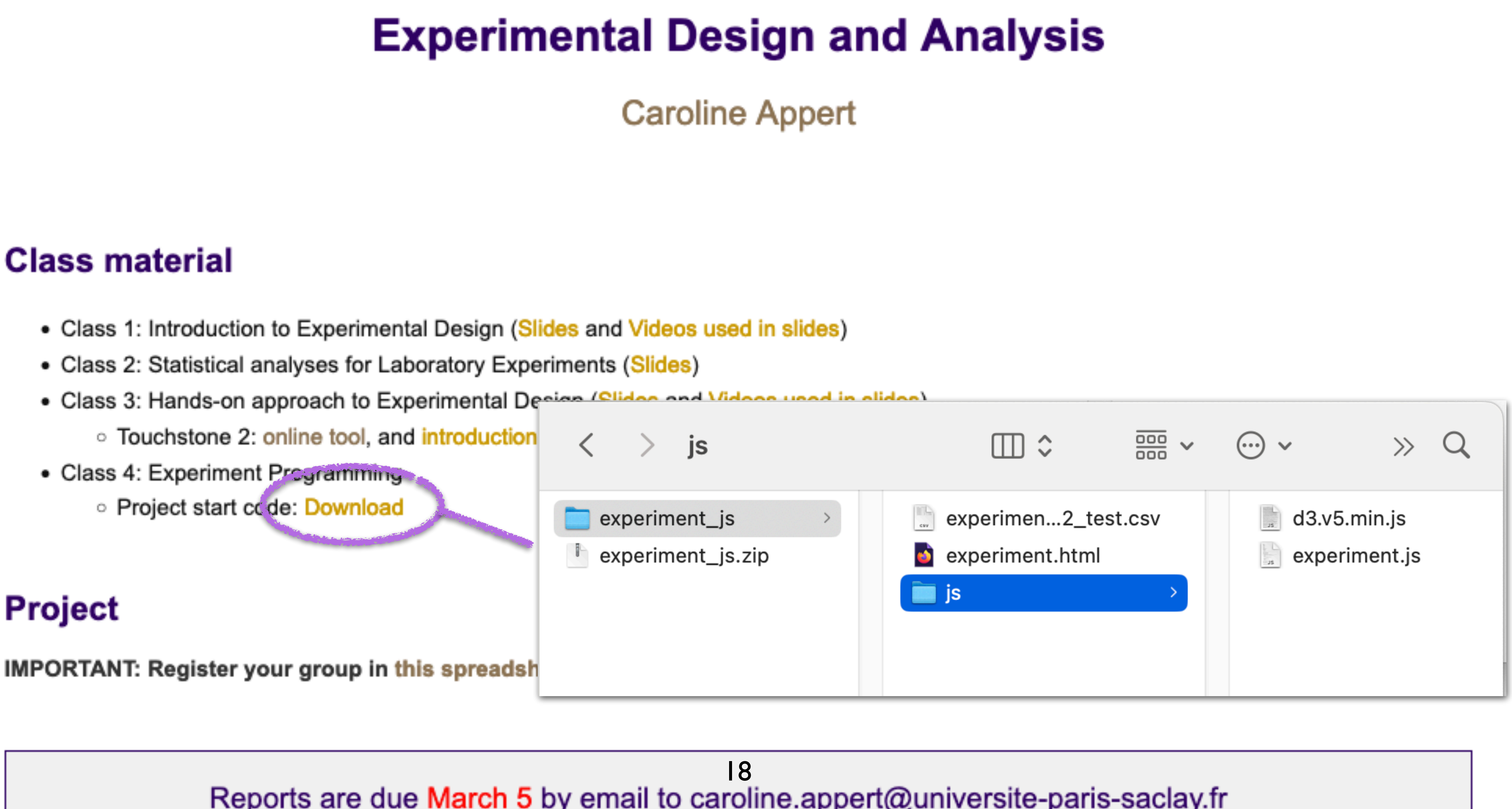
↓

log file (csv file for your statistical analyses)

```
DesignName,ParticipantID,TrialID,Block1,Block2,DT,OC,visualSearchTime,ErrorCount
PreattentionExperiment,1,1,1,1,Color,Medium,1632,0
PreattentionExperiment,1,2,1,1,Color,Medium,1552,1
PreattentionExperiment,1,3,1,1,Color,Medium,2030,0
...
```

