# Capstone Project

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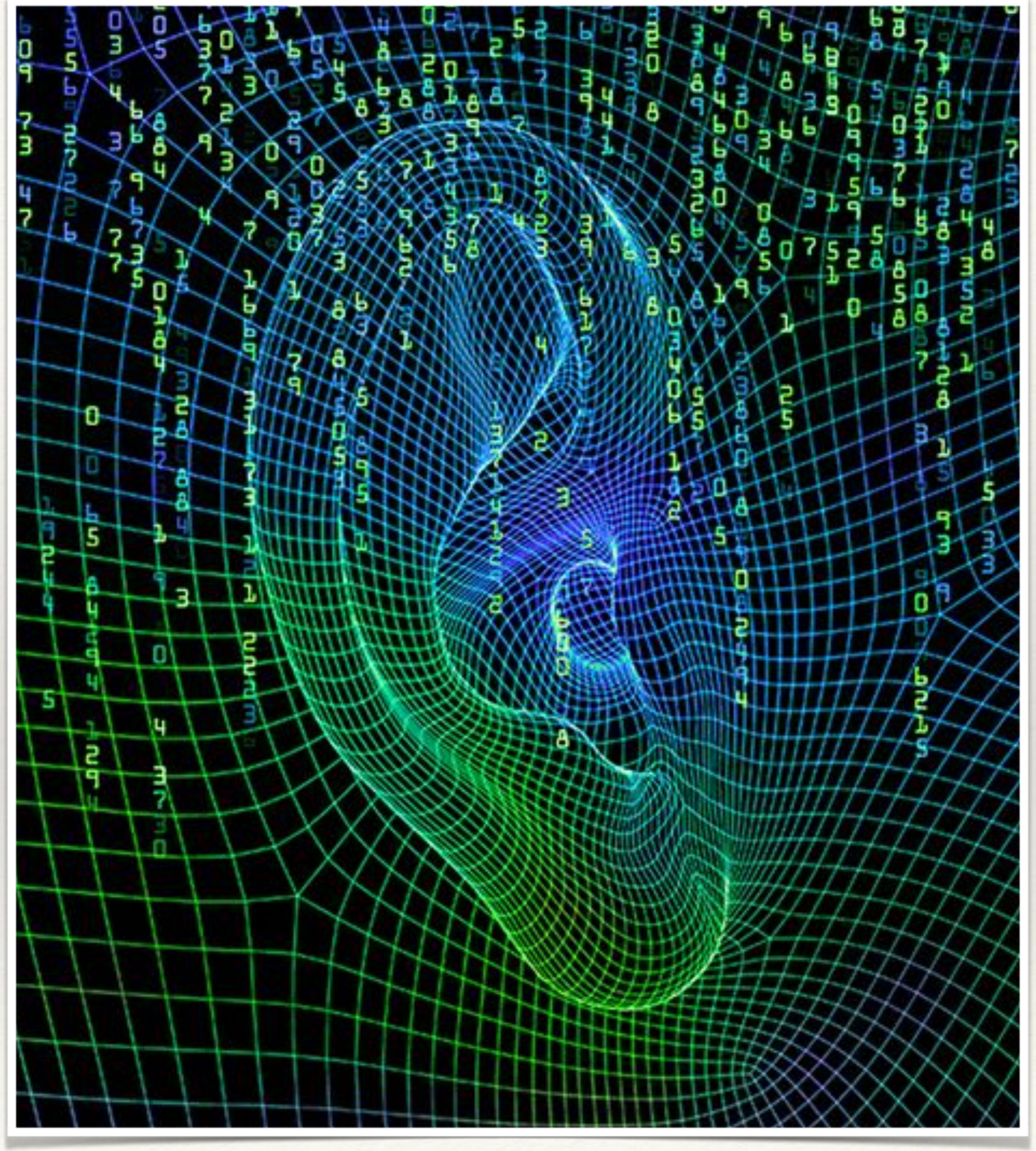
# Using Sound Cue to Improve Time Perception Accuracy in Data Sonification

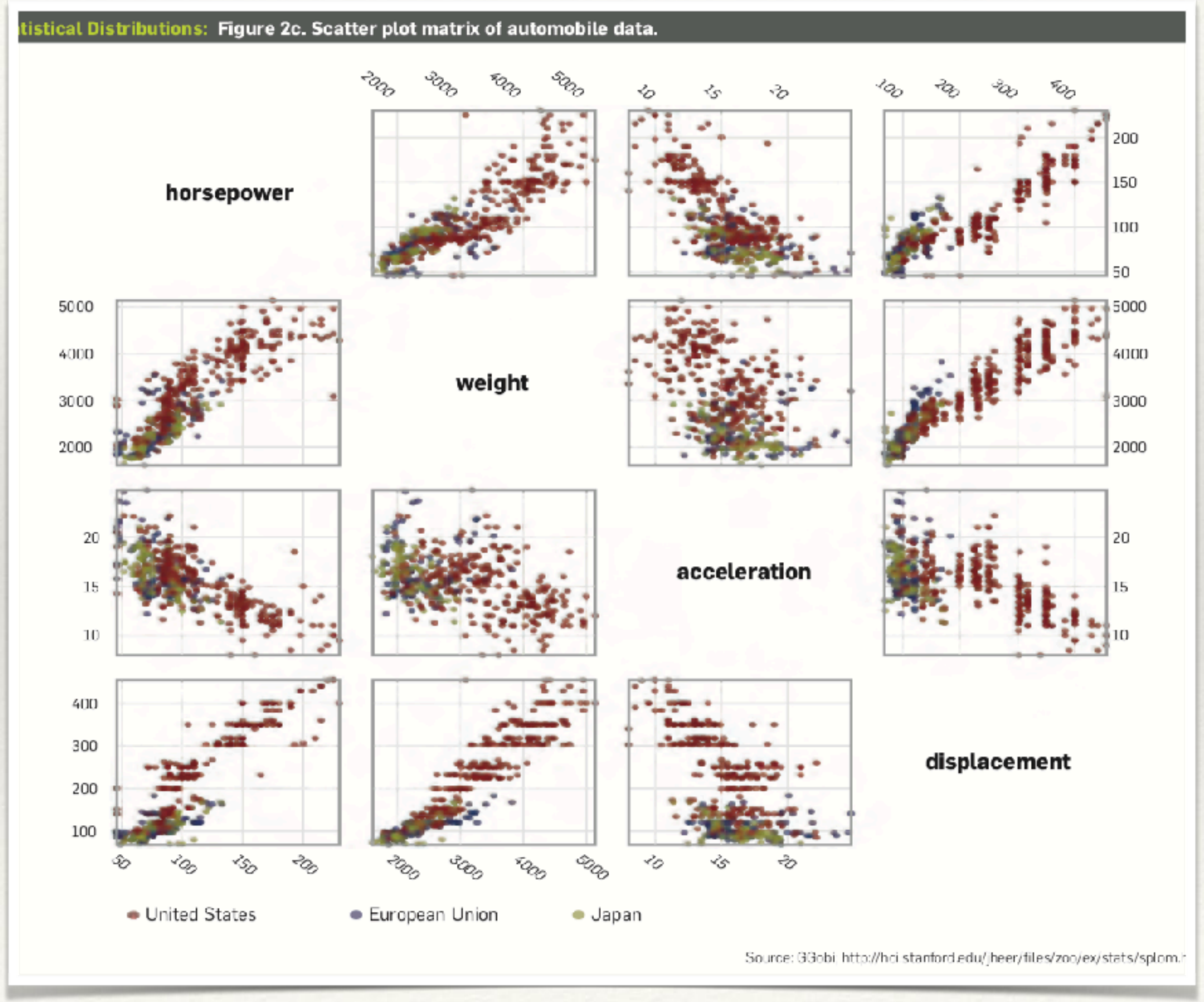
Data signification is a technology that transfer data into sounds for people to hear. This is a quite new technology trying to match data visualization.
In this work, I've proposed a design approach to improve people's perception accuracy over time when listening to a data sonification.
Also, I've designed and conducted a within-subject test to test it. The design approach was proved effective.



# Background and Goal

- Data charts has become more and more important since the end of last century.

- An estimate pointed out that “in 2010 alone, we will generate 1,200 exabytes—60 million times the content of the Library of Congress.”



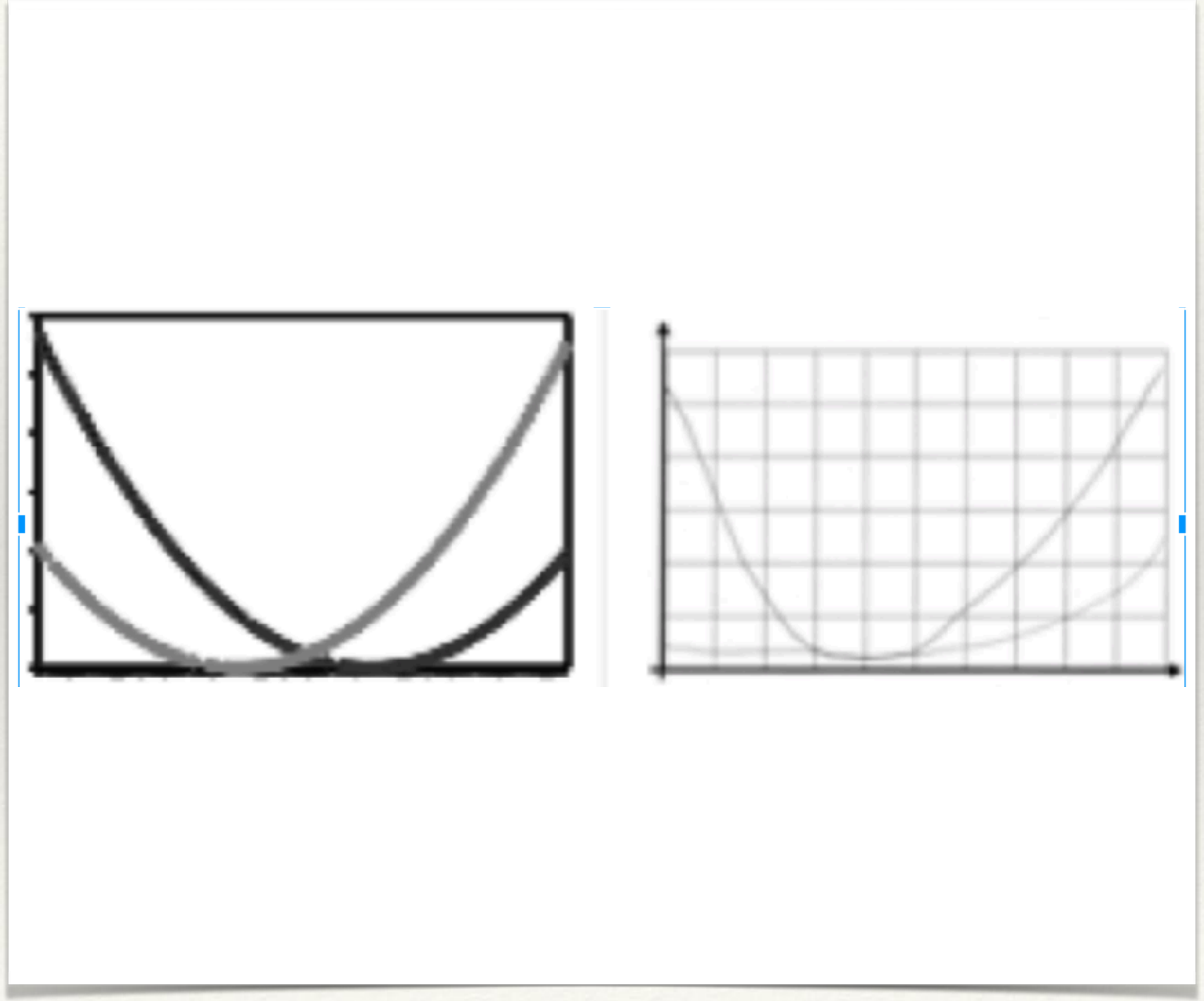
# Background and Goal

- 4 Types of accessible data chart:
  - Tactile
  - Natural Language
  - Data Sonification
  - Hybrid

