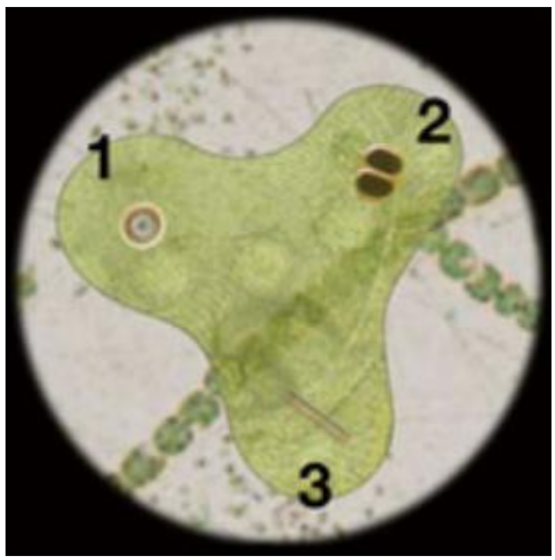
Category-VR: A tool for conducting rule-based category learning experiments in virtual reality

Essence Statement

Category-VR is a toolkit for researchers to be able to easily set up a wide variety of experimental environments in the rule-based category learning paradigm, deploy executable versions of the experiment onto lab computers, and than have the data from each run-through streamed to a file in a designated directory for later retrieval and analysis.

To date, much work has been done to describe how people's attention changes over time as they learn to recognize and accurately identify members of different categories based on rule-based feature detection. A compendium of such experiments can be found at McColeman et al. (2014). In these experiments, participants eye movements were tracked to follow the changes in how they access information from the time when they are starting the experiment and just guessing at the categories, to the time where they have mastered the task and quickly fixate to only the relevant information in the scene. An example of the kind of stimulus used in one of these experiments can be found below:



In these kinds of experiments, a participant uses the 3 lablled features to make a decision about whether or not this is an example of a particular category, and is usually given feedback afterwards to guide future trials. Credit: Chen et al (2012)

Recent work with StarCraft 2 (McColeman et al. 2020) has found that the changes in how people access information as they improve their skills in these eyetracking experiments are very similar to the way in which StarCraft 2 players at varying levels of skill access information relevant to their domain. This is interesting because it implicates that attention, as a cognitive phenomena, is not just applicable to eye movements, but is also extendable to other types of information access, such as mouse and keyboard based screen movements which require the use of a player's hand to initiate.

The next step of this research is to try and implement a traditional rule-based category learning experimental task into a context where the method of accessing information requires the use of a participant's hands. Using VR, we can achieve this by having participants rotate an object in space to reveal information hiding on its different sides. This is the goal of Category-VR.

Key Features:

Category-VR is comprised of four main components that work together as a researcher tool.

Experimental Environment: Here Participants will be presented with stimuli and will be asked to classify them into categories and given feedback on the accuracy of their answers.

Stimulus Set: An example set of stimuli so that researchers can easily get started making their own experiments.

Researcher UI: An area for researchers to be able to adjust the experimental parameters. Might be UI based or Unity based depending on technical skills of lead programmer

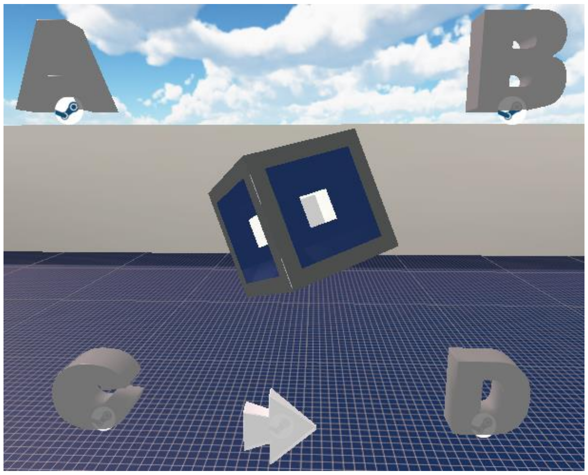
Data Streamer: This is more of a backend feature but is arguably the most important piece of the toolkit. This set of scripts will stream positional data, ray casting data, trial level and experimental level data to a file in a pre-designated folder on the researcher's computer.