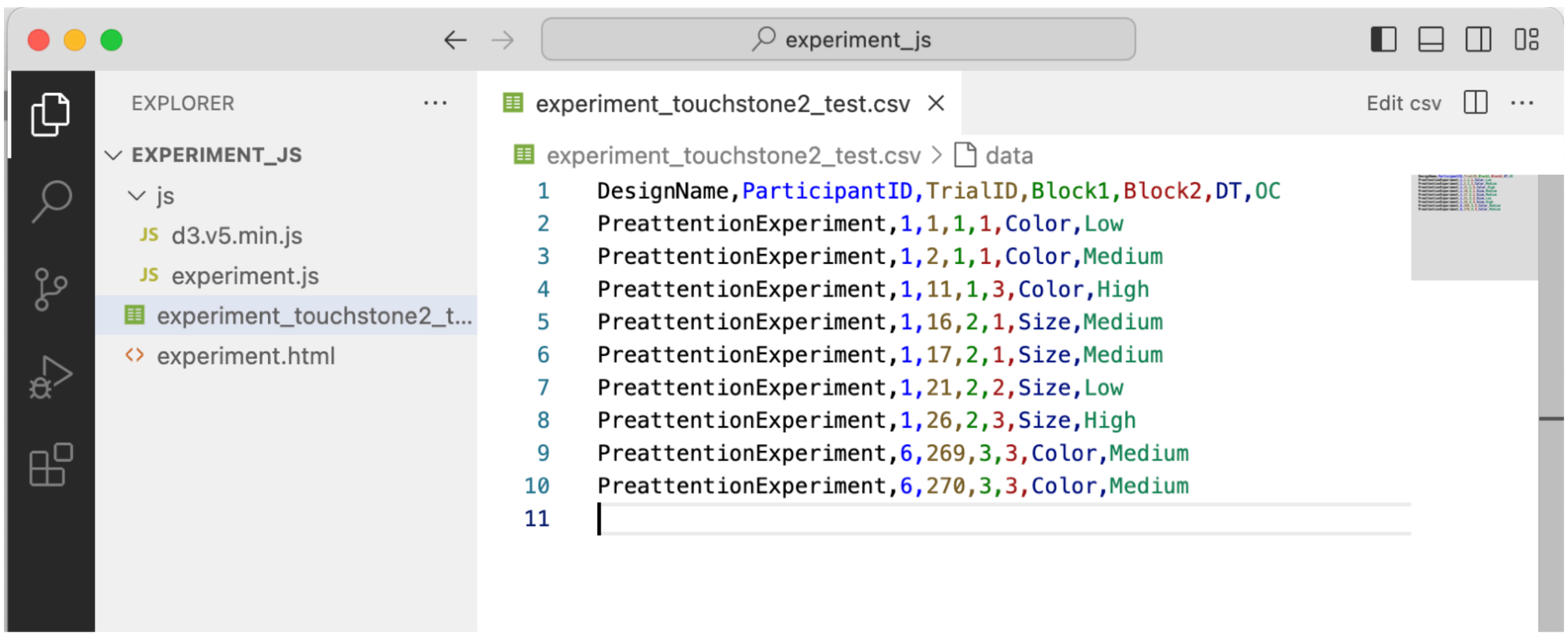
Getting started

Download JavaScript code skeleton on class website



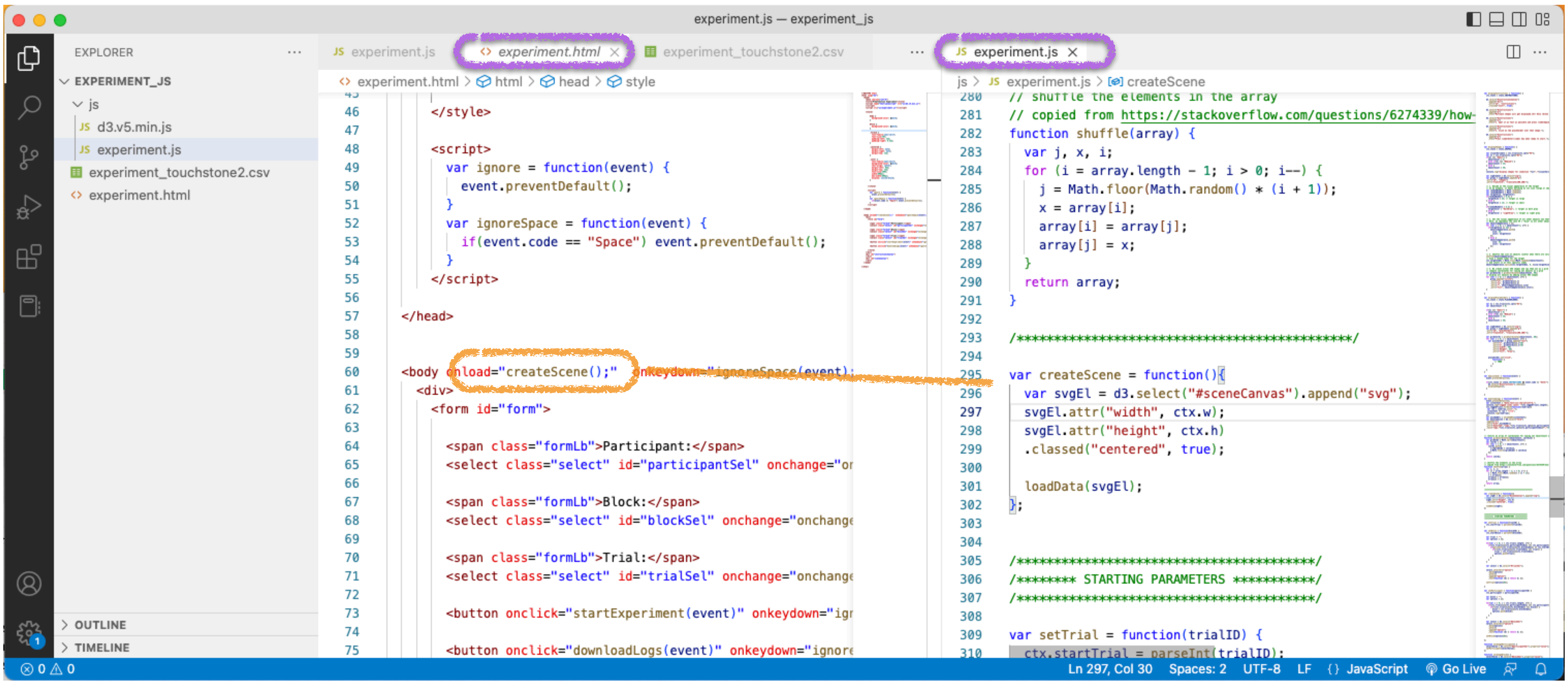
Getting started

`experiment_touchstone2_test.csv` is just an excerpt from a TouchStone2 design file. You have to replace it with your own design.



Two main files: `experiment.html` and `experiment.js`

We will modify `experiment.js` only



At page loading time, function `createScene` is called.

`createScene` then calls `loadData`.

`loadData` needs to access the CSV design file output by TouchStone, which is a local file on your system

Use a (local) Web server to serve local files with HTTP

Option 1

Launch an HTTP server in the TD's directory

`> cd experiment_js/`

`> python -m http.server 8888` (python 3) or `> python -m SimpleHTTPServer 8888` (python 2)