# Background and Goal

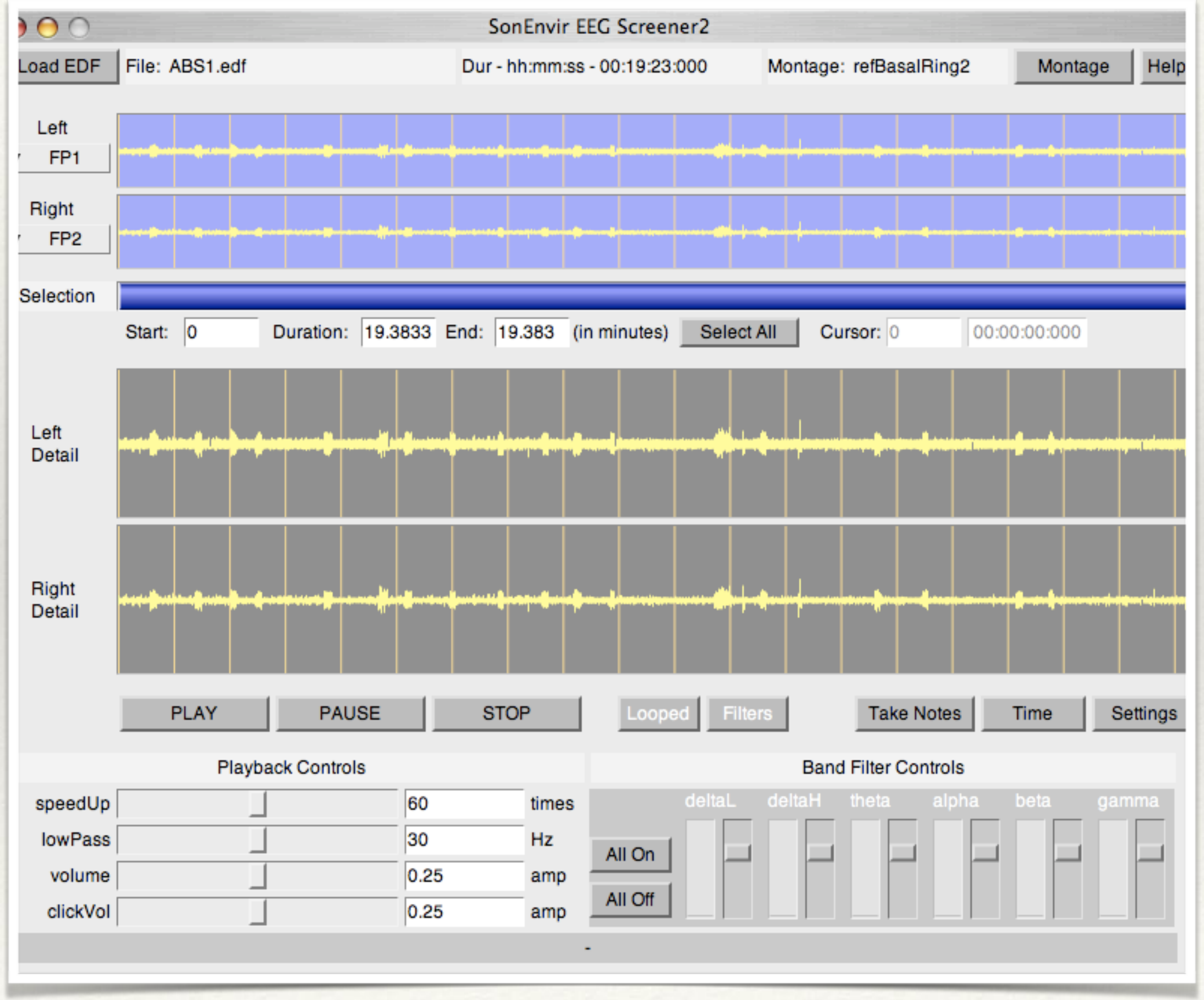
- When facing a data sonification, people's perception over time is not very accurate.

- Lorna M. Brown and Stephen A. Brewster. 2003. Drawing by ear: Interpreting sonified line graphs. (July 2003). Retrieved November 8, 2018 from https://smartech.gatech.edu/handle/1853/50453



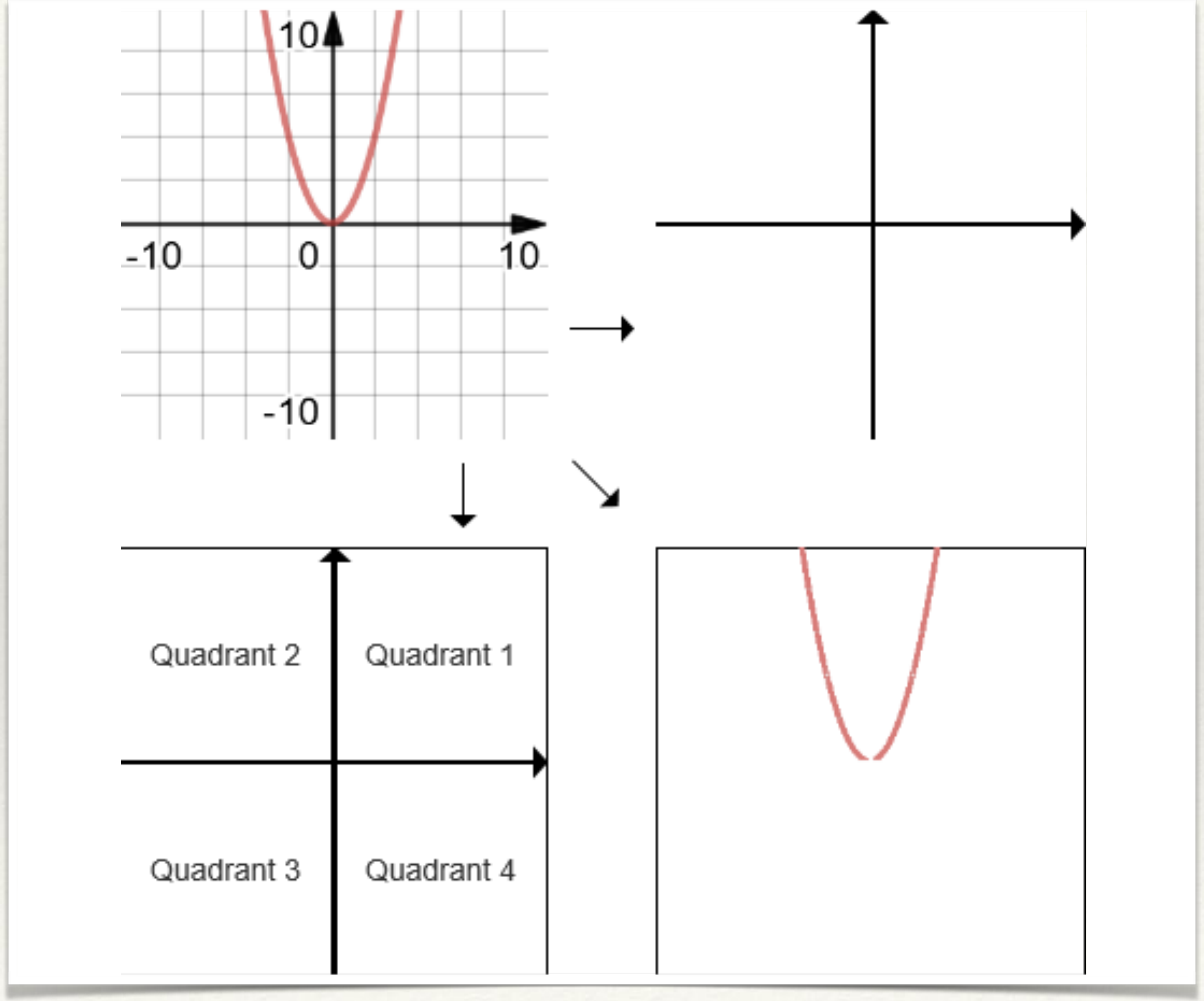
# Background and Goal

- Later Development basically fall into two branches:
  - Using sonification combined with visualization to catch abnormality.
  - Focusing more on realtime application, like EEG.



# Background and Goal

- The elements of a data chart using Cartesian coordinate system
  - X-Axis, Y-Axis
  - An Enclosure
  - Four Quadrants



# Background and Goal

- Research Questions 1:

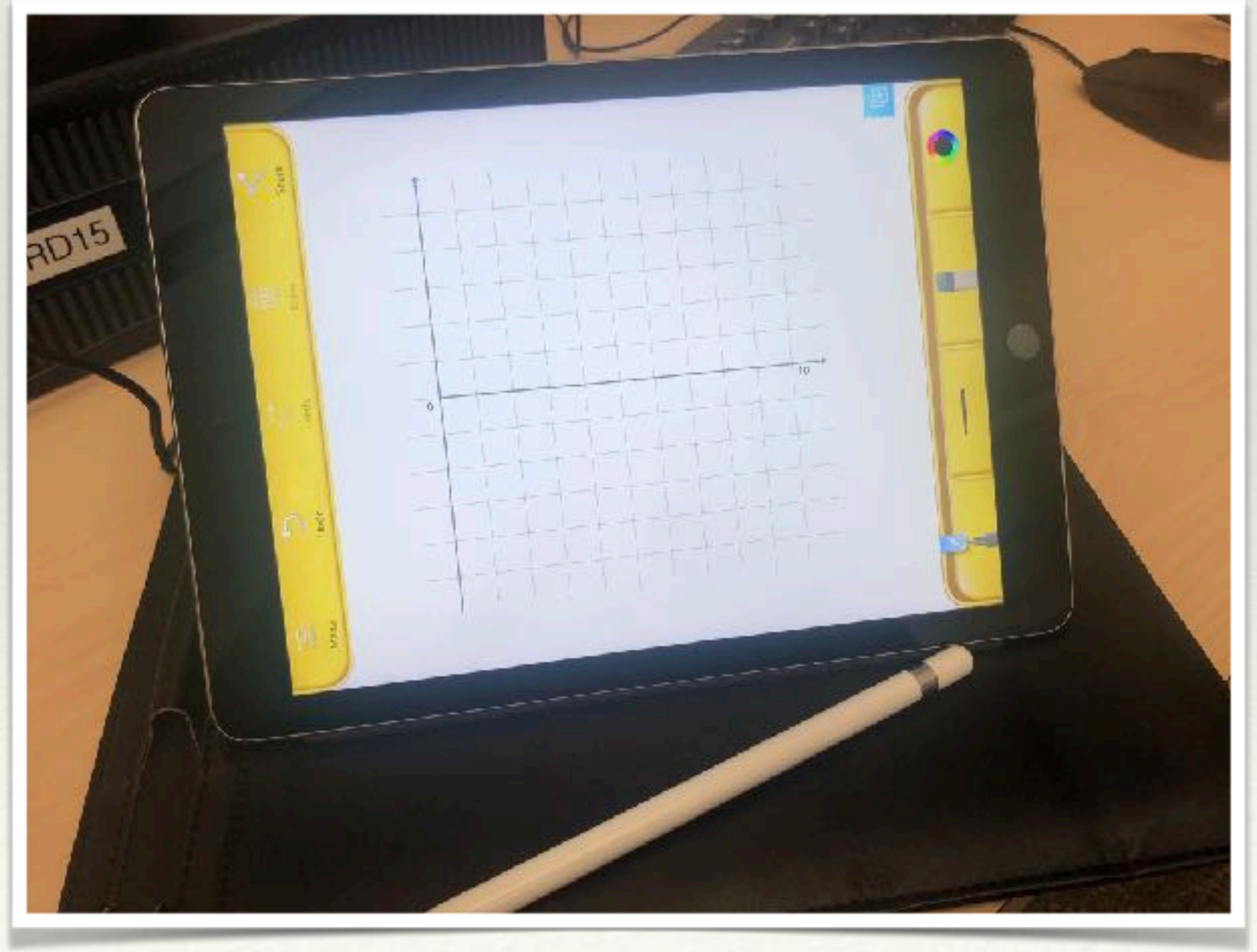
  Whether or not including a referential sound which slice time equally in signification improves people's accuracy of the axis represented by time?

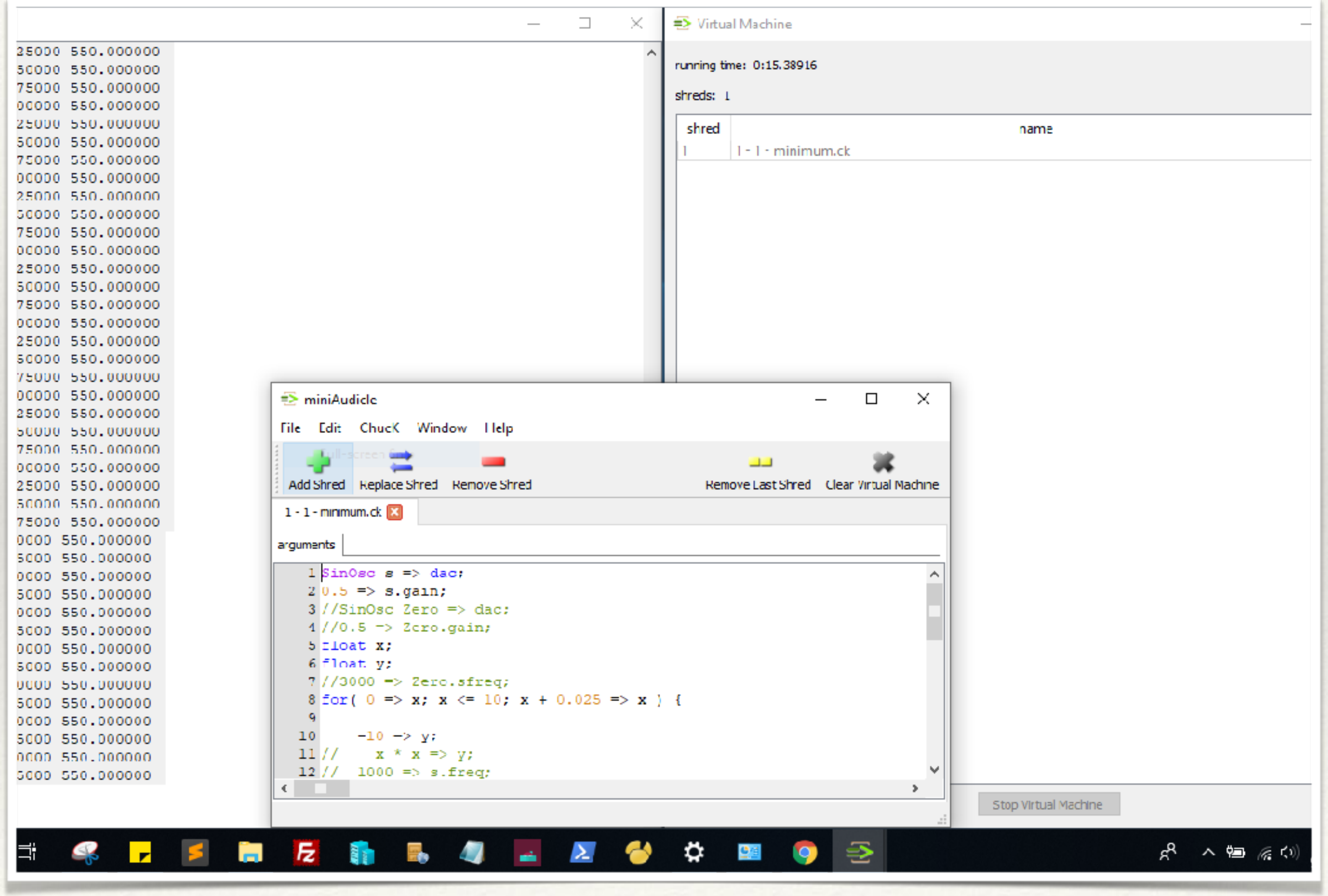
- Original Questions 2:

  Whether or not including such a referential sound in sonification deteriorates people's accuracy of the other dimension represents the y-axis?