Look and Feel:

There are two main users to be considered when describing the experience of using this toolkit: both the research participant and the researcher setting up the experiment.

Experience of the Participant

From the perspective of the research participant, care must be taken to create an environment that is immersive, but not distracting from the experimental task. Participants will be seated in a virtual environment and following a training period where they will be introduced to the controls, they will be presented with various stimuli which they will then classify in different categories. These classifications will be simply guessing at first, but through feedback presented after each trial, participants will hopefully be able to learn the categories over time. This will continue until the total number of trials specified has been reached



An example test cube which participants can rotate to see the different features of the stimulus. Note how the white space at the bottom of the indentation is only visible when the participant has fully rotated the cube, meaning that no two features can be visible at any one time.

Experience of the Researcher

From the researcher's perspective, this tool will be a Unity Package paired with documentation explaining in simple terms how to adjust the different parameters depending on what kind of study the researcher wishes to conduct. The researcher will be able to adjust the settings of the program to prepare for different sets of conditions, including stimulus features, feedback phase timing, and pre-experiment text. The toolkit will then track how many independent variables have been set and create an exhaustive list of every permutation of the current conditions, which will also specify the minimum number of participants needed to test certain hypotheses. Each of these will also be paired with a suggested list of participant ids to be used during data collection. Following data collection, the researcher will be able to find a folder in a designated directory filled with .csv files containing all the data for each participant to be parsed by the researcher as they like.

Unity Requirements:

At minimum, there will be three main virtual environments created for the participant. One to introduce them to the controls and teach them the basics of making responses in VR. There will also be the experimental environment where they will be presented with stimuli over a set number of trial blocks, and given feedback as to the accuracy of their answers. Lastly, there will be an "end of experiment" room, where the participant can be rewarded for their participation with a nice environment to either explore or be let out from as they choose.

As a stretch goal, I may attempt to implement inter-trial-block rooms where the overall accuracy of participants' responses will be either rewarded with a pleasant scene, or met with a blank area encouraging them to perform better in the coming trials.

For the researchers, the minimum requirements that must be developed for this project start with the data streaming module. This program absolutely must stream data from the unity environment to a file in a folder on the researcher's computer. The second requirement for this project will be for the program to be able to output a report for the researcher which gives them a specific list of participant numbers to enter as they run the experiment. These participant numbers will be based on the minimum number of participants needed to exhaust all possible permutations of the independent variables used in the experiment, and as such, entering these numbers will indicate to the program which condition to give to the participant currently being run.

As a stretch goal of high priority, the third requirement for this project is to create a settings GUI that will allow researchers to adjust the parameters of the experiment based on the experimental conditions used and described by other previously published scientific literature.

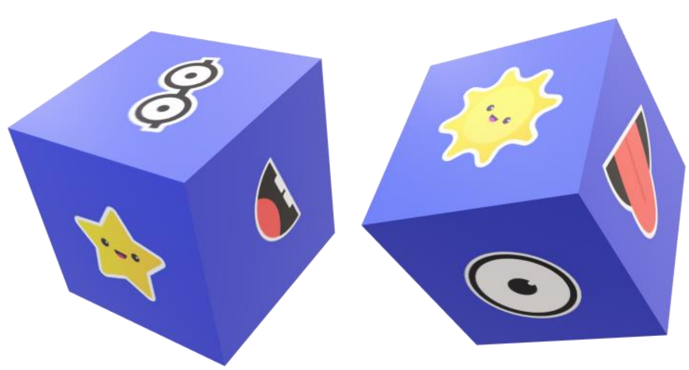
For example, if the researcher wishes to study the impact of feedback duration on learning, they can toggle on "timed feedback", and then specify the number of conditions, and the duration of the feedback phase in each condition. If a researcher wanted to test the impact of feature saliency on learning, they could swap out the example stimulus set for a set of features of their own creation, and have the program fit those images into the designated location of the stimulus mesh renderer for feature locations.