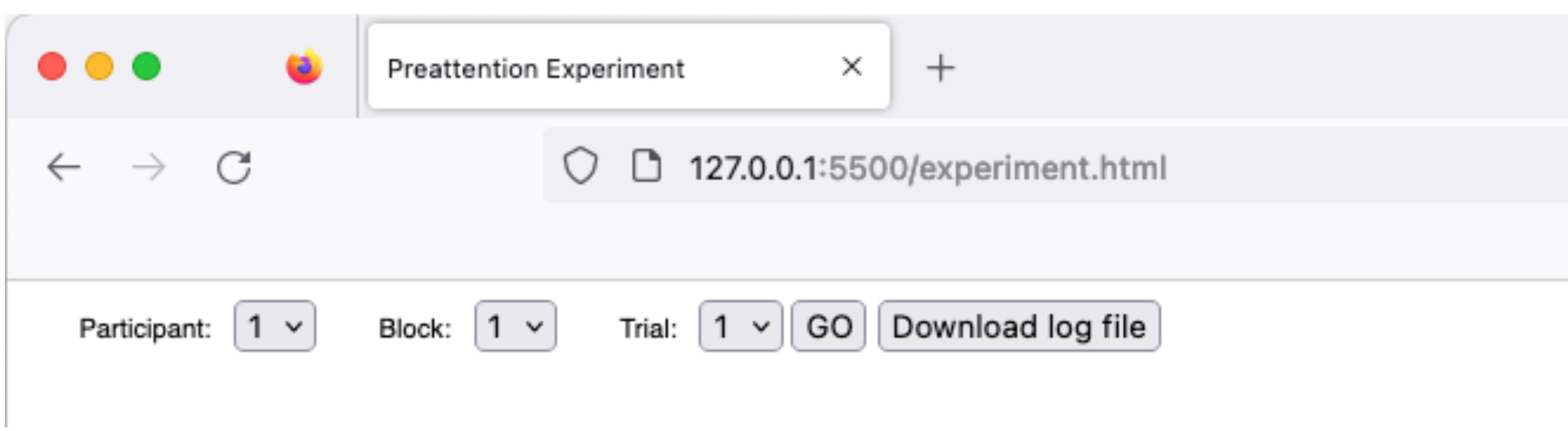
Access the page from your browser

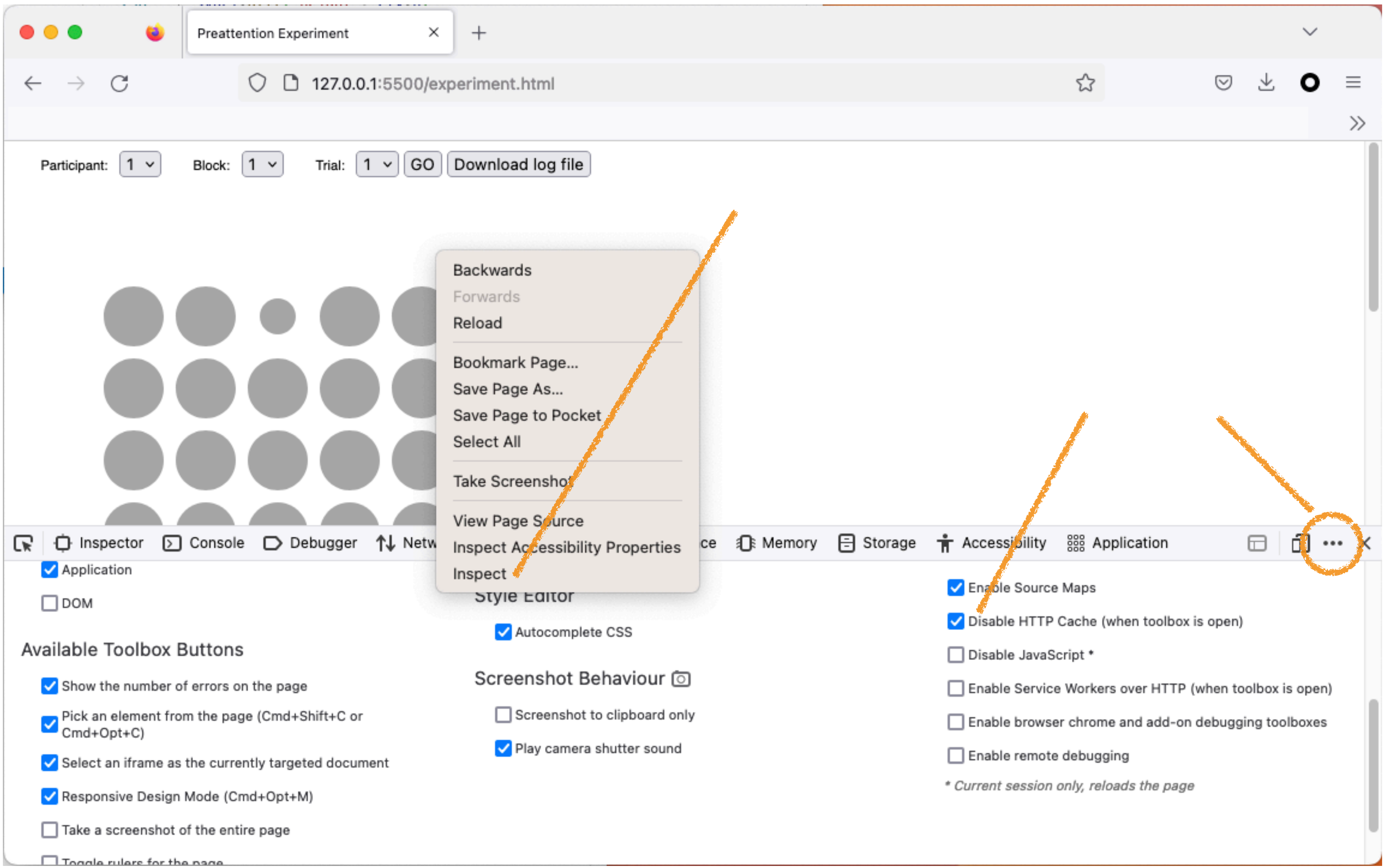
`http://localhost:8888/experiment.html`

Option 2

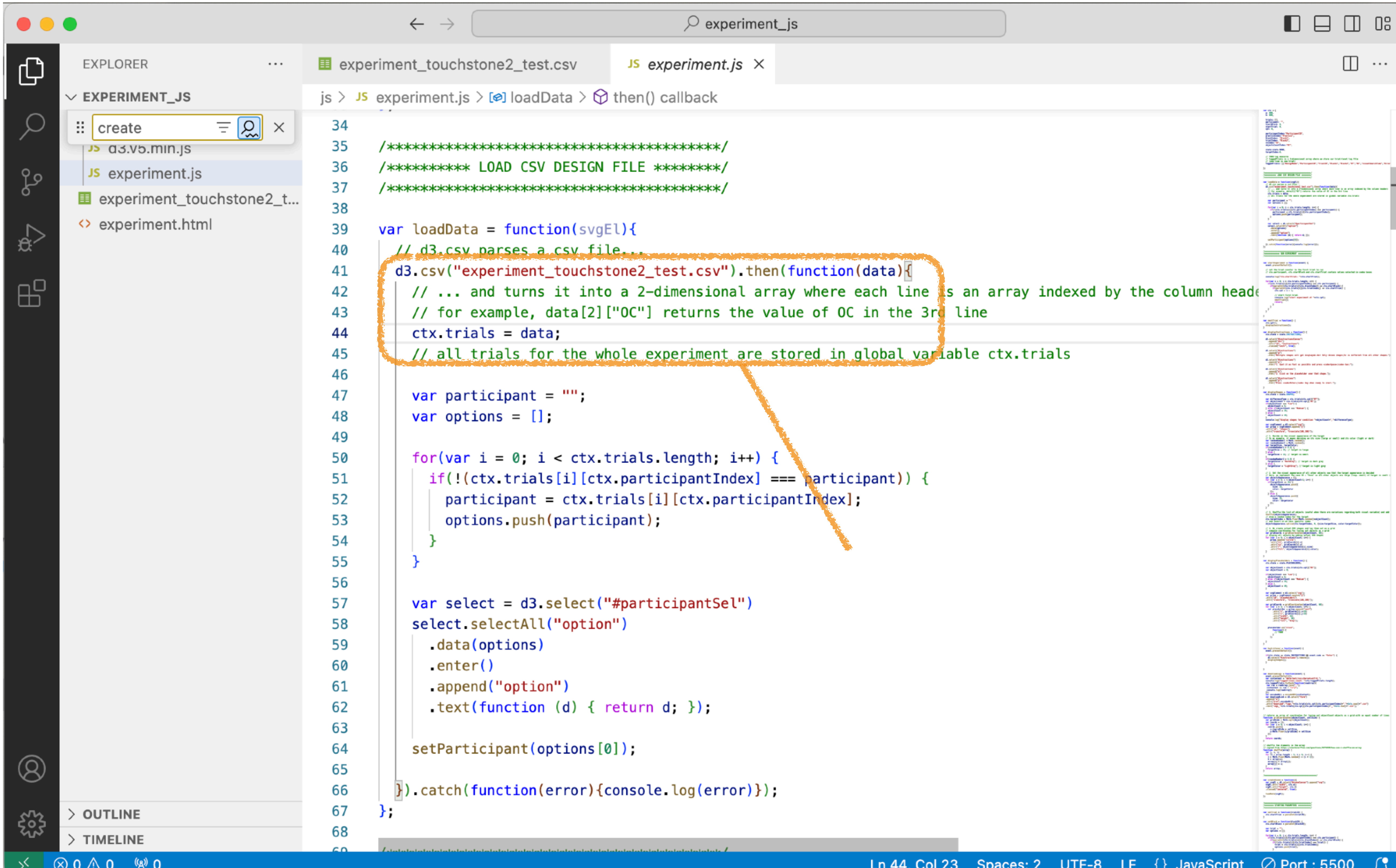
Use a plugin for your code editor

`e.g., Live Server for Visual Studio Code, or atom-live-server for Atom, etc.`

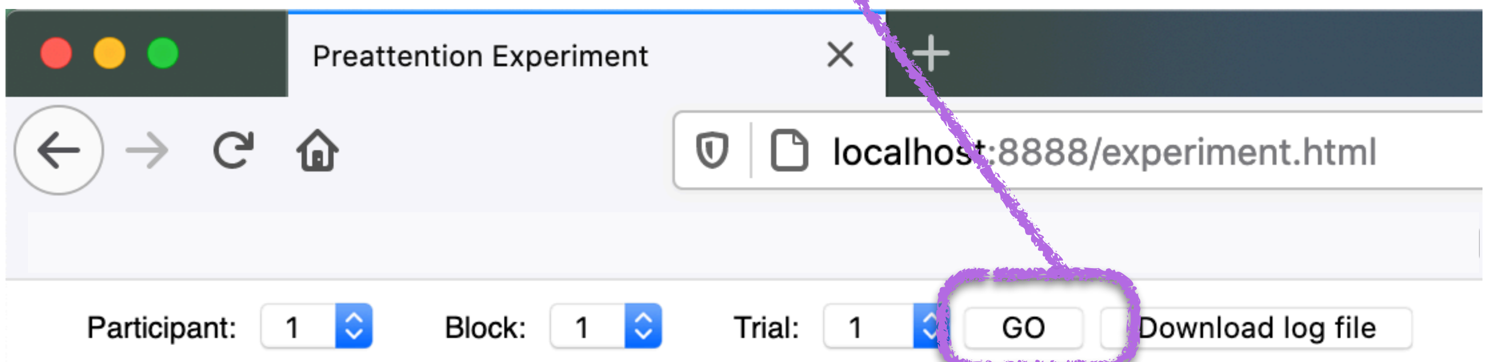



Preattention Experiment
127.0.0.1:5500/experiment.html
Participant: 1
Block: 1
Trial: 1
GO
Download log file
Backwards
Forwards
Reload
Bookmark Page...
Save Page As...
Save Page to Pocket
Select All
Take Screenshot
View Page Source
Inspect Accessibility Properties
Inspect
Inspector
Console
Debugger
Memory
Storage
Accessibility
Application
Application
DOM
Available Toolbox Buttons
Show the number of errors on the page
Pick an element from the page (Cmd+Shift+C or Cmd+Opt+C)
Select an iframe as the currently targeted document
Responsive Design Mode (Cmd+Opt+M)
Take a screenshot of the entire page
Style Editor
Autocomplete CSS
Screenshot Behaviour
Screenshot to clipboard only
Play camera shutter sound
Enable Source Maps
Disable HTTP Cache (when toolbox is open)
Disable JavaScript *
Enable Service Workers over HTTP (when toolbox is open)
Enable browser chrome and add-on debugging toolboxes
Enable remote debugging
* Current session only, reloads the page

`loadData` function reads `experiment_touchstone2_test.csv` and turns it into an array of trials.