# Tools and Implementation

- Windows PC with ChucK
- iPad with "sketchpad", and an Apple pencil





# Design Iterations

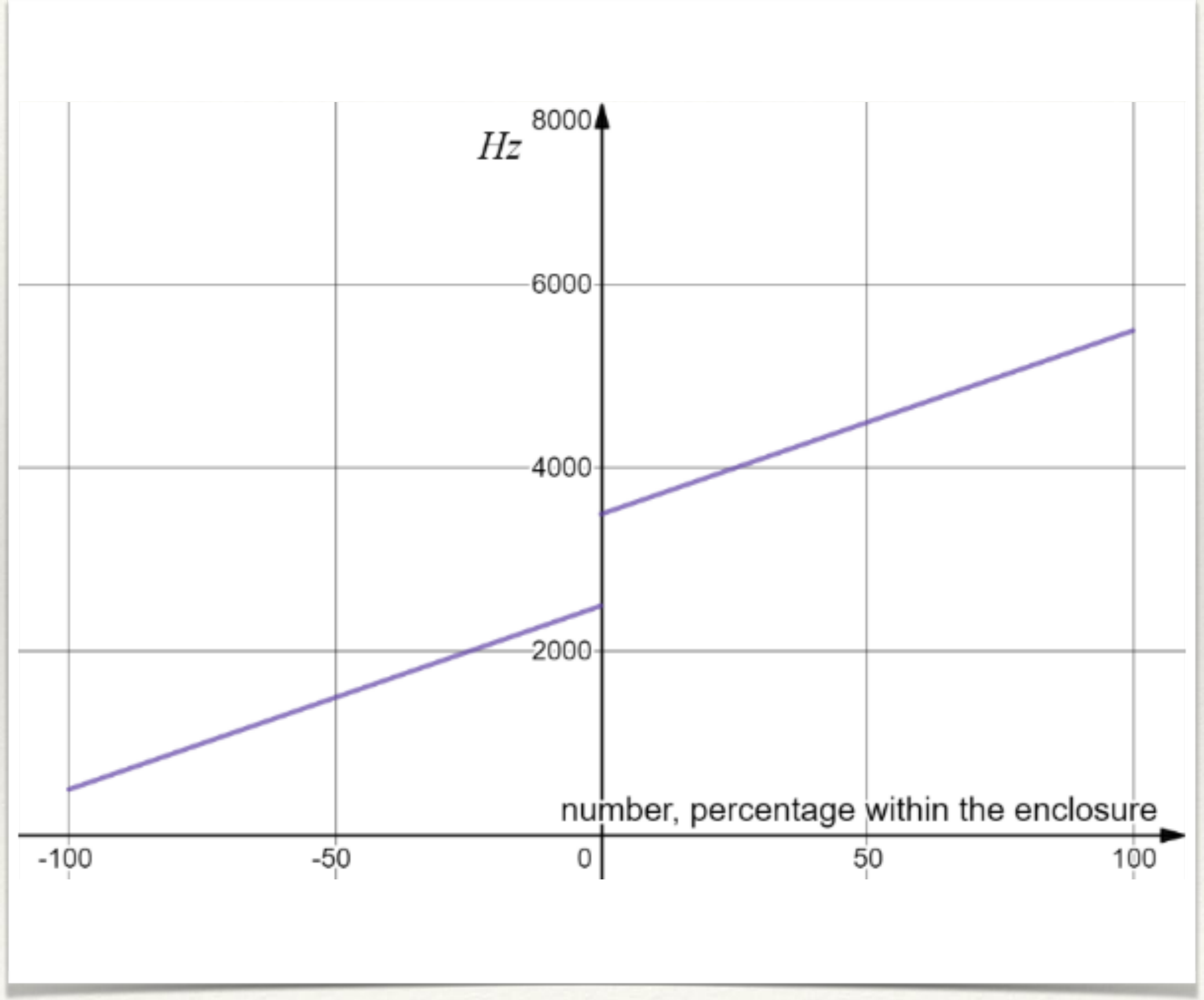
- Iteration 0: How to use ChucK

  - different classes. SinOsc is basically like a sound fork. it generates sin wave DAC is Digital Audio Converter.
  - sound properties: frequency, gain,
  - Every loop do a calculation to determine the property of the sound
  - 25 ms will make it sound pretty “continuous”

# Design Iterations

- Iteration 1: Use pitch to represent value in y-axis

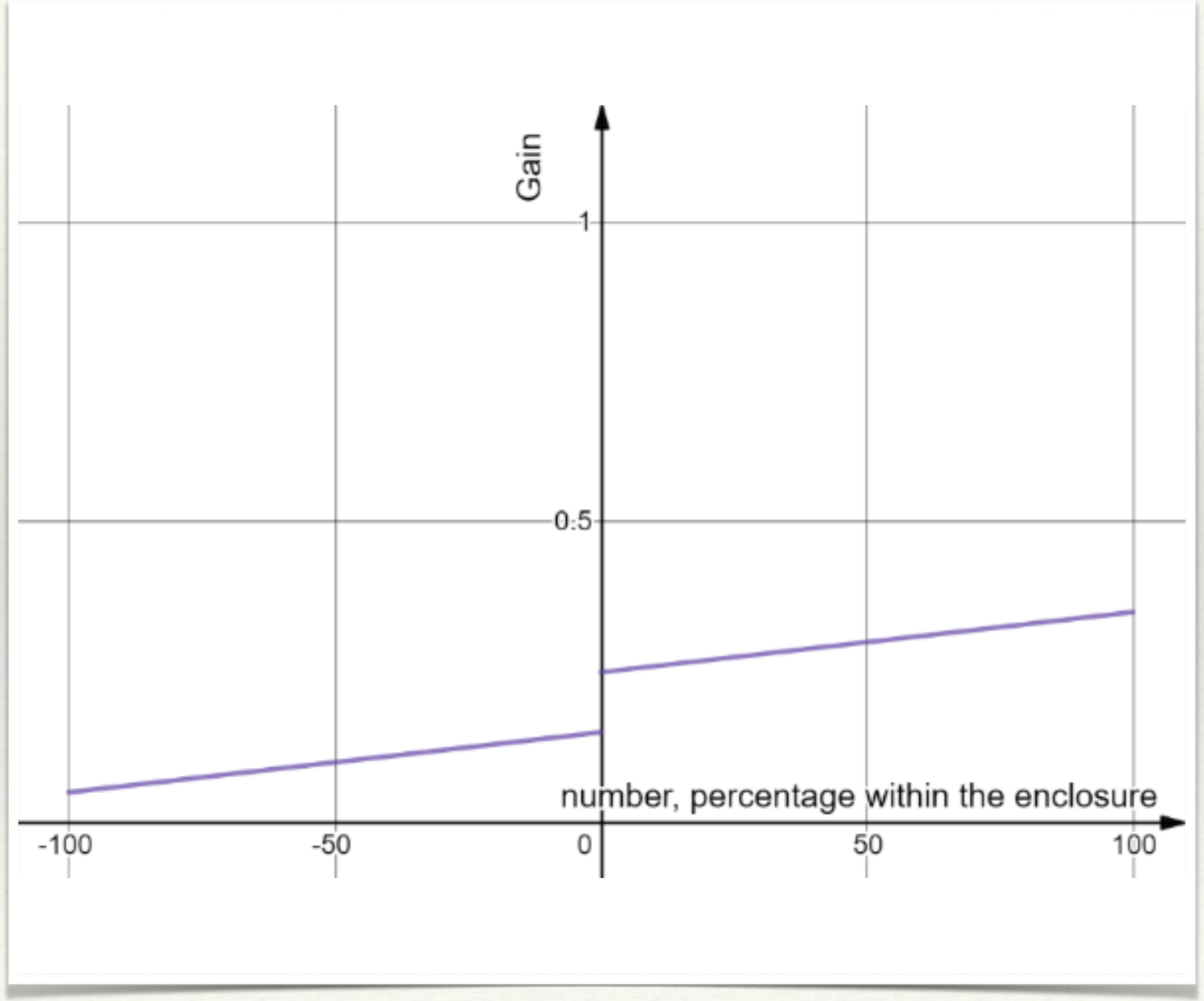
- Participants Feedback:
  - Don't know what's going on.
  - Sounds like police sirens.
  - Feels anxious and nauseating.



# Design Iterations

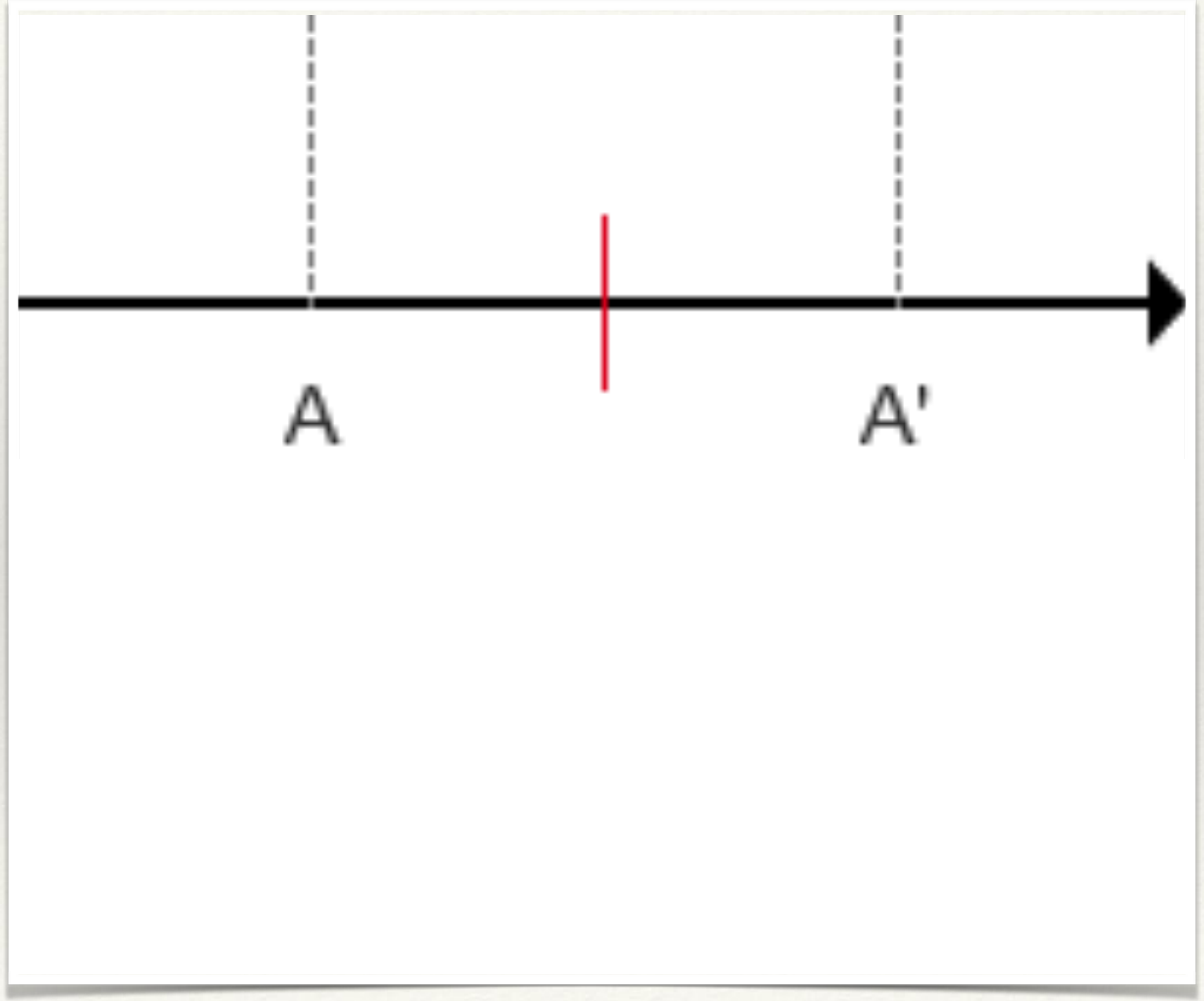
- Iteration 2: Use loudness to represent value in y-axis

- Participants Feedback:
  - Totally confused
  - Can’t tell the similarity between a number and it’s negative.



