PSYCHOLOGY 196B PROJECT REPORT

Experimental Design on Effect of Video Games on Visual Learning

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1 Introduction and Background Information

In the Fall quarter of 2022, I have been working in Zili Lab at the Psychology Department of UCLA. Led by Professor Zili Liu, the lab members are interested in visual, proprioceptive, and motor learning and perception, and solve problems using computational, psychophysical, and neuroimaging techniques. In the lab, I was mentored by Maggie Yeh, who is particularly interested in the effect of video games on visual learning and tries to explain the mechanism involved in boosting visual skills due to video games. I was mainly involved in the coding portion of different projects that focused on ideas related to visual learning.

The main research project I worked on this quarter is to build an experiment using PsychoPy, based on the paper *Action-video-game experience alters the spatial resolution of vision* by Green and Bavelier in 2007. The paper aims to find supporting evidence for or against the hypothesis that "playing action video games leads to enhanced spatial resolution" (Green & Bavelier, 2007) and uses a crowding paradigm based on a previous model presented in the paper *The two-dimensional shape of spatial interaction zones in the parafovea* by Toet and Levi in 1992.

2 Purpose and Theoretical Basis of the Experiment

The aim of my work and my report this quarter is to examine the implementation of the experiment and discuss how certain characteristics of video games may result in a better boost in perceptual learning compared to other games by improving the experiment done by Green & Bavelier. While the previous experiment did show the effectiveness of action video games on cognitive mechanisms to a certain extent, it is questionable whether it shows the full capability of video games due to certain factors, such as lack of similarity to the actual gaming environment. By revising the previous experiment, we may look into the relation between action video games and cognitive traits like visual perceptual functions in a more precise way.

Visual crowding is the central concept investigated in this experiment, which refers to the phenomenon that "it is substantially more difficult to identify a target object when other distracting objects are present in its immediate vicinity than when the target object is presented in isolation" (Green & Bavelier, 2007). Previous literature had identified a few variables which contribute significantly to the visual crowding effect, such as the number of distractors and the distance between distractors and the target (e.g., Leat, Li, & Epp, 1999; Miller, 1991; Orbach & Wilson, 1999), and had been studying the crowding region, which is the neighborhood around the target object where the presence of distracting objects leads to a decreased sensitivity for the target. Because visual crowding is generally considered to be "a fundamental limitation on the spatial resolution of the visual system" (Green & Bavelier, 2007), an improved study based on Green and Bavelier's may result in a better understanding of why playing video games tend to have a boost in multiple aspects of visual processing.

The presence of feedback mechanism has been considered as a key factor in *perceptual learning*, the involvement of senses in our learning process, which is generally thought of as complicated by many studies. For example, studies have shown that the feedback mechanism has a significant effect when performing difficult motion-detection tasks. (Goldhacker et al., 2014) External reinforcement and feedback are also considered to play a role in this process. (Seitz et al., 2006) There are also studies focusing on how the frequency of feedback provided plays a role in perceptual learning. In this study, we focus on the concept of visual learning, which is the involvement of vision, and study how trial-by-trial feedback can affect the learning process.

3 Experiment design and implementation

In this report, all codes were written and implemented in PsychoPy (version 2022.2.3), a programming tool primarily based on Python, which allows precise spatial control and timing of stimuli for experiments in behavioral science. PsychoPy not only allows the usual way of coding like other Python IDEs do, but also allows visual coding, which is a way to write the code by building modules visually and therefore helps to clarify the code structure. A general introduction to this application can be found in the paper *PsychoPy2: Experiments in behavior made easy* (Jonathan Peirce et al., 2019).

The experiment I built mostly follows the mechanism from the task introduced in Green and Bavelier's work but with several adjustments, which will be highlighted in this section.

3.1 Stimuli and General Task

The stimuli used in this experiment are a series of black T-shapes with both lines of the same width and length, presented either right-side up or upside-down. The T-shapes have a variable length that will only be fixed after the experimental trials start. The participants would be asked to locate a particular stimulus (if multiple stimuli were presented) and identify its orientation, i.e., either right-side up or upside-down, by pressing the corresponding key "F" or "J", respectively. Because there were no time limits for the participants to answer the prompt, they were encouraged to prioritize answering correctly instead of quickly. Each trial consists of a set of stimuli and a choice the participant should make. Thus, the experiment consisted of several portions, each with a number of trials, which will be explained later in this section.

A white background was implemented so the stimulus could be presented on the screen with clarity. During trials, the screen is divided into four quadrants without boundaries so that in each trial, a set of stimuli would appear at the center of two opposite quadrants, i.e., either in the first and third quadrants or in the second and fourth quadrants. The stimuli should occur on both quadrants at the same time and should be identical.

3.2 Trial Setting

In each trial, an audio clip will first be played for 350 ms, followed by a 150 ms interval of blank screen, and then a 100 ms interval where a set of stimuli will be presented on either one of the two quadrant pairs, with each T-shape occurring in a random orientation. After the stimuli have been presented, a prompt will appear asking for the participant's answer, and the experiment will not resume until a valid key has been entered. Finally, the participant would know if their answer is correct in two ways, 1) from the screen where the result is displayed for 800 ms, and 2) from the audio clip concurrently played for 300 ms. This provides a feedback function in perceptual learning mechanism.