Clicking button GO calls function `startExperiment`




```
var startExperiment = function(event) {
  ...

   // start first trial
   console.log("start experiment at "+ctx.cpt);
   nextTrial();

}
```

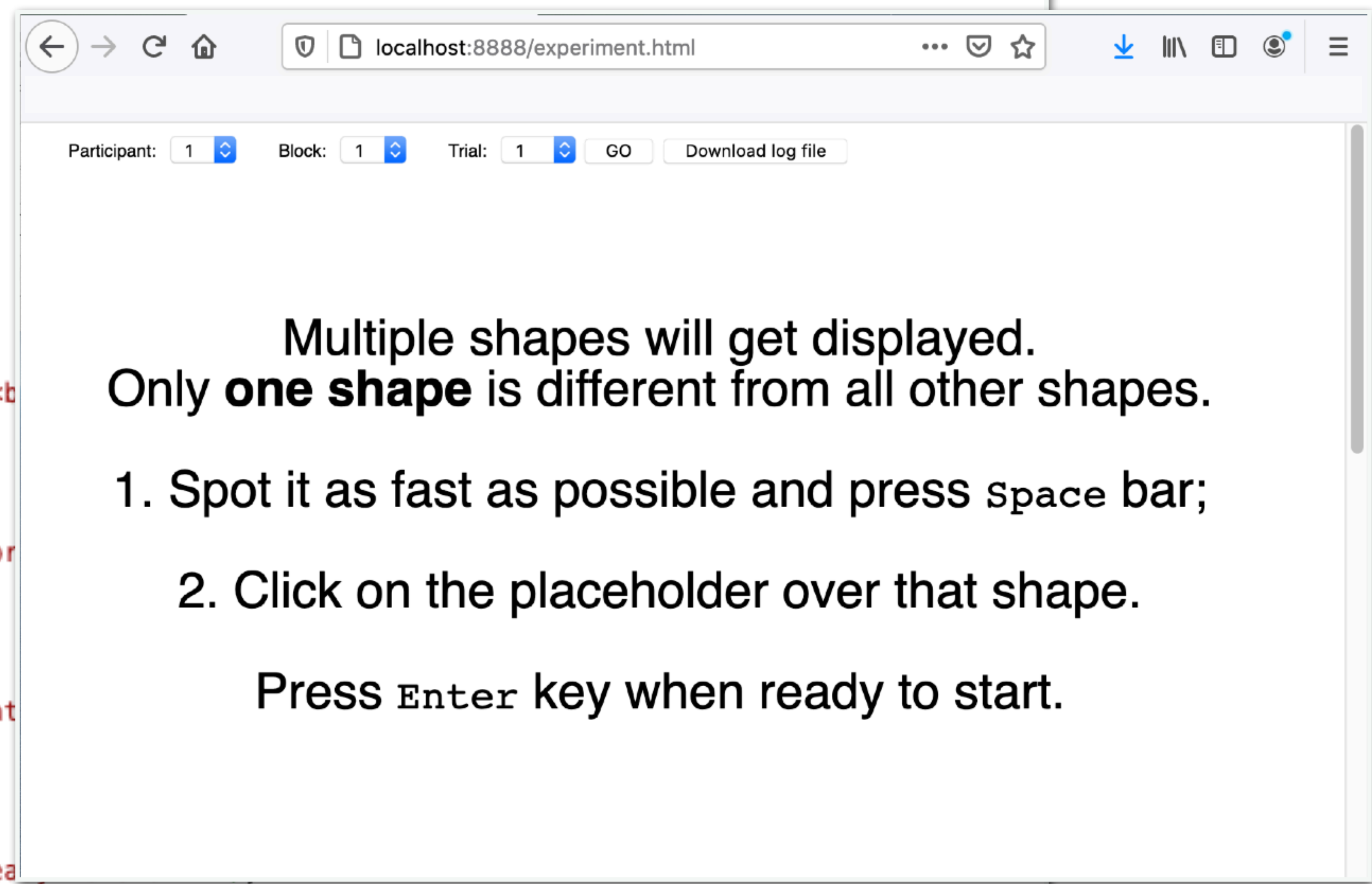
`ctx.cpt` is now the index just before the first trial to run in the trial table **`ctx.trials`**.

`nextTrial` function is called.

```
var nextTrial = function() {
  ctx.cpt++;
  displayInstructions();
}
```

`nextTrial` calls `displayInstructions`

```
var displayInstructions = function() {
  ctx.state = state.INSTRUCTIONS;

  d3.select("#instructionsCanvas")
    .append("div")
    .attr("id", "instructions")
    .classed("instr", true);

  d3.select("#instructions")
    .append("p")
    .html("Multiple shapes will get displayed.<b

  d3.select("#instructions")
    .append("p")
    .html("1. Spot it as fast as possible and pr

  d3.select("#instructions")
    .append("p")
    .html("2. Click on the placeholder over that

  d3.select("#instructions")
    .append("p")
    .html("Press <code>Enter</code> key when rea

}
```



```
var displayInstructions = function() {
  ctx.state = state.INSTRUCTIONS;

  d3.select("#instructionsCanvas")
    .append("div")
    .attr("id", "instructions")
    .classed("instr", true);

  d3.select("#instructions")
    .append("p")
    .html("Multiple shapes will get displayed.<br> Only <b>one

  d3.select("#instructions")
    .append("p")
    .html("1. Spot it as fast as possible and press <code>Space

  d3.select("#instructions")
    .append("p")
    .html("2. Click on the placeho

  d3.select("#instructions")
    .append("p")
    .html("Press <code>Enter</code:

}
```

experiment.js

We use library d3 to make DOM selections and manipulations easy. For example,

```
d3.select("#instructionsCanvas")
  .append("div")
  .attr("id", "instructions")
  .classed("instr", true);
```

selects element whose id is `instructionsCanvas`, in the HTML document, adds a new **`div`** child to this element, sets id of this new **`div`** to `instructions` and adds CSS class `instr` to it.

```
<body onload="createScene();"  onkeydown="ignoreSpace(event);" onkeyup="keyListener(event);">
  <div>
    <form id="form">

      <span class="formLb">Participant:</span>
      <select class="select" id="participantSel" onchange="onchangeParticipant()"></select>

      <span class="formLb">Block:</span>
      <select class="select" id="blockSel" onchange="onchangeBlock()"></select>

      <span class="formLb">Trial:</span>
      <select class="select" id="trialSel" onchange="onchangeTrial()"></select>

      <button onclick="startExperiment(event)" onkeydown="ignore(event);" onkeyup="ignore(event);">GO</button>

      <button onclick="downloadLogs(event)" onkeydown="ignore(event)" onkeyup="ignore(event)">Download log file</button>

    </form>
  </div>
  <div id="instructionsCanvas">
  </div>
  <div id="sceneCanvas">
  </div>
</body>
```

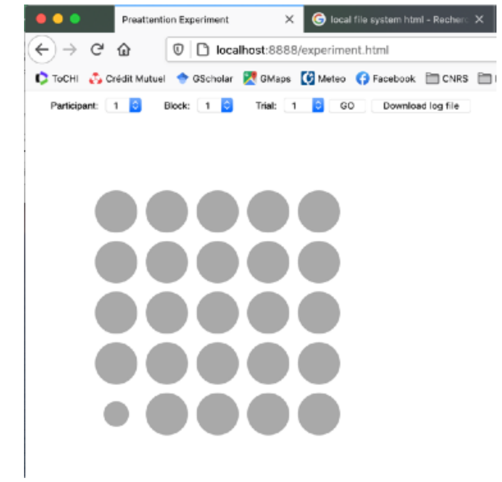
experiment.html

Keyboard events

Function **`keyListener`** gets called when a key is pressed

```
var keyListener = function(event) {
  event.preventDefault();

  if(ctx.state == state.INSTRUCTIONS && event.code == "Enter") {
    d3.select("#instructions").remove();
    displayShapes();
  }

}
```