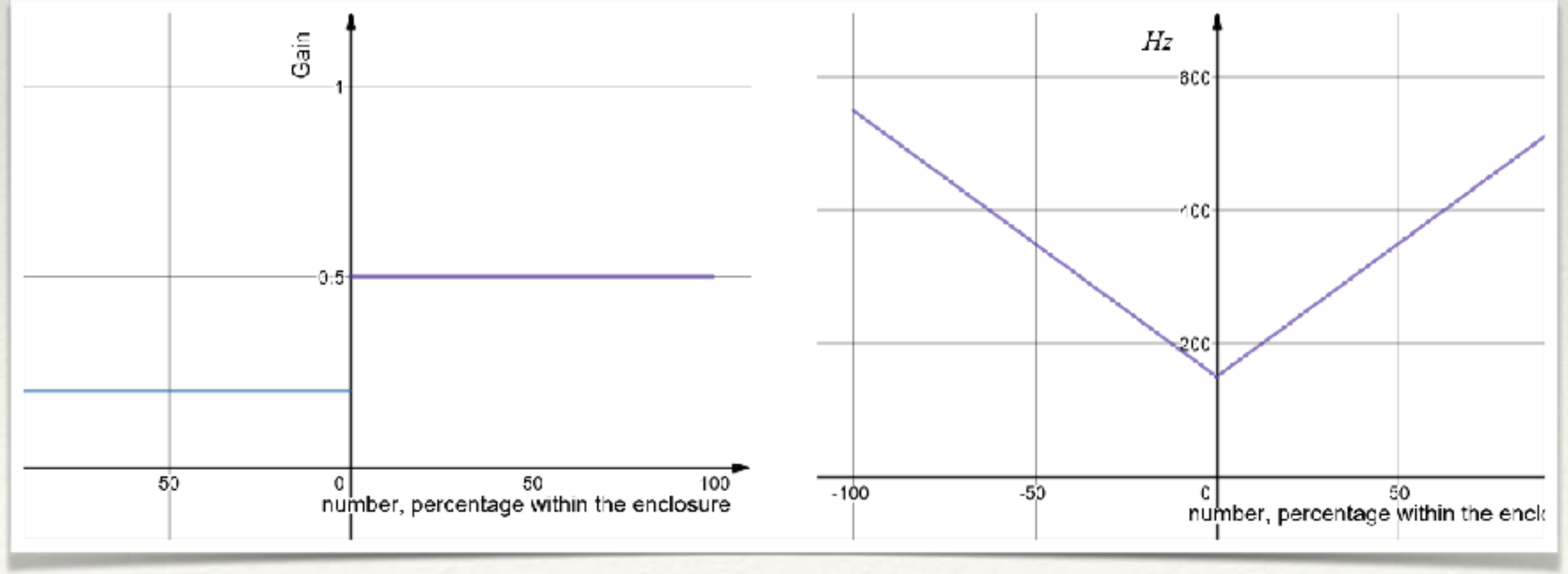
# A Number and It’s Negative

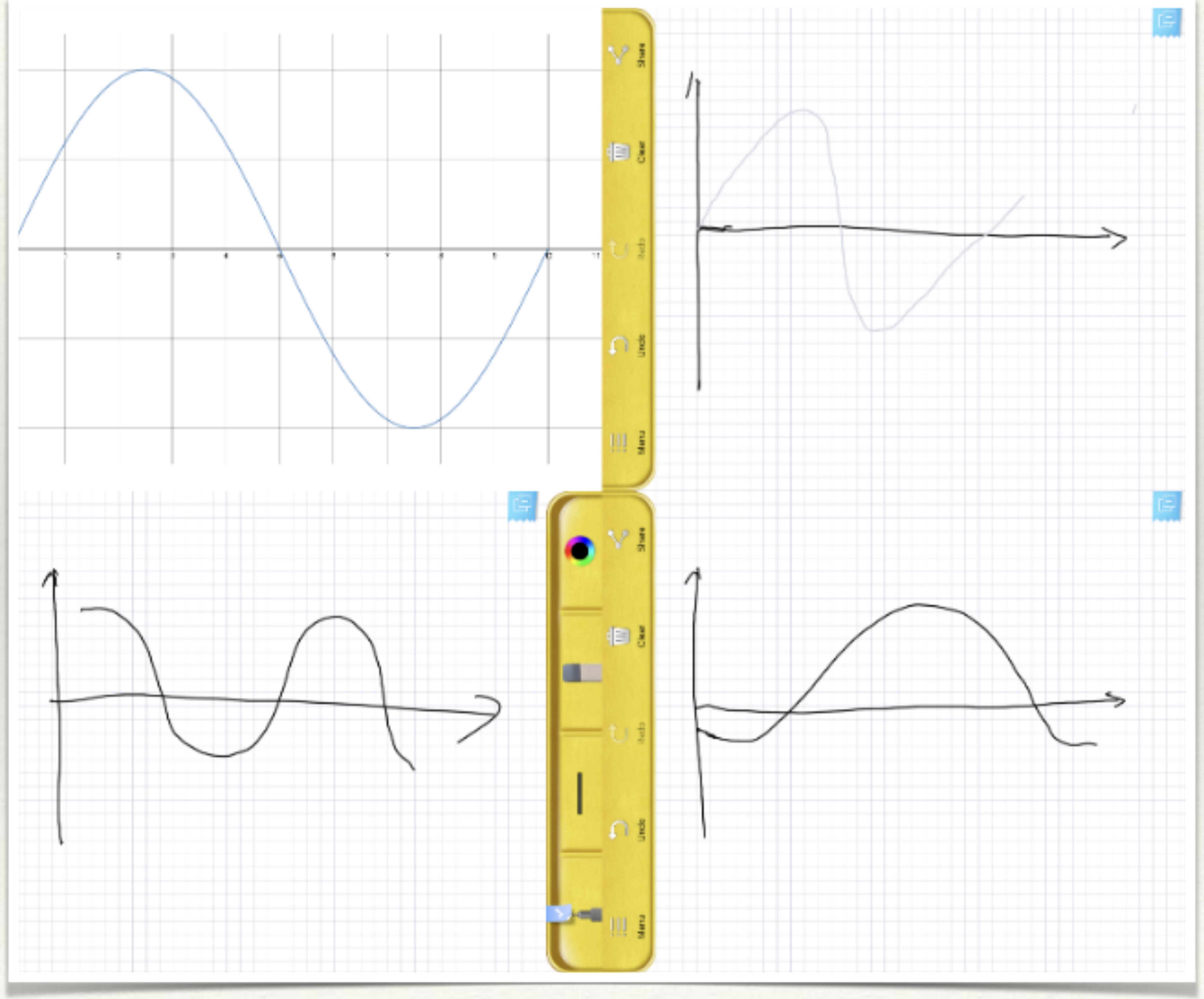
- A and A′ have a similar distance towards the original point.
- Which suggests they have a similar absolute value.



# Design Iterations

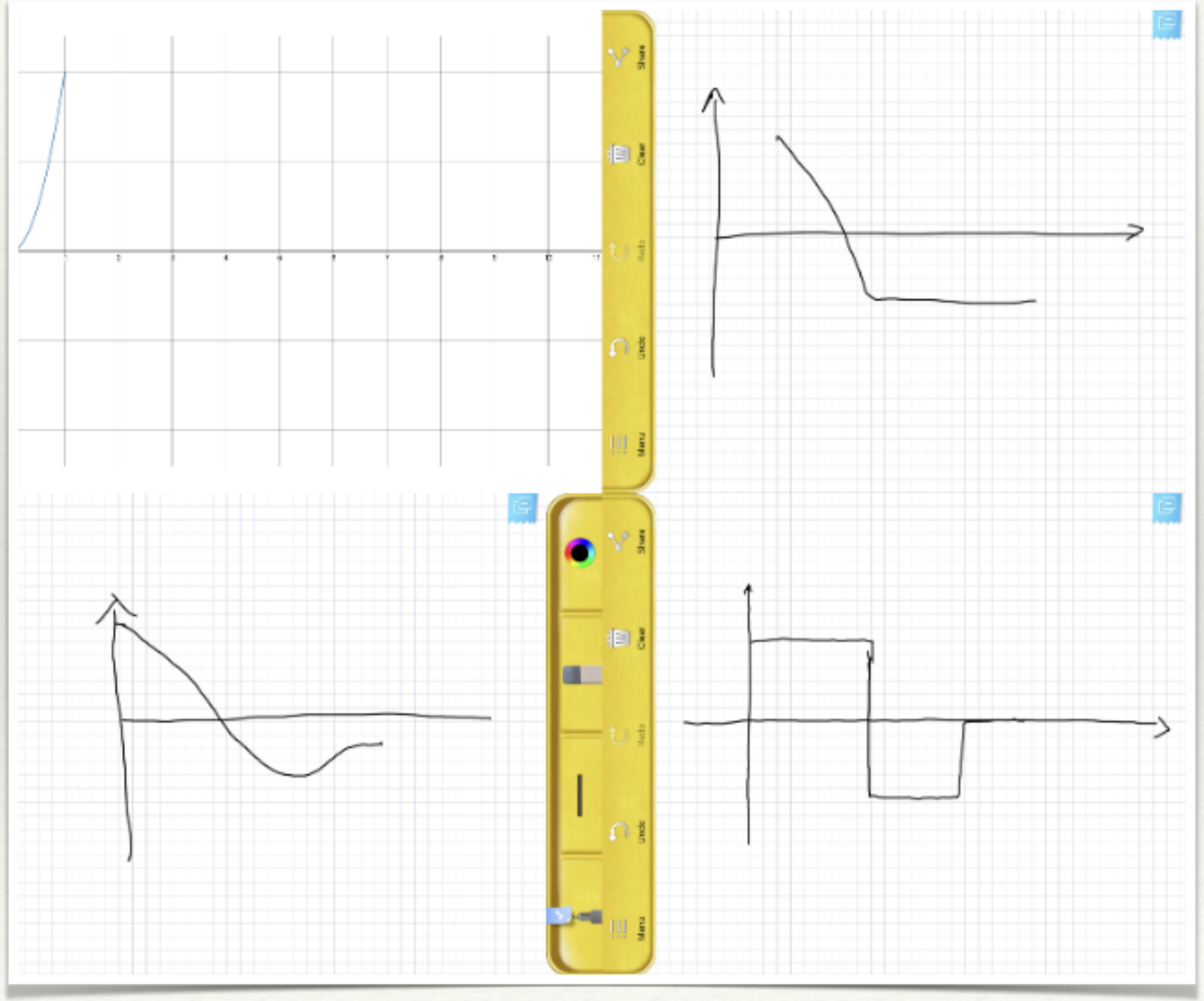
- Iteration 3: Use pitch as absolute value, and loudness to represent
  - Only use pitches lower than 550hz
- Participants Feedback:
  - It's hard to do.



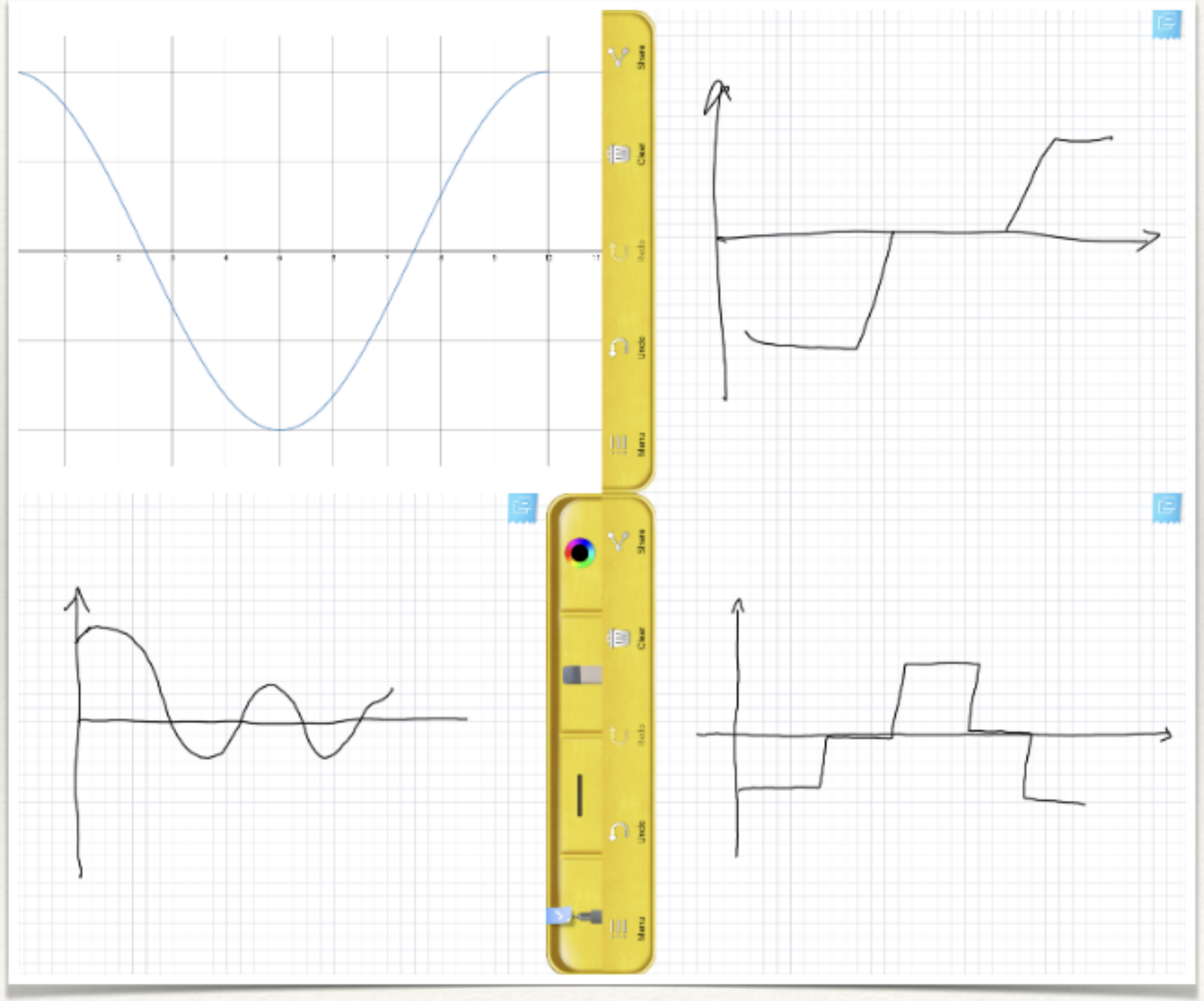
# Design Iterations

- Iteration 4: Dotted Sound 1
- Similar to Iteration 3, Just the sound is not continuous.
- There is actually a bug… so when the data is out of range, there are still sounds playing.