Timeline:

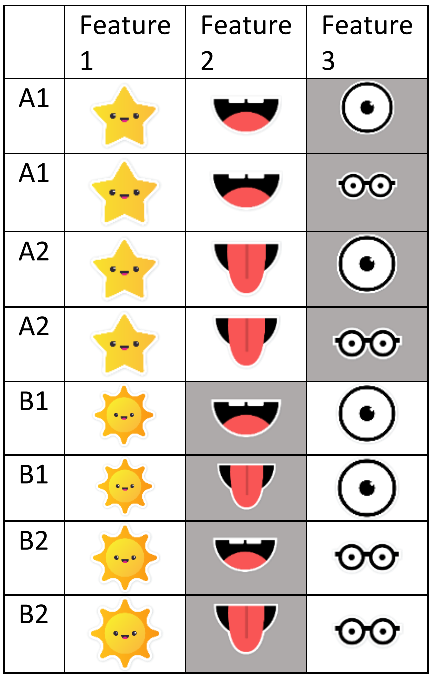
- **Oct 31st:** By this point, a shell of the experimental environment should be completed, and be able to be run through experiment with protype stimuli. Basic feedback system should be done also.
- **Nov 7th:** Data Streaming will be implemented.
- **Nov 14th:** Base version of the experiment should be ready with meshes properly created for stimulus set. Some researcher UI should be ready by here.
- **Nov 21st:** Catch up on any trailing requirements or begin implementing stretch goals if time permits.
- **Nov 28th:** Continue implementing stretch goals and write up documentation for using the toolkit.

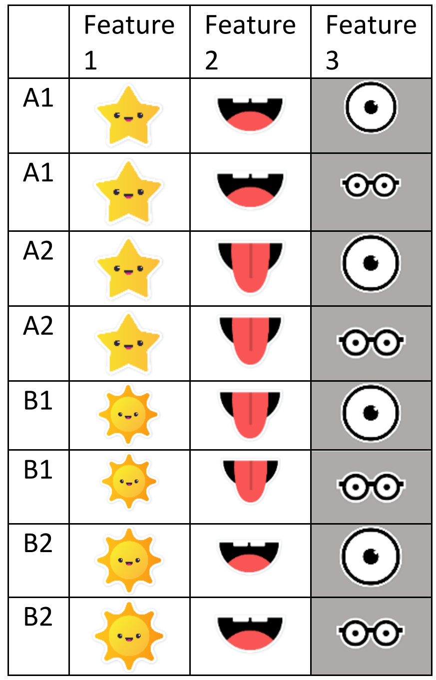
Concept Art

The cubes on the next stage show how features can be placed on different sides of a stimulus to create different feature sets. Since most VR HMD's do not have built in eyetracking, stimulus cubes will need to be built in such a way that the features cannot be seen simultaneously simply by holding the cube on its corner as shown below. As such, cubes will be built with indents for the features, requiring that the participant turn the cube fully in order to reveal the feature hidden in the indentation on each side. Currently, I am looking into constructing a tesseract style shape to achieve this goal.



Below are two examples of a category sets commonly used in rule-based category learning experiments. In the experiments below, participants learn to identify four categories – A1, A2, B1, and B2 – by learning which arrangement of features correspond to which category. Grayed out cells indicate the feature that is irrelevant for identifying the category. In the example on the left, Feature 1 is used to determine the relevance of the other 2 features, while in the example on the left, feature 3 is always irrelevant.





References

Chen, L., Meier K.M., Blair, M.R., Watson, M.R., Wood, M.J.(2013). Temporal characteristics of overt attentional behaviour during category learning. Attention Perception & Psychophysics, 75 (2), 244-256.

McColeman, C. M., Barnes, J., Chen, L., Meier, K., Walshe, R. C., & Blair, M. (2014). Learning-induced changes in attentional allocation during categorization: a sizable catalog of attention change as measured by eye movements. PLoS ONE (9)1. doi: 10.1371/journal.pone.0083302

McColeman, C., Thompson, J., Anvari, N., Azmand, S. J., Barnes, J., Barrett, R. C., ... & Blair, M.R. (2020). Digit eyes: Learning-related changes in information access in a computer game parallel those of oculomotor attention in laboratory studies. Attention, Perception, & Psychophysics, 1-14.