Display grid of shapes

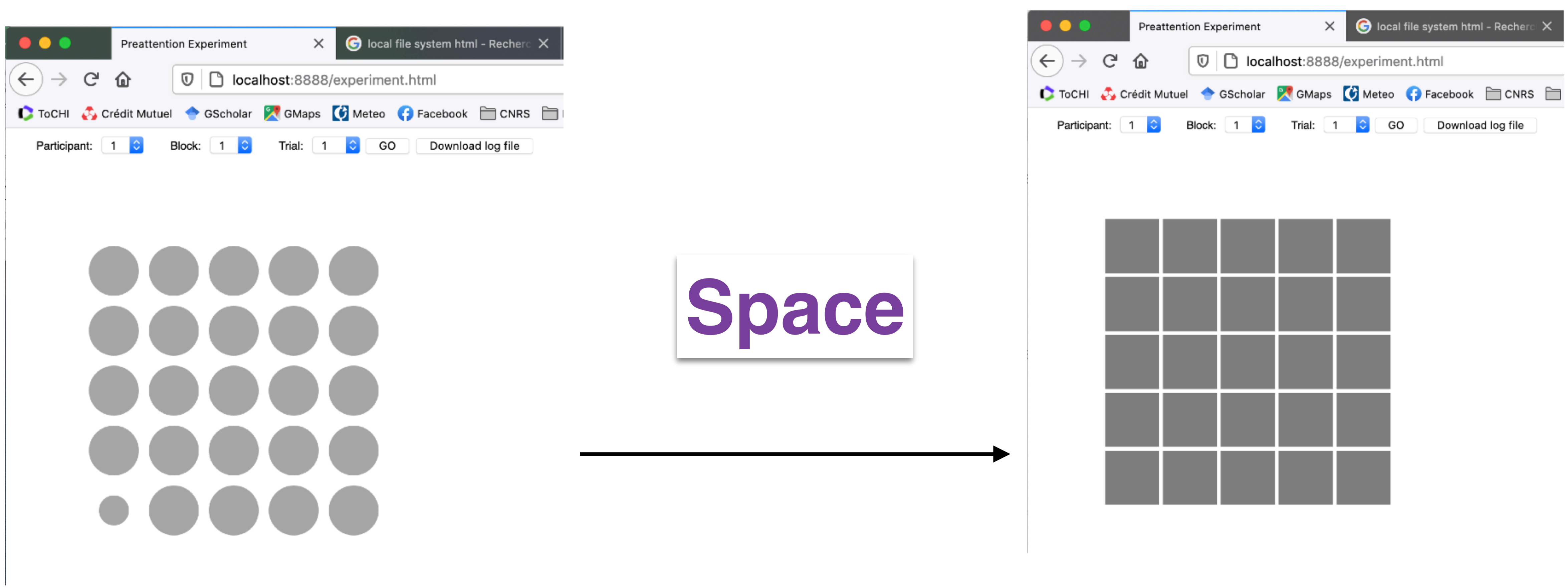


Function `displayShapes` does the job

```
var displayShapes = function() {
  ctx.state = state.SHAPES;

  var differenceType = ctx.trials[ctx.cpt]["DT"];
  var objectCount = ctx.trials[ctx.cpt]["OC"];
  if(objectCount === "Low") {
    objectCount = 9;
  } else if(objectCount === "Medium") {
    objectCount = 25;
  } else {
    objectCount = 49;
  }
  console.log("display shapes for condition "+objectCount+","+differenceType);

  var svgElement = d3.select("svg");
  var group = svgElement.append("g")
  .attr("id", "shapes")
  .attr("transform", "translate(100,100)");
```

TODO step 1-a

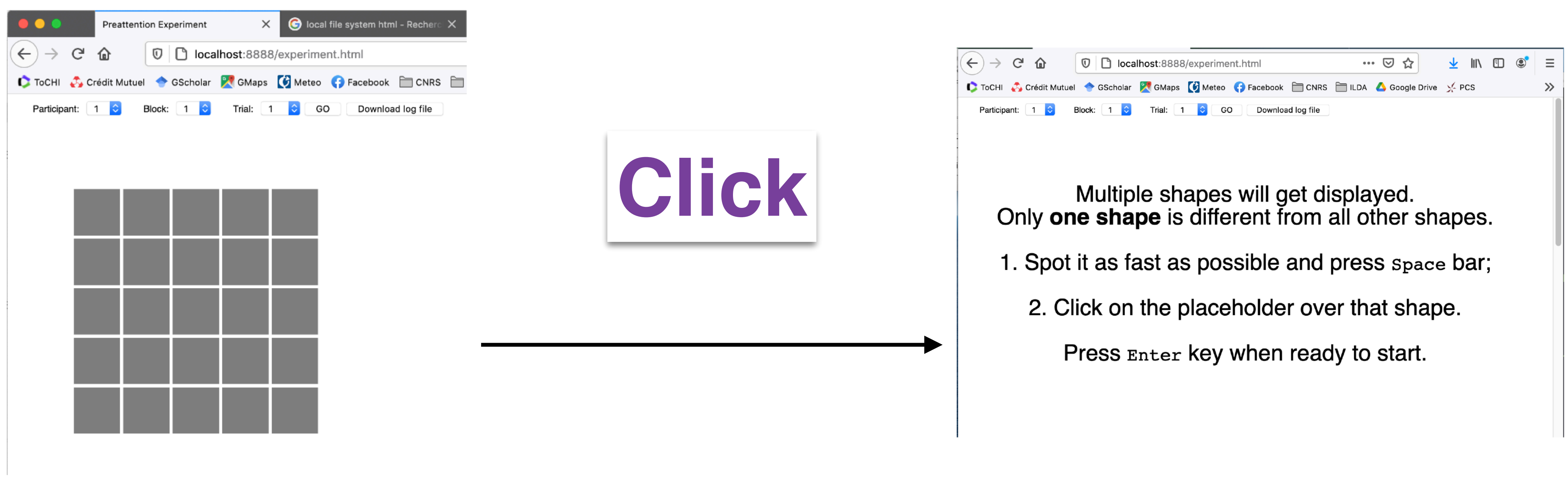
Update function **`keyListener`** to remove shapes and display placeholders instead when participant presses **`Space`** bar in state **`state.SHAPES`**.



Function `displayPlaceholders` is provided

TODO step 1-b

Update function **`displayPlaceholders`** to remove placeholders and progress to next trial (call **`nextTrial`**) when participant clicks a placeholder. Ignore errors for now, progress to next trial in all cases.



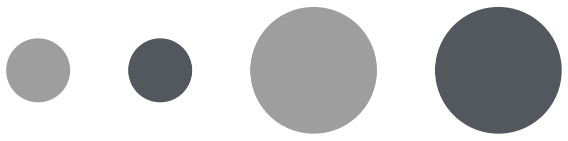

```
var displayPlaceholders = function() {
    ...
    placeholder.on("click",
        function() {
          // TODO
        }
    );
  }
```

Scene of objects

Let's take a closer look at function **`displayShapes`**

```
var displayShapes = function() {
  ...

  // 1. Decide on the visual appearance of the target
  // In my example, it means deciding on its size (large or small) and its color (light or dark)
  var randomNumber1 = Math.random();
  var randomNumber2 = Math.random();
  var targetSize, targetColor;
  if(randomNumber1 > 0.5) {
    targetSize = 25; // target is large
  } else {
    targetSize = 15; // target is small
  }
  if(randomNumber2 > 0.5) {
    targetColor = "DarkGray"; // target is dark gray
  } else {
    targetColor = "LightGray"; // target is light gray
  }
```