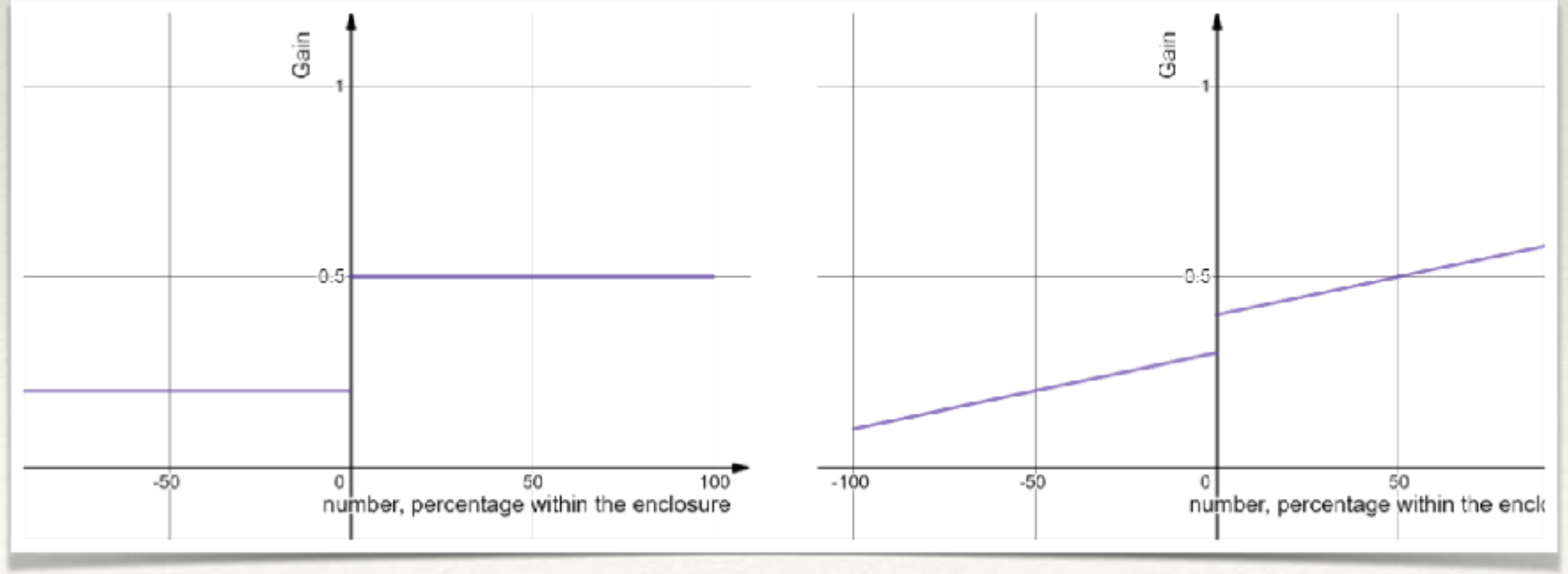
# Design Iterations

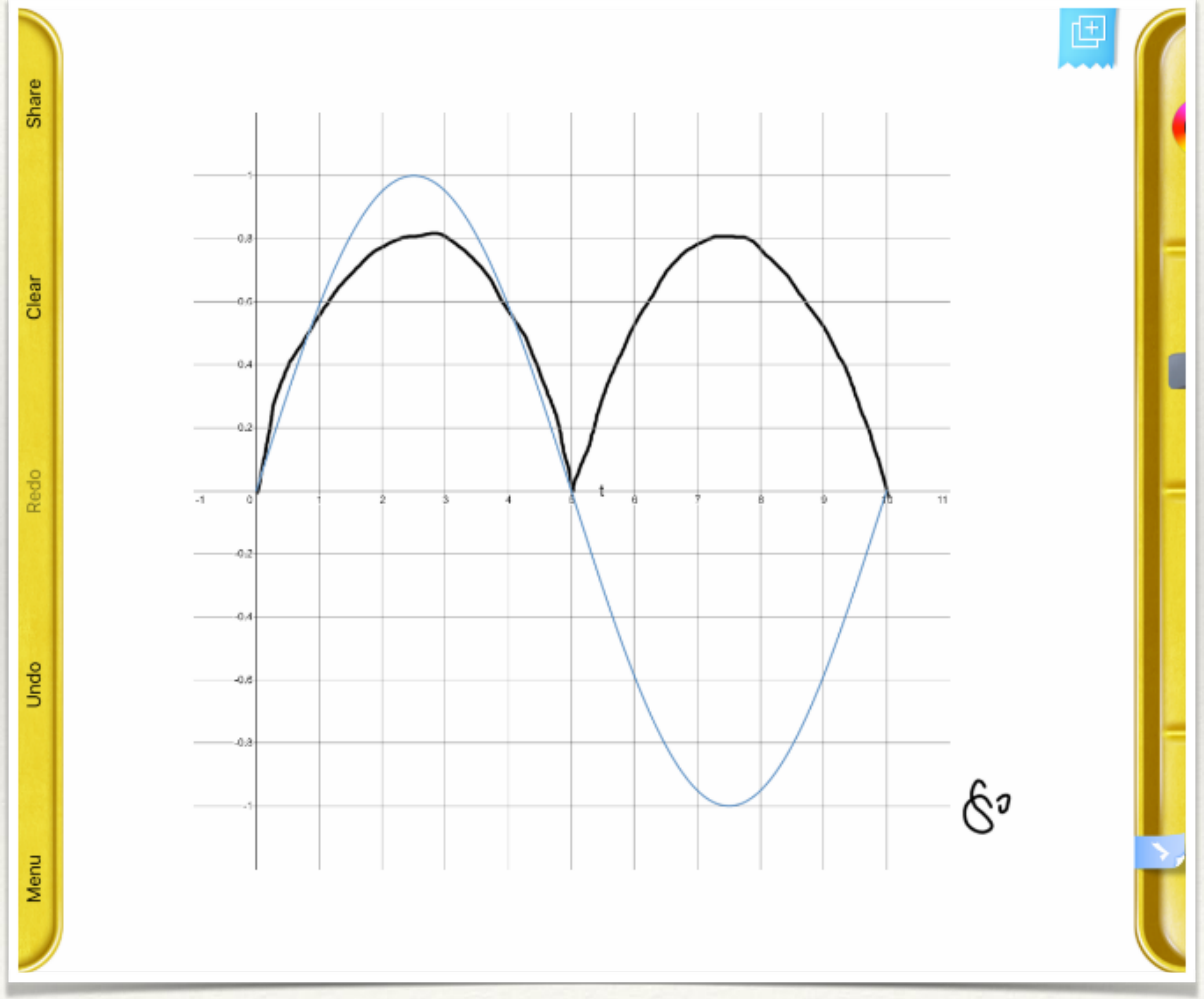
- Iteration 4: Dotted Sound 2
  - The higher the absolute value, the more rapid the sound



# Design Iterations

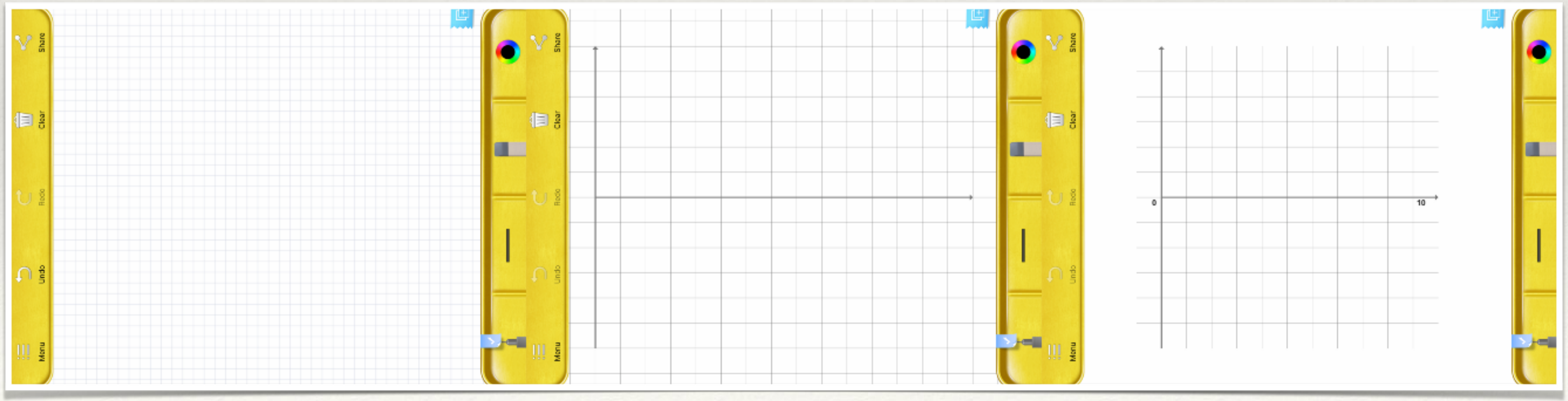
- Iteration 5:
  - Repair Bugs
  - Changes how loudness react to positive and negative numbers