The two following subsections explain the general routine of the experiment and how each part of the experiment is structured.

3.3 Practice Trial Routine

In the first part of the experiment, we introduce the experimental task and then provide a few practice trials to the participant (as in Figure 3.1). Only the target T-shape would occur on each quadrant in each practice trial. These trials serve as a set of benchmarks to decide the discrimination threshold of the T-shape, i.e., the approximate borderline size of the stimulus, which the participant can identify correctly.

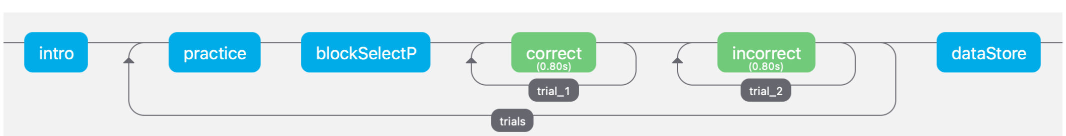

Figure 3.1: Introduction and Practice Routine

In order to determine the discrimination threshold, an interleaved staircase with four different staircases in total was used, with two per quadrant pairs. The interleaved staircase mixes all four staircases up so that the trials of the four staircases occur in random order. We record the size of the T-shape after the last trial of each staircase, and then we calculate the average across all four staircases to obtain the discrimination threshold of the participant. The interleaved staircase is supposed to be completed after at least 20 trials were done in each staircase. Figure 3.2 below shows the screen display in a typical practice trial, and Table 3.1 below shows the basic required setting of the staircase done in the practice trials, using pixel as the unit for convenience in adjusting the position.

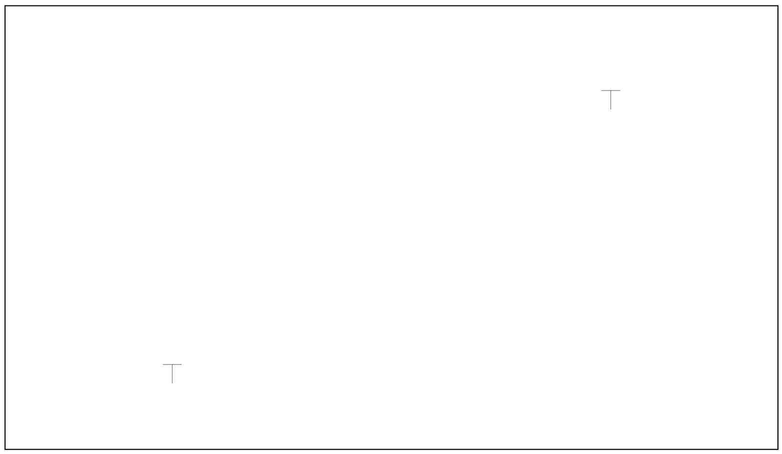

FIGURE 3.2: Example Practice Trial

label	startVal	stepSizes	minVal	maxVal	postype
Left1	30	2	1	50	-1
Right1	30	2	1	50	1
Left2	30	2	1	50	-1
Right2	30	2	1	50	1

Table 3.1: Setting of Practice Trial

3.4 Experimental Trial Routine

After calculating the discrimination threshold of the participant, we use the code to fix the stimuli size in actual experimental trials at 1.5 times the calculated discrimination threshold. In the actual experimental trials, each set of stimuli consists of a target T-shape in the middle as well as two T-shape distractors above and below the target. The orientation of each of those T-shapes is determined randomly, and each orientation is independent of the others. In the actual experimental trials, the variable we are interested in is the center-to-center spacing between the target and the distractors. The original experiment done by Green and Bavelier chooses angular measurement to determine the initial spacing (which are 30, 400, and 600 min of arc, respectively), which is challenging to deploy in PsychoPy because it requires the control of the size of the actual screen and the distance between the participants and the display screen. Therefore, we use centimeters to measure the spacing instead by converting the parameters to 0.5 cm, 20/3 cm, and 10 cm, respectively. In order to match the setting in the original experiment, we have the option of adjusting the distance between the participants and the display screen instead. Finally, to accommodate the limitation in the size of the screen, parameters were shrunk proportionally so that the stimuli could occur on the screen.

We also want to study the effect of eccentricities on the accuracy of trials. In the study by Green and Bavelier, eccentricities were introduced to help measure the distance of the stimuli from the center of the screen, where they measured eccentricity by using the visual angle. That is, they measure the angle created by the line segment between the human eye and the target and the line segment between the human eye and the center of the screen, as illustrated in Figure 3.3 below.

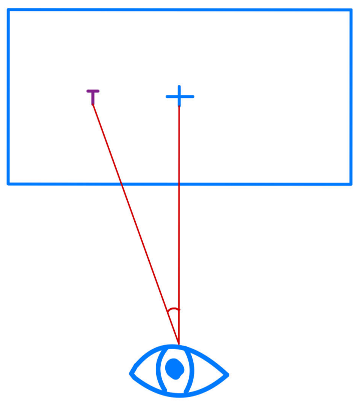

Figure 3.3: Measurement of Eccentricity using Visual Angle

Three different levels of eccentricities were studied in the experiment by Green and Bavelier, which were set at 0°, 10°, and 25°, respectively. Similar to the adjustments we