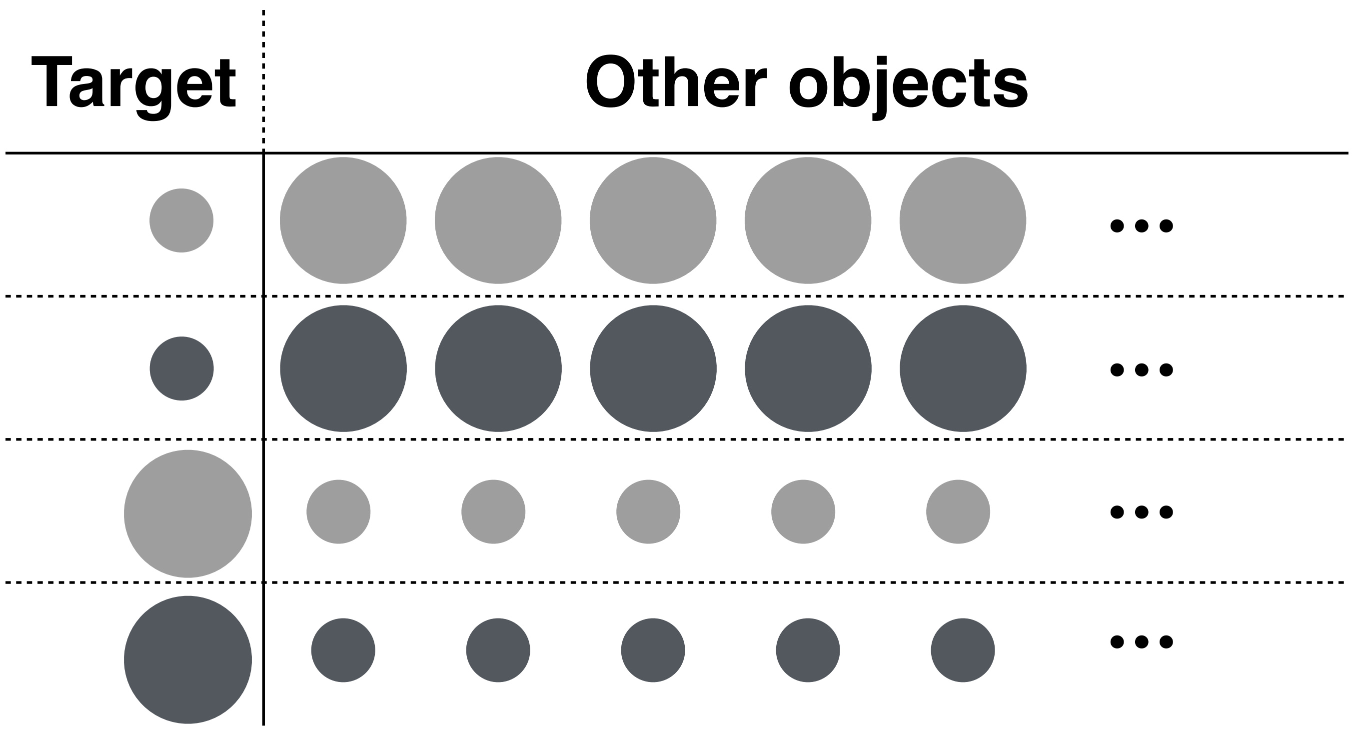
We decide on the target's appearance



Scene of objects

Let's take a closer look at function **`displayShapes`**

```
var displayShapes = function() {
  ...

  // 2. Set the visual appearance of all other objects now that the target appearance is
decided
  // Here, we implement the case DT = "Size" so all other objects are large (resp. small)
if target is small (resp. large) but have the same color as target.
  var objectsAppearance = [];
  for (var i = 0; i < objectCount-1; i++) {
    if(targetSize == 25) {
      objectsAppearance.push({
        size: 15,
        color: targetColor
      });
    } else {
      objectsAppearance.push({
        size: 25,
        color: targetColor
      });
    }
  }
```



We generate the list of other objects depending on the target's appearance

Scene of objects

Let's take a closer look at function **`displayShapes`**

```
var displayShapes = function() {
  ...

  // 3. Shuffle the list of objects (useful when there are variations regarding both visual
variable) and add the target at a specific index
  shuffle(objectsAppearance);
  // draw a random index for the target
  ctx.targetIndex = Math.floor(Math.random()*objectCount);
  // and insert it at this specific index
  objectsAppearance.splice(ctx.targetIndex, 0, {size:targetSize, color:targetColor});
```

We shuffle (*) the list of other objects and then insert the target at a specific index

(*) explanation for shuffling later on

Scene of objects

Let's take a closer look at function **`displayShapes`**

```
var displayShapes = function() {
  ...

 // 4. We create actual SVG shapes and lay them out as a grid
  // compute coordinates for laying out objects as a grid
  var gridCoords = gridCoordinates(objectCount, 60);
  // display all objects by adding actual SVG shapes
  for (var i = 0; i < objectCount; i++) {
      group.append("circle")
      .attr("cx", gridCoords[i].x)
      .attr("cy", gridCoords[i].y)
      .attr("r", objectsAppearance[i].size)
      .attr("fill", objectsAppearance[i].color);
  }
```

We actually display shapes as a SVG shapes laid out as a grid.

We use d3 library to manipulate the DOM structure (add elements and set their attributes' values)

TODO step 2-a

For now, function **`displayShapes`** ignores the actual value of DT and simply implements the case DT = "Size"

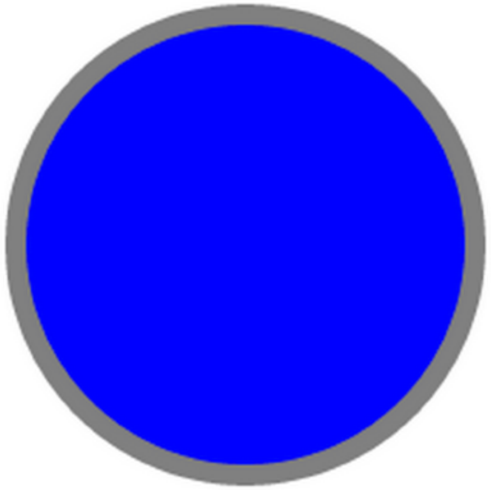
Adapt the code to your visual variable VV_1
(i.e., handle your own case DT= VV_1)

adapted from Emmanuel Pietriga's slide

SVG and visual variables

I used circles with Size and Color visual variables, but SVG provides you with different types of graphical shape and various graphical attributes