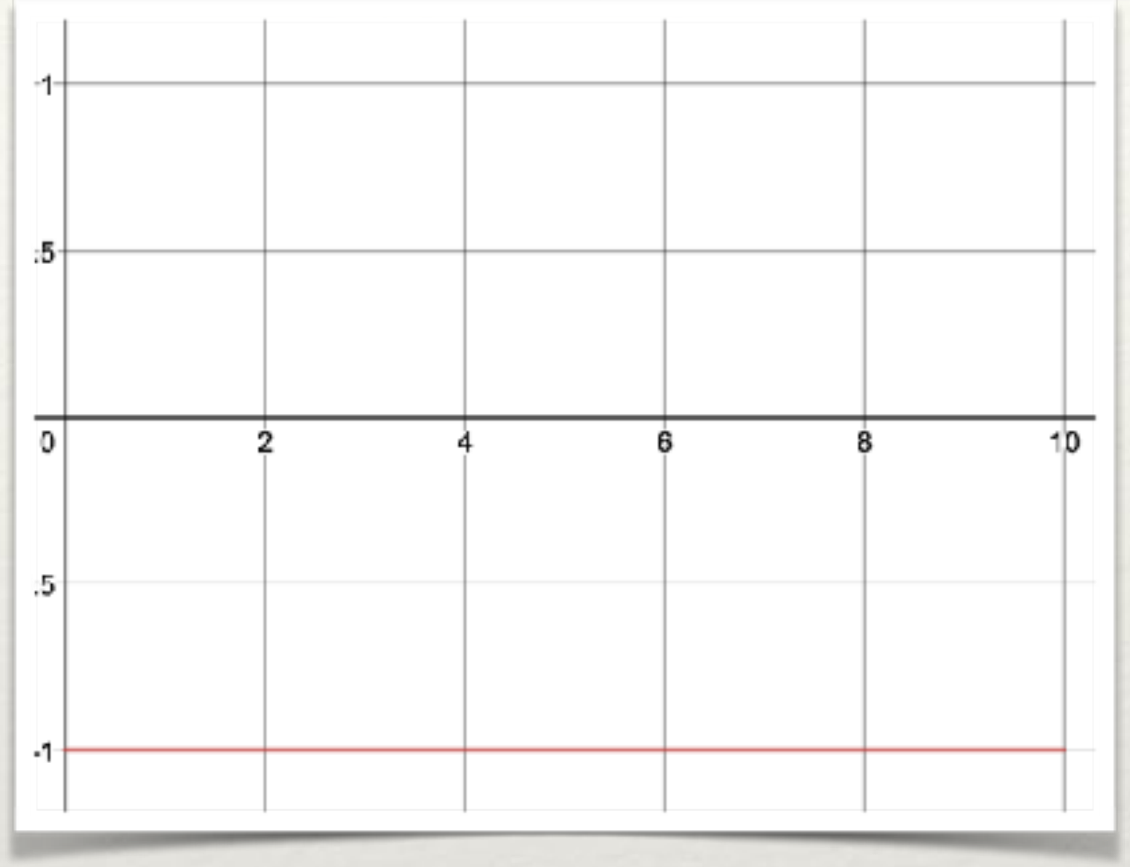
# Design Iterations

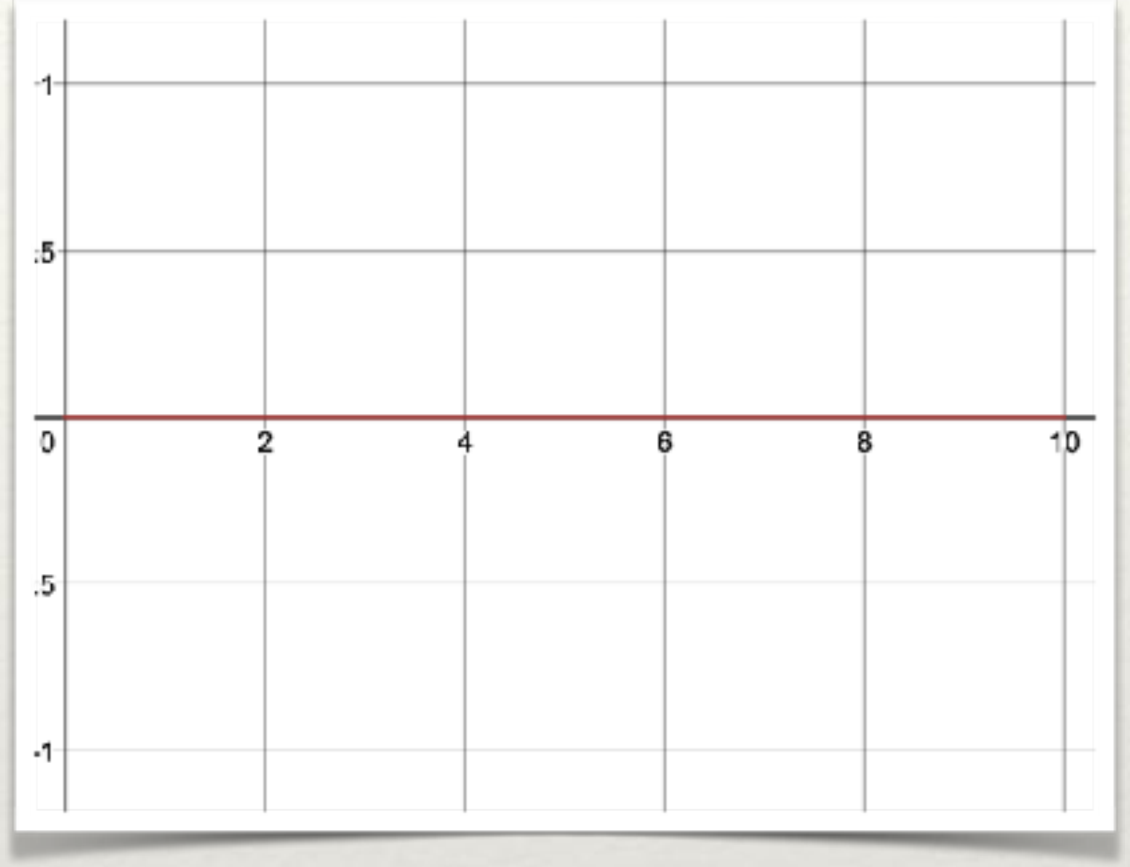
- On the provided drawing material.
- On the questions and explanation of the design.

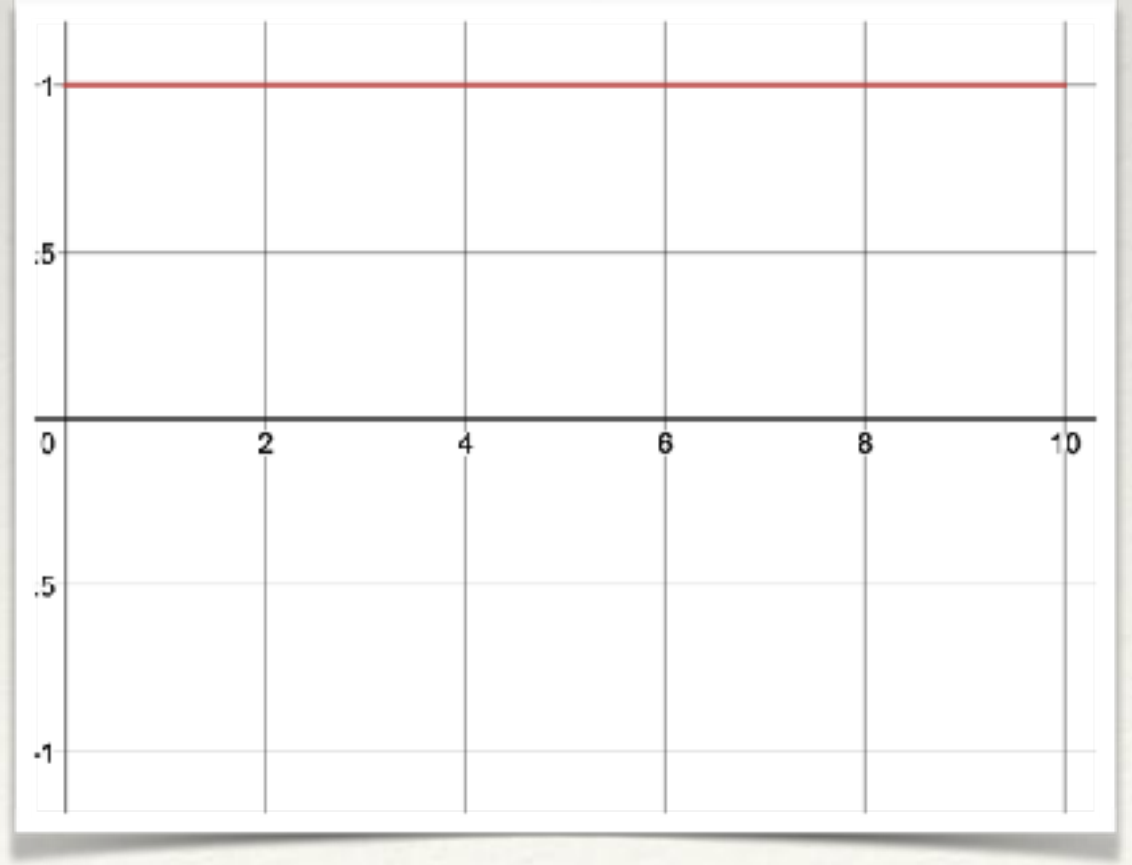


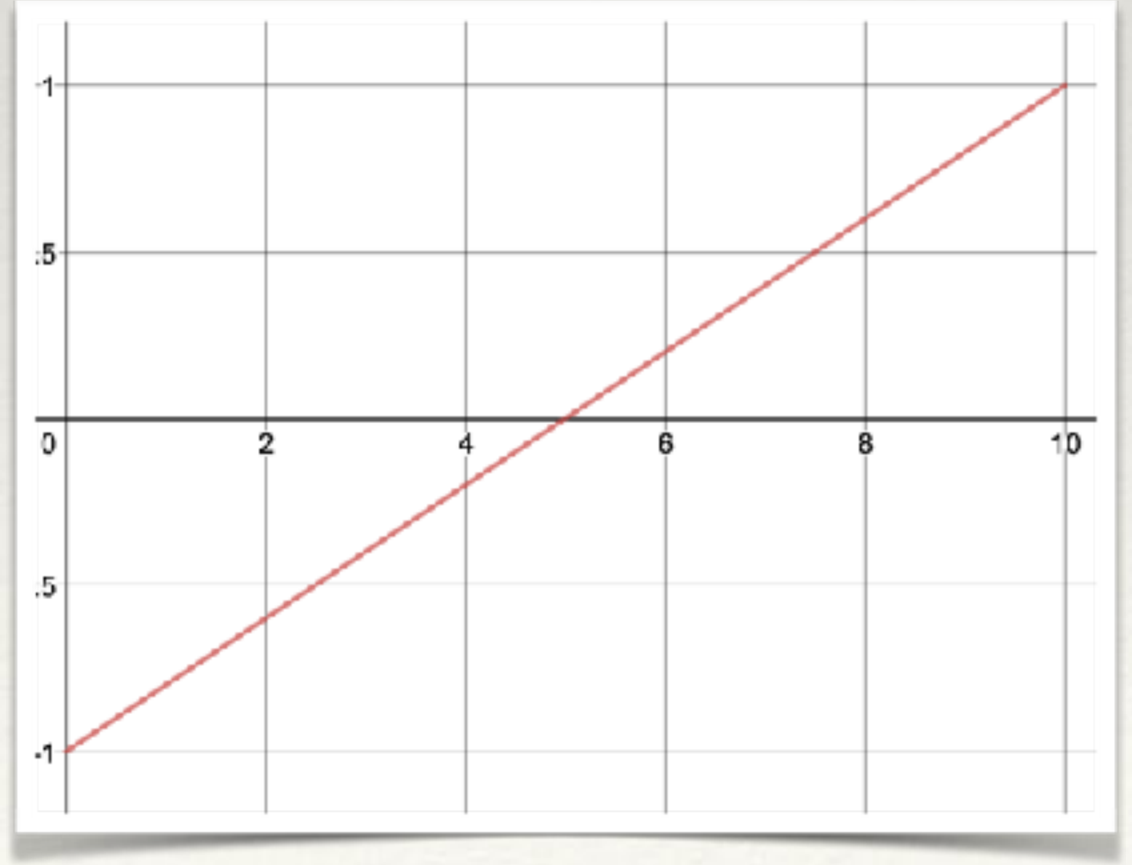
# Within-Subject Experiment

- 4 Sample Sound to help participants get familiar with the sound:
- Play once without the referential sound cue
- Play again with the referential sound cue



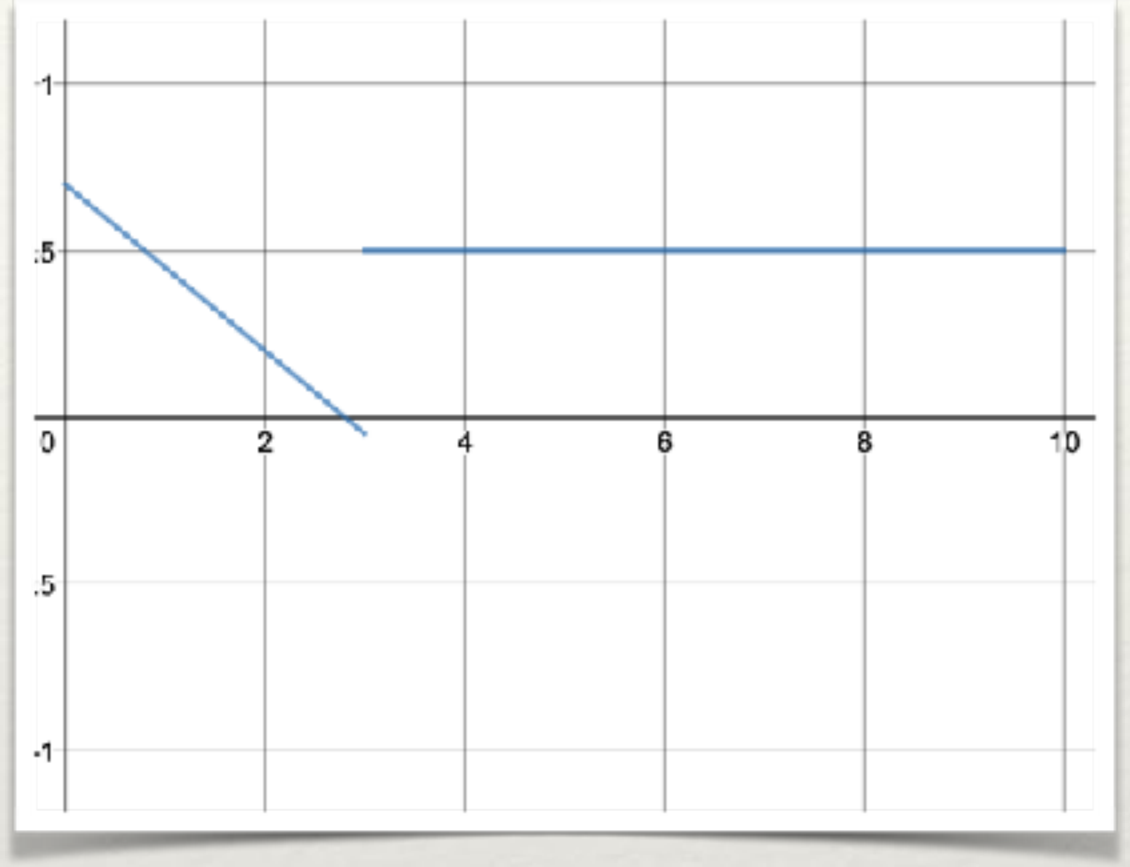


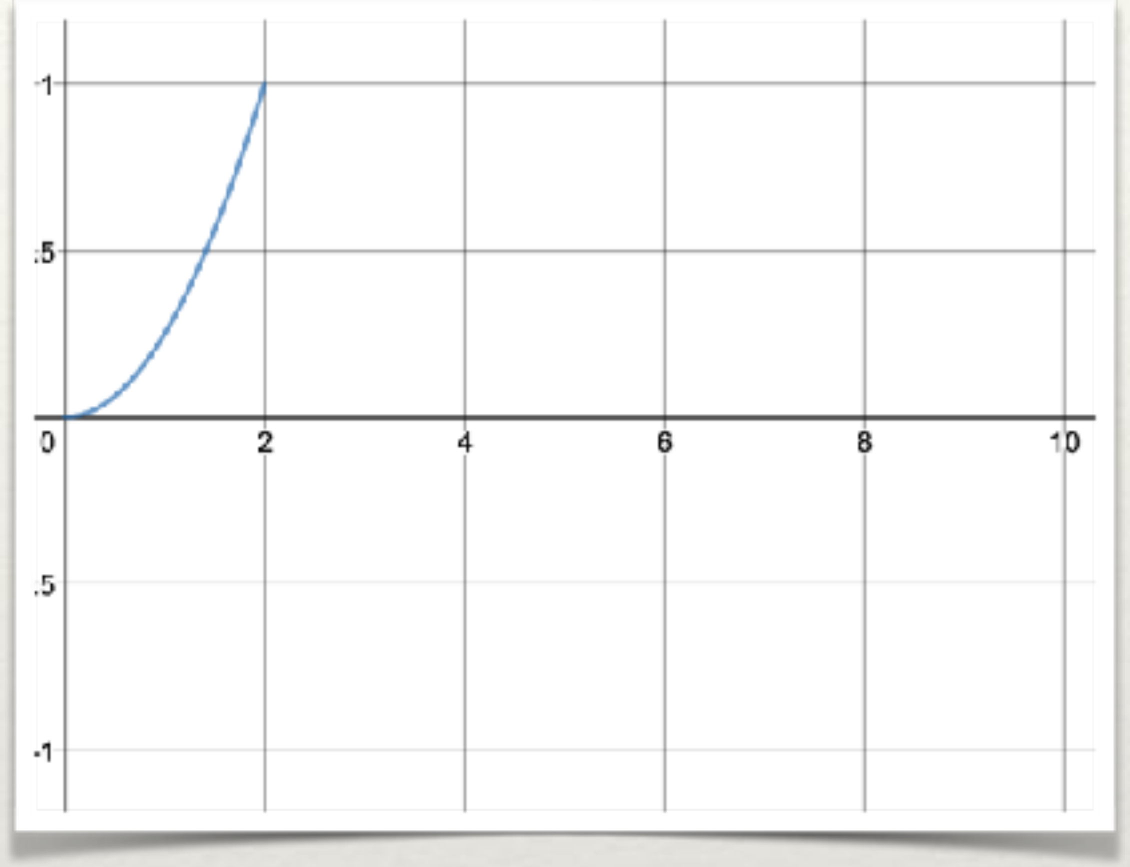


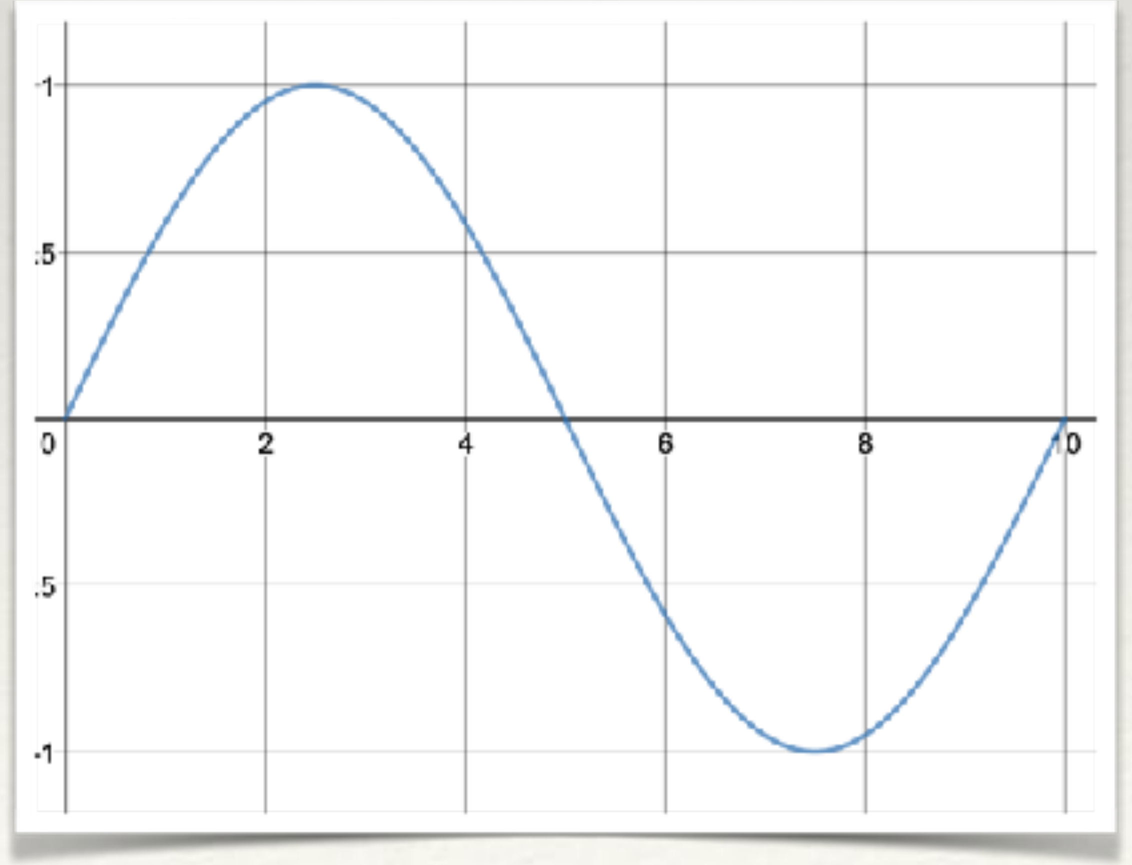


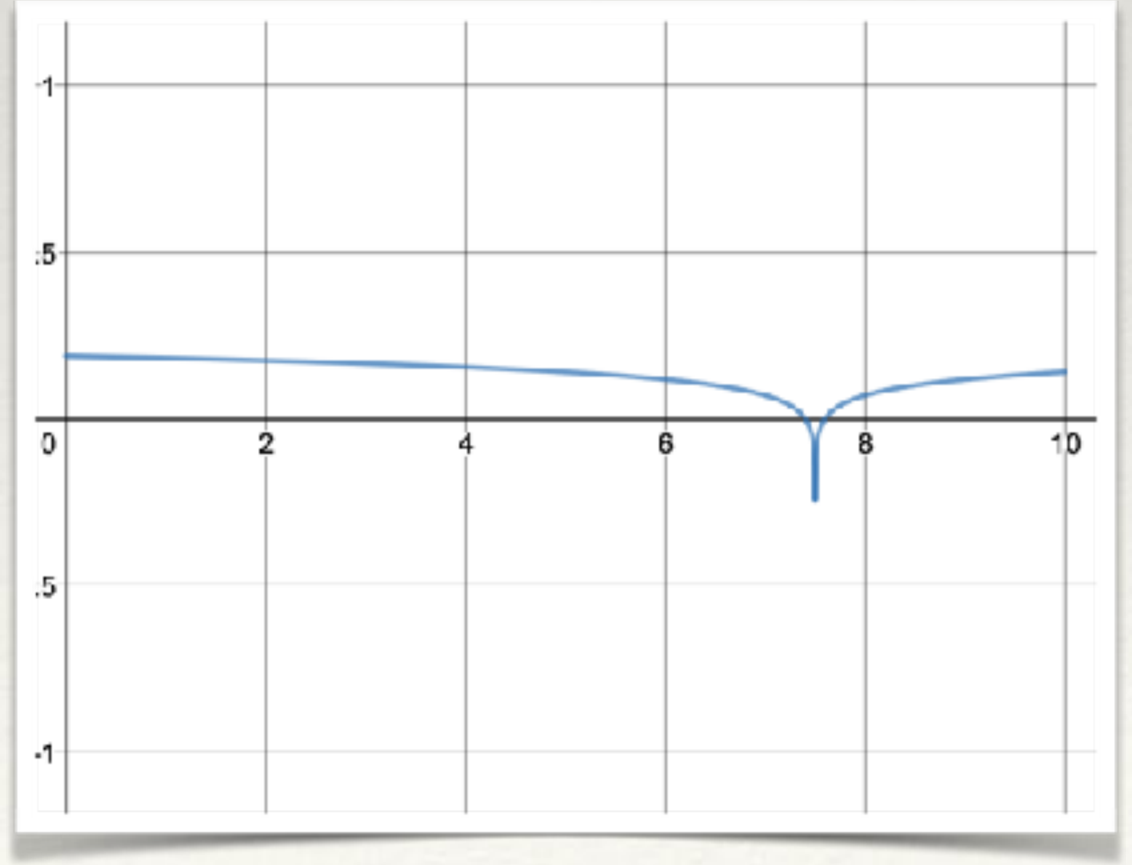
# Within-Subject Experiment

- 4 test sounds requires participants to draw
- Play once with/without the referential sound cue (random)
- The order of 4 charts is random too.



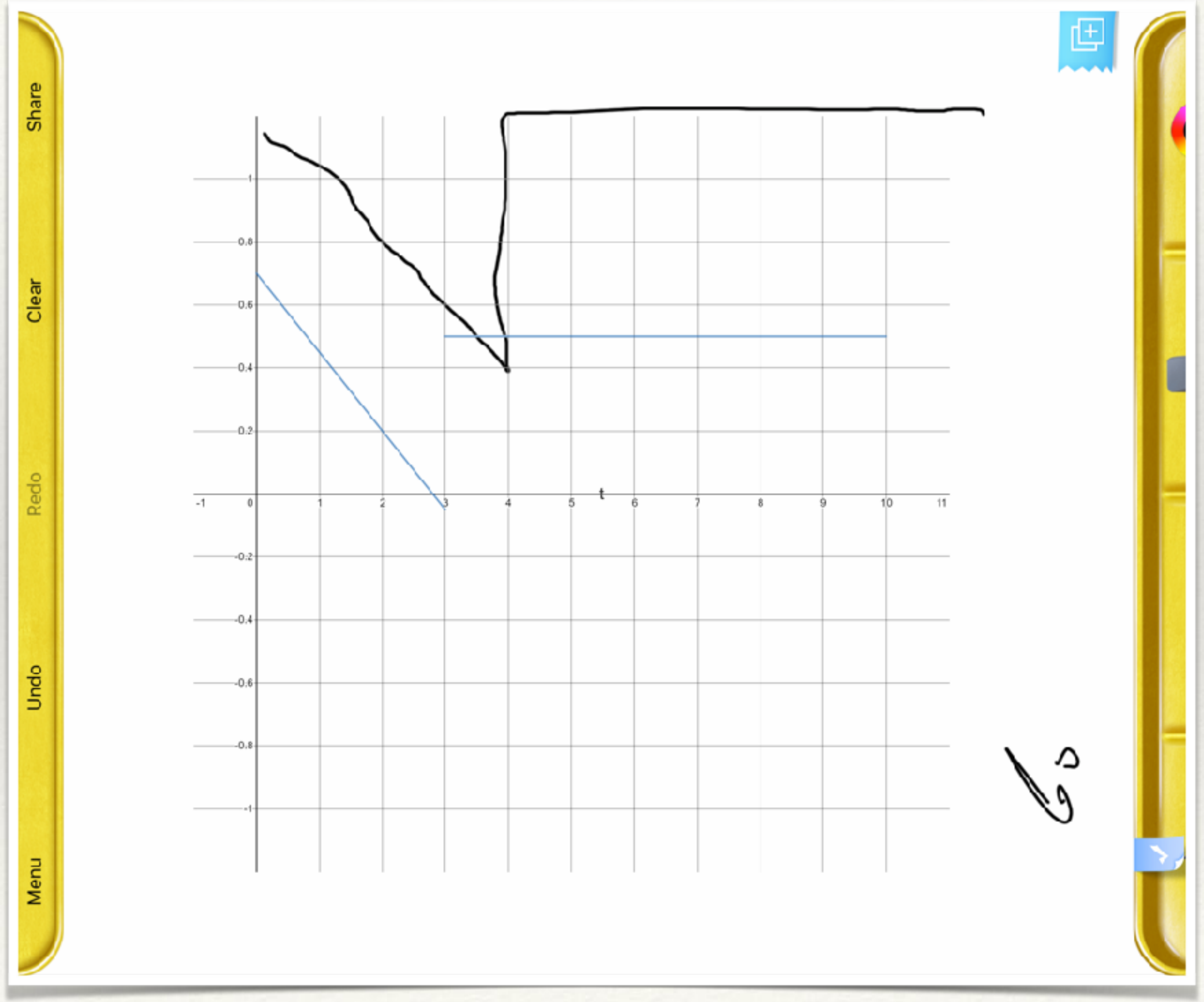






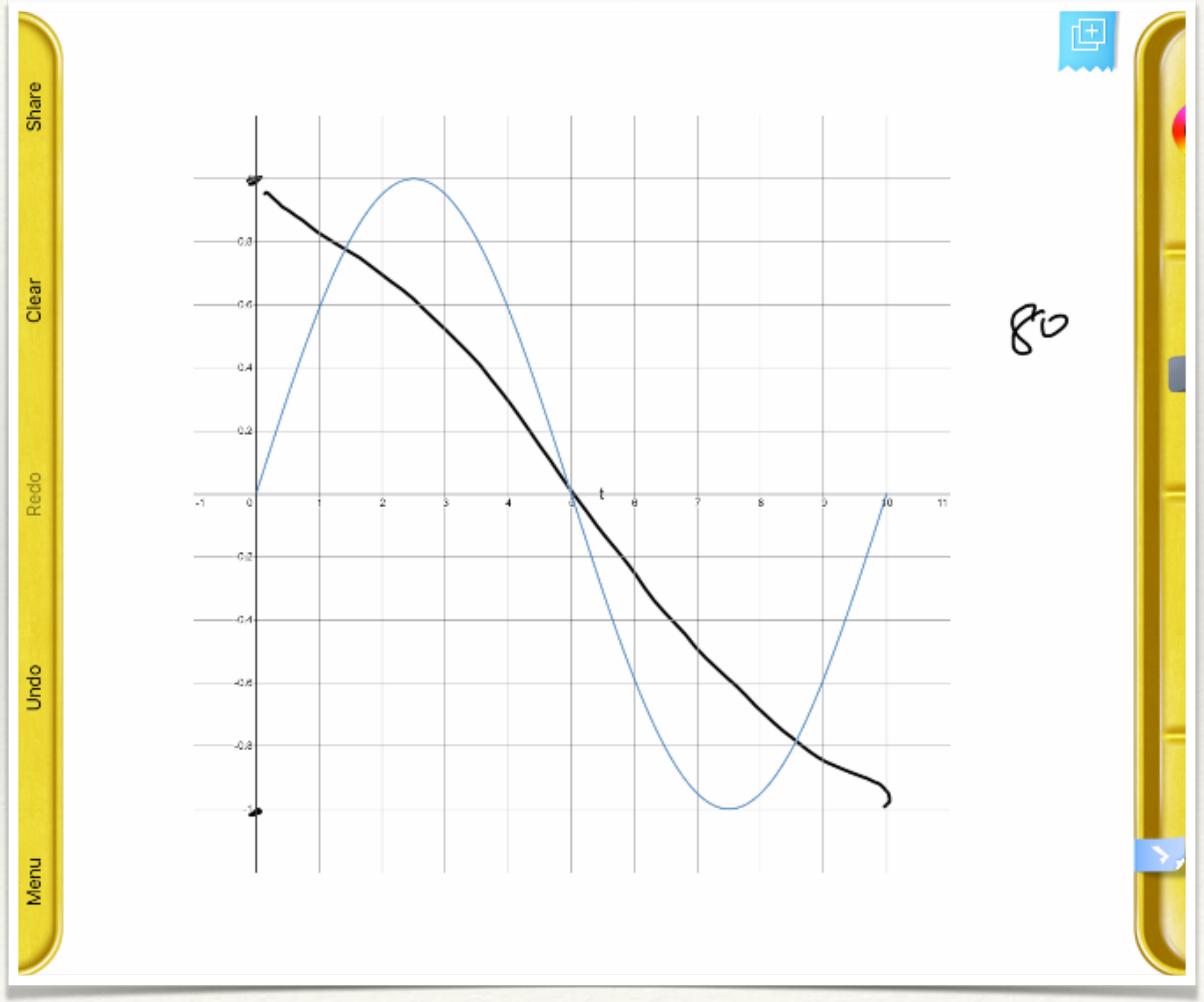
# Participants and Samples

- 19 participants
- 76 samples (4 from each participant)
- Calculate the deviation from the participant's drawing to the original chart



# Participants and Samples

- Some samples show the participant didn't make sense of the sonification. So some samples are discarded as they can't be analyzed.
- Overall, I have 61 samples left.
- I used unbalanced factorial Anova to exam the significance between different pictures and with/without the sound cue.