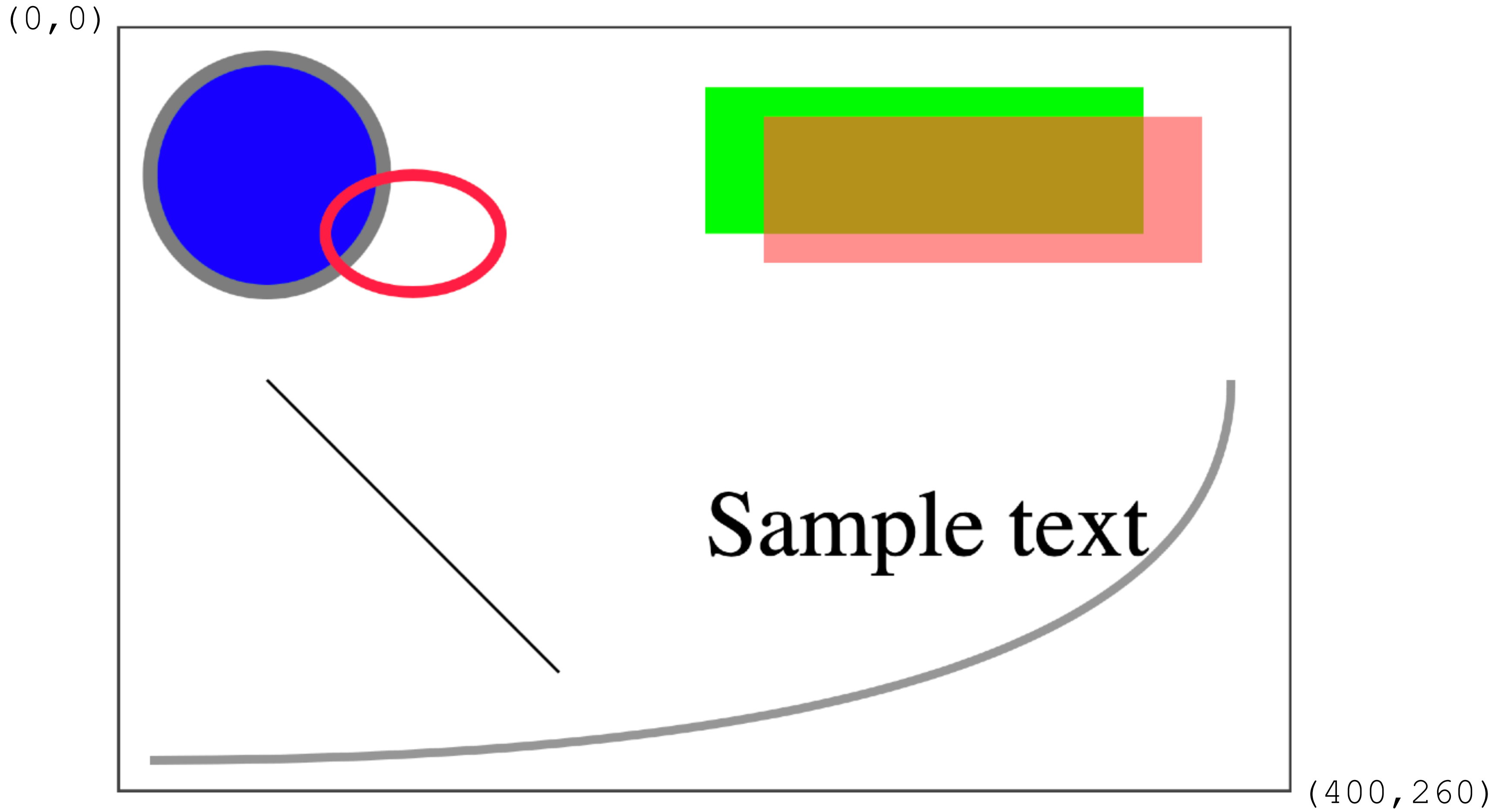
```
<svg width="100" height="100">
    <circle cx="50" cy="50" r="22" fill="blue" stroke="gray" stroke-width="4"/>
</svg>
```



- SVG code can be included directly in HTML documents
- Shapes: **`rect, circle, ellipse, line, text, path`**
- Styling: **`fill, stroke, stroke-width, opacity, font-family, font-size`**
- or use CSS rules
- Transparency can be controlled with **`opacity`** or **`rgba(r,g,b,a)`** color tuples

SVG - Scalable Vector Graphics

source: Emmanuel Pietriga

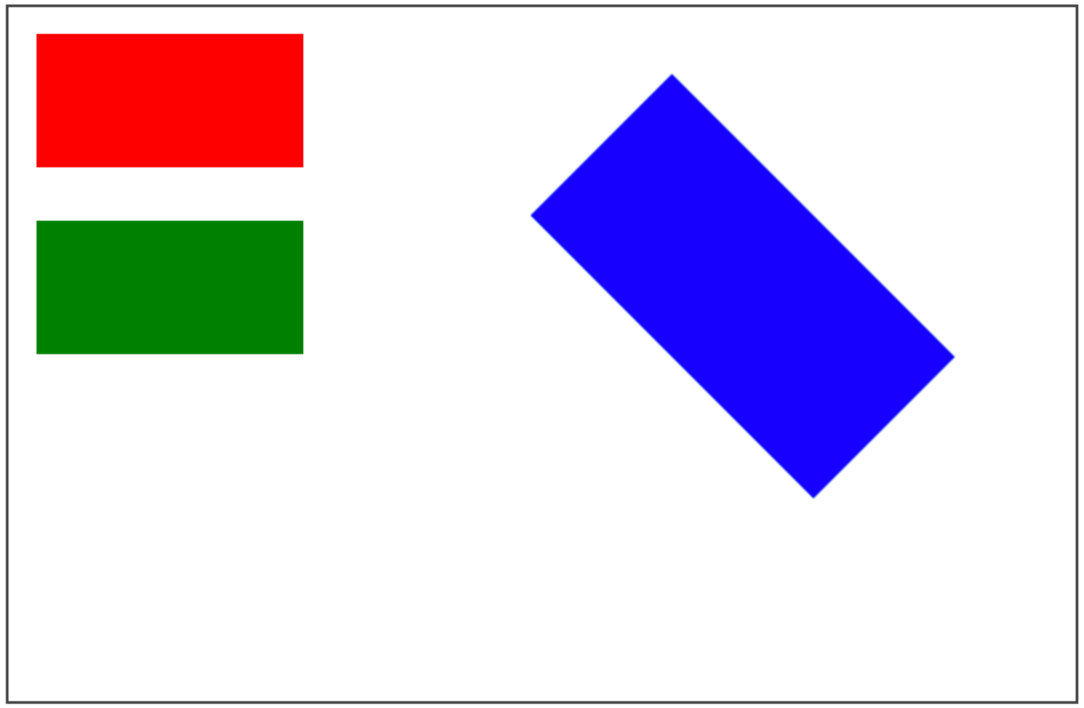



```
<svg width="400" height="260">
    <!-- blue circle with a 5px-gray border-->
    <circle cx="50" cy="50" r="40" fill="blue" stroke="gray" stroke-width="5"/>
    <!-- ellipse with a 4px redish border and no fill color-->
    <ellipse cx="100" cy="70" rx="30" ry="20" fill="none" stroke="#FF2244" stroke-width="4"/>
    <!-- two rectangles partially overlapping, the one above (which us red) is semi-transparent-->
    <rect x="200" y="20" width="150" height="50" fill="#0F0"/>
    <rect x="220" y="30" width="150" height="50" fill="#F00" opacity=".5"/>
    <!-- simple black line -->
    <line x1="50" y1="120" x2="150" y2="220" stroke="black"/>
    <!-- simple text element -->
    <text x="200" y="180">Sample text</text>
    <!-- a quadratic bézier curve -->
    <path fill="none" stroke="#999" stroke-width="3" d="M10,250 Q380,250 380,120" />
</svg>
```

SVG - Scalable Vector Graphics

source: Emmanuel Pietriga

Affine Transforms

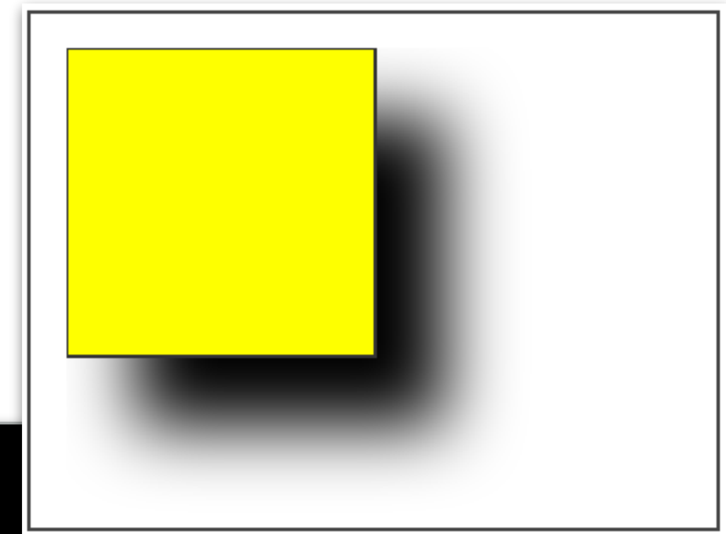


```
<rect x="10" y="10" width="100" height="50" style="fill:red"/>
<rect x="0" y="0" width="100" height="50" style="fill:green"
      transform="translate(10,80)" />
<rect x="0" y="0" width="100" height="50" style="fill:blue"
      transform="translate(10,150) scale(1.5) rotate(45 180 150)"/>
```