# Data and Findings

- Original Questions 1:

  Whether or not including a referential sound which slice time equally in signification improves people's accuracy of the axis represented by time?

- The raws refers to different pictures
- The columns refers to with/without the sound cue

| Two Factor Anova (via Regression) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| ANOVA | | | | Alpha | 0.05 | |
| | *SS* | *df* | *MS* | *F* | *p-value* | *sig* |
| Rows | 25.99936 | 3 | 8.666453 | 9.589008 | 3.69E-05 | yes |
| Columns | 2.572543 | 1 | 2.572543 | 2.846393 | 0.097457 | no |
| Inter | 11.63899 | 3 | 3.879664 | 4.29266 | 0.008748 | yes |
| Within | 47.90089 | 53 | 0.90379 | | | |
| Total | 89.56318 | 60 | 1.49272 | | | |

# Data and Findings

- Original Questions 2:

  Whether or not including such a referential sound in sonification deteriorates people's accuracy of the other dimension represents the y-axis?

- Unable to answer

# Data and Findings

- New Questions 3:

  Is it possible, with or without the test sound cue, the participants will appeal to perform better in time perceiving accuracy if the turning point happens to be at the middle point of the full duration?

- Used Welch's t-test to exam the data.
- The result t-statistic is 5.20, while the $t_{0.05/2,32}$ is 1.697.

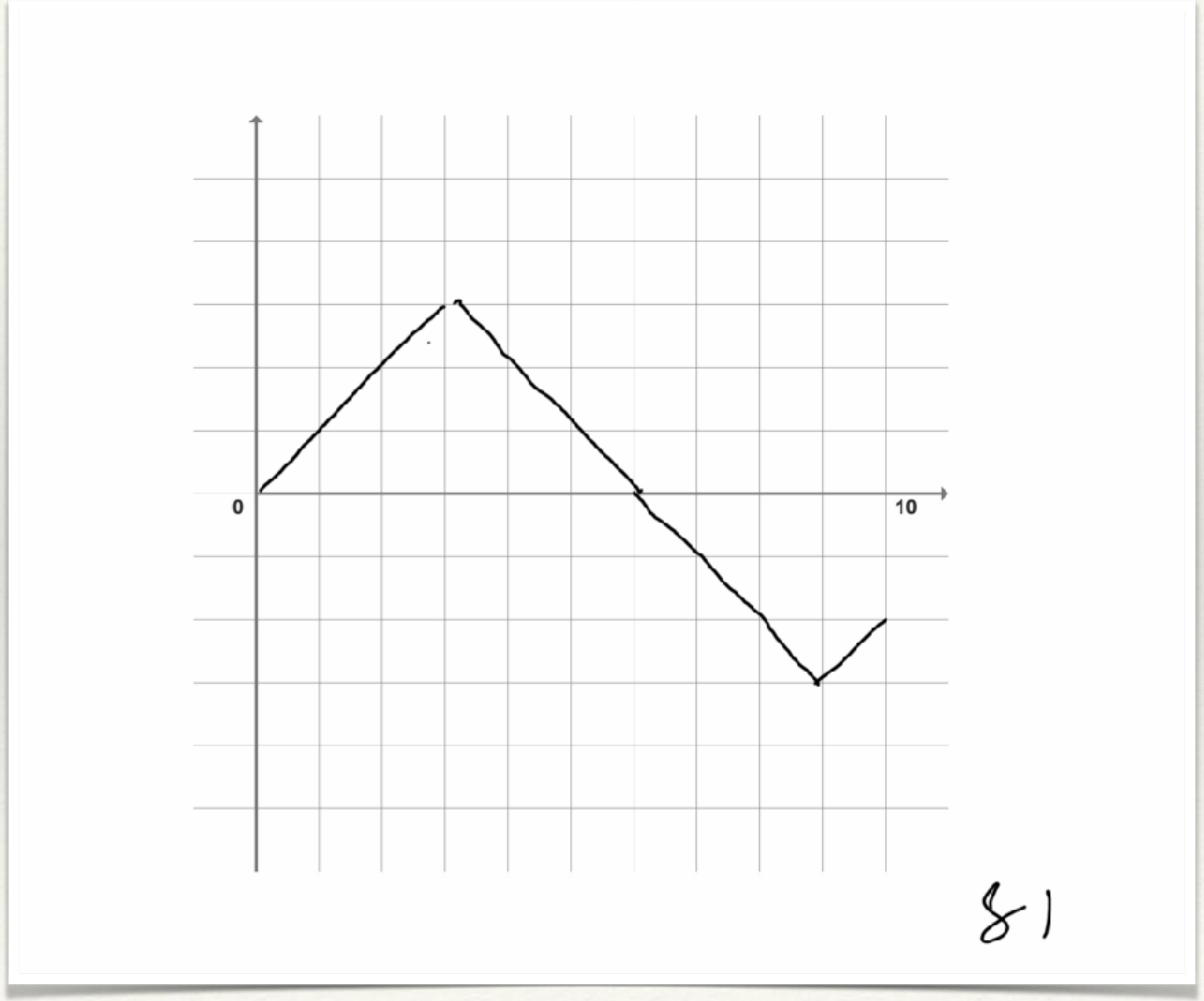
| | | | |
|---|---|---|---|
| MEAN | | | |
| | With Sound Cue | Without Sound Cue | |
| Picture 1 | 1.555555556 | 1.25 | 1.402778 |
| Picture 2 | 0.9375 | 2.8125 | 1.875 |
| Picture 3 | 0.357142857 | 0.241111111 | 0.299127 |
| Picture 4 | 0.375 | 0.583333333 | 0.479167 |
| | 0.806299603 | 1.221736111 | 1.014018 |
| | | | |
| VARIANCE | | | |
| | With Sound Cue | Without Sound Cue | |
| Picture 1 | 1.277777778 | 1.175 | 1.17381 |
| Picture 2 | 0.602678571 | 3.424107143 | 2.816667 |
| Picture 3 | 0.226190476 | 0.146961111 | 0.17239 |
| Picture 4 | 0.053571429 | 0.141666667 | 0.09478 |
| | 0.78125 | 2.252671429 | 1.49272 |

# Error

- 10 seconds length of sound with 11 referential sound cues.

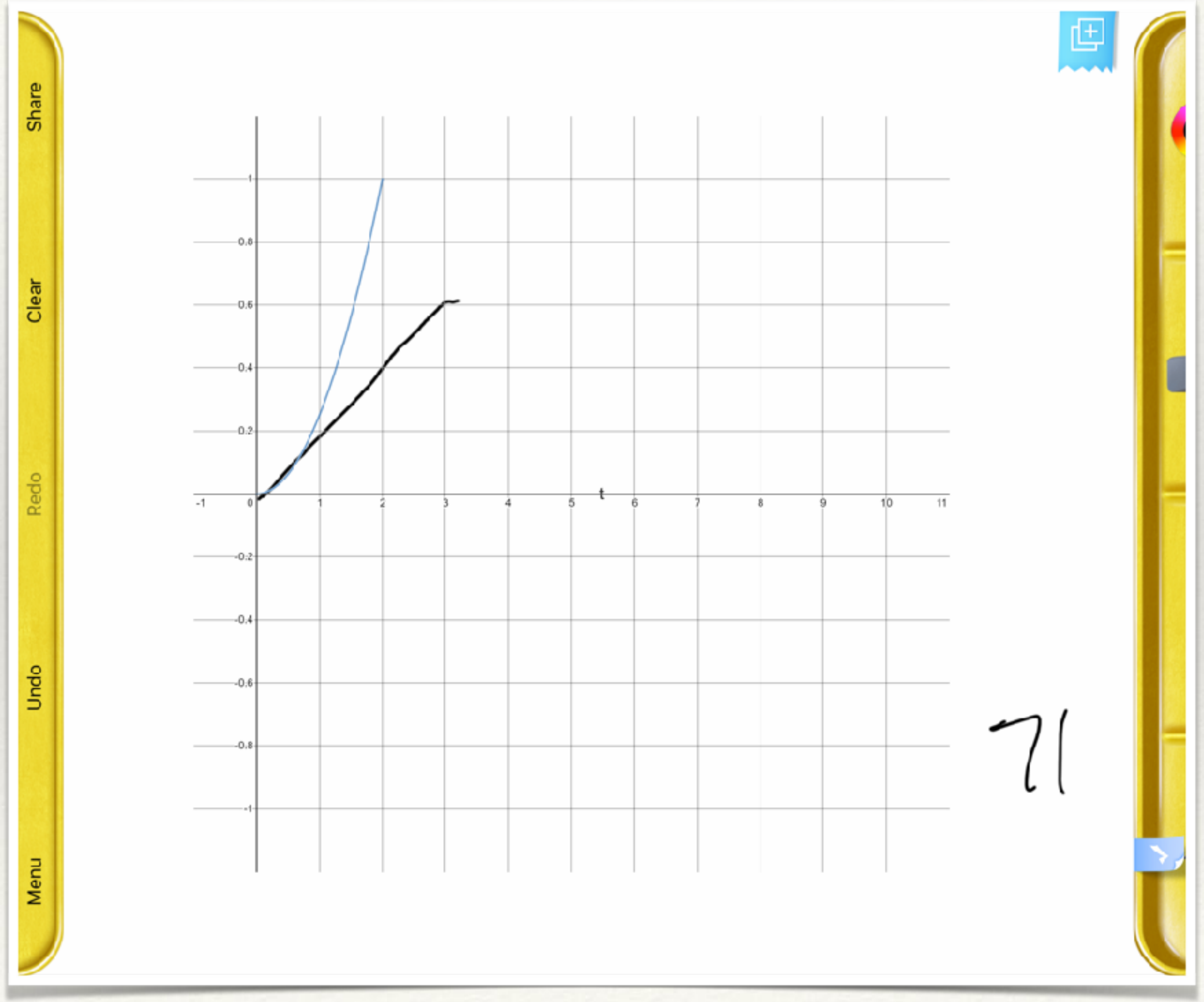
- Creates 1 seconds deviation.

- Participants testimony:
  - “I used the referential sound cue by counting them.”
  - “Yes I count them start from 1.”



# How this Error Impacts Data

- Data which are highly possible influenced by this mechanism:
  - Little room for ambiguity.
  - Turning point happens in the first half of the time.
  - Five of them in picture 2, more possible in picture 1 and 3.



# How this Error Impacts Data

- After I changed all those “1” to “0” in picture 2, the result shows there are indeed significance between the columns.

- I only need to change 3 of them into 0 to make the result to show the significance.

| Two Factor Anova (via Regression) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| ANOVA | | | | Alpha | 0.05 | |
| | *SS* | *df* | *MS* | *F* | *p-value* | *sig* |
| Rows | 20.17367 | 3 | 6.724558 | 7.314955 | 0.000342 | yes |
| Columns | 5.499256 | 1 | 5.499256 | 5.982076 | 0.017806 | yes |
| Inter | 19.17503 | 3 | 6.391677 | 6.952849 | 0.000496 | yes |
| Within | 48.72232 | 53 | 0.919289 | | | |
| Total | 95.30154 | 60 | 1.588359 | | | |

# Conclusion

- From the test result, I can say the design of using a sound cue to help people improve the time perceiving accuracy is working.
- From the test result, I can also say that the design of number - sound transferring system, although need more modification to be useful, does expand the drawing enclosure on the y-axis. So now it could hold both positive and negative numbers.
- However, only the potential, not the promise of an accessibility approach is proved in this work.

# Future Works

- Answering Question 2. Keep modify the sound cue so it does not impact people's perception of the sound itself.
- Keep iterating the sound. So people don't need much training to tell what the sound represents.
- Keep iterated the sound. So people could tell the difference between a straight line, an upper curve, and a lower curve.
- Try it on participants who are actually blind and low vision, and see how this sound help them absorbing data chart quickly.

Thanks!