SVG - Scalable Vector Graphics

source: Emmanuel Pietriga

Many more possibilities, including, *e.g.*, filters:



```
<svg width="200" height="150">
    <defs>
      <filter id="ds" x="0" y="0" width="200%" height="200%">
        <feOffset result="offOut" in="SourceAlpha" dx="20" dy="20" />
        <feGaussianBlur result="blurOut" in="offOut" stdDeviation="10" />
        <feBlend in="SourceGraphic" in2="blurOut" mode="normal" />
      </filter>
    </defs>
    <rect x="10" y="10" width="90" height="90" fill="yellow" stroke="#333"
          filter="url(#ds)" />
</svg>
```

Detailed SVG documentation:

https://developer.mozilla.org/en-US/docs/Web/SVG/Element

Manipulating the DOM of a web page

with d3

```
var svgElement = d3.select("svg");
var group = svgElement.append("g")
  .attr("id", "shapes")
  .attr("transform", "translate(100,100)");

group.append("circle")
   .attr("cx", 50)
   .attr("cy", 50)
   .attr("r", 20)
   .attr("fill", "red");
```

```
<svg>
  <g id="shapes" transform="translate(100,100)">
    <circle cx=50 cy=50 r=20 fill="red" />
  </g>
  ...
<svg>
```

TODO step 2-b

Complement the code to make it work for your second visual variable (i.e., handle case DT= VV_2)

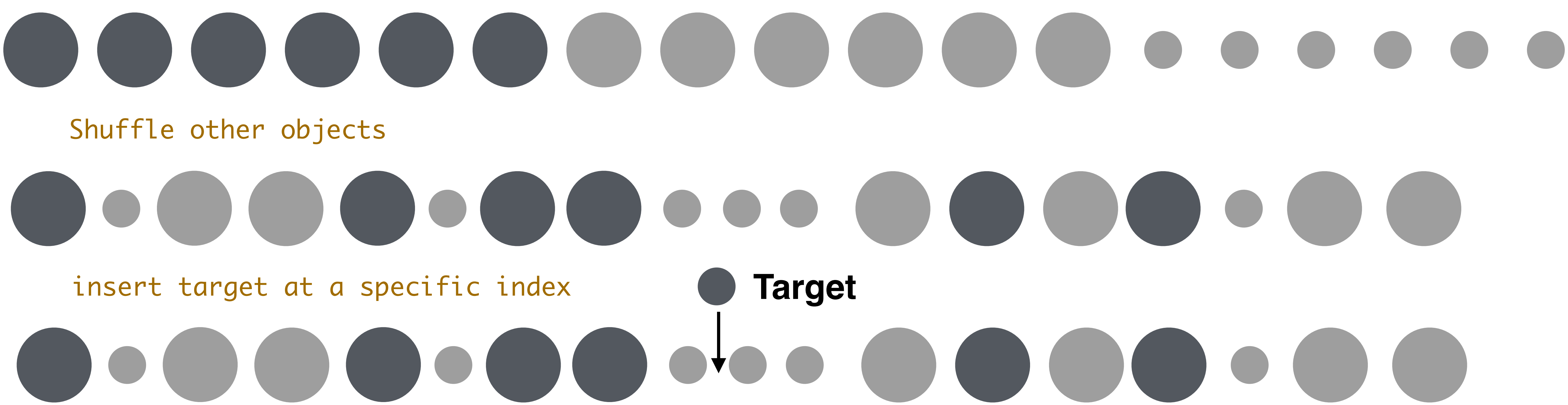
TODO step 2-c

Complement the code to make it work for the combination of your two visual variables (i.e., handle case DT= VV_1VV_2)

This is where shuffling other objects in `displayShapes` makes sense

example for DT="ColorSize" with a target

Other objects (generated by series of objects that have the three possible apperances)



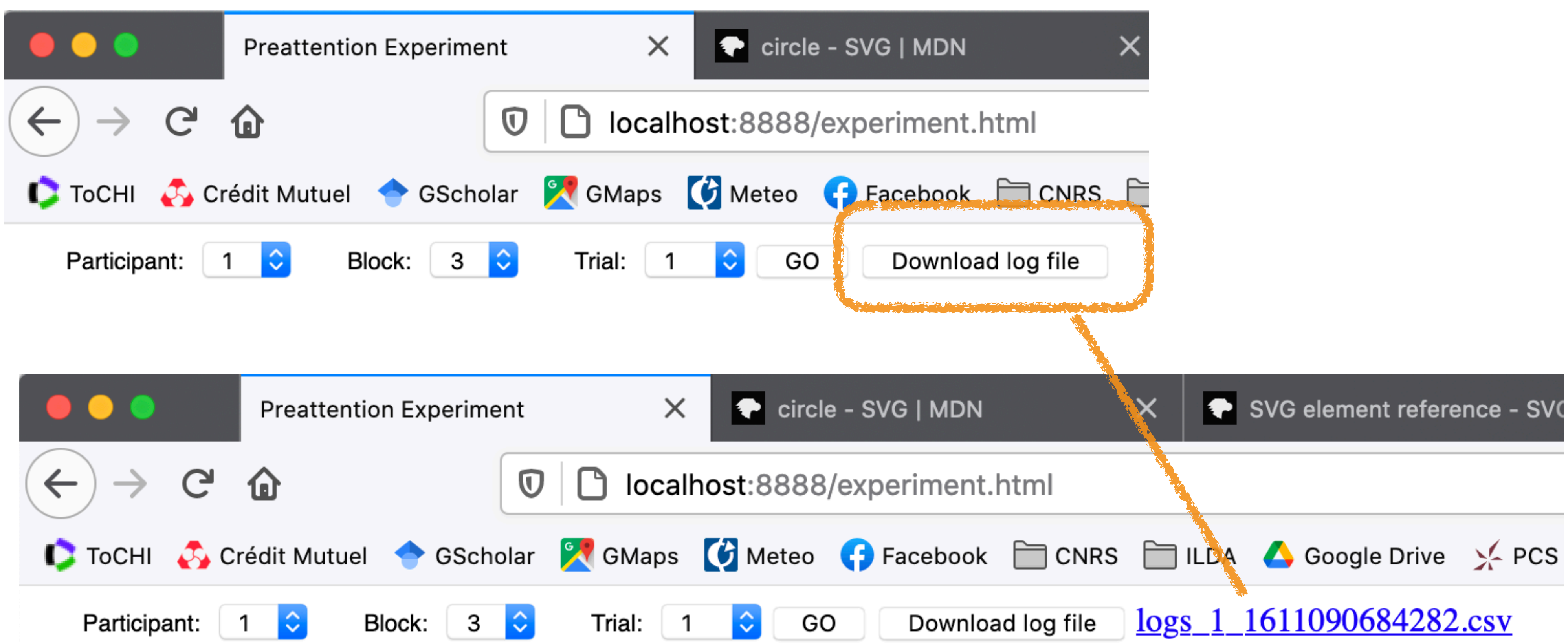
TODO step 3

Log measures by adding an array with values each time a trial ends at the end of the **`ctx.loggedTrials`** array which contains one line for each trial that has been run until now.

```
ctx.loggedTrials = [
["DesignName","ParticipantID","TrialID","Block1","Block2","DT","OC","visualSearchTime","ErrorCount"]];
...
ctx.loggedTrials.push(
   ["Preattention-experiment",1,1,1,1,"Size","Medium",1582,0]
)
```

TODO step 3

Button download log file calls function downloadLogs which turns `ctx.loggedTrials` into a csv that you can download



TODO step 3-a

a) Log measure visualSearchTime, the function `Date.now()` can be useful for handling the timer. It returns the current time in ms.

TODO step 3-b

b) Log measure ErrorCount: In case of error (wrong element clicked), just count an error but do not log anything. Restart a trial in the same condition (restart the timer as well...). We want to have one correct completion time measure for each experimental condition.

```
DesignName,ParticipantID,TrialID,Block1,Block2,DT,OC,visualSearchTime,ErrorCount
...
PreattentionExperiment,1,2,1,1,Color,Medium,1582,2
...
```

The successful trial in this condition took 1582 ms. It was preceded by two incorrect selections.

TODO step 4

Make sure that your program stops when all trials for this participant are completed (i.e., when `ctx.trials[ctx.cpt]["ParticipantID"]` is no longer the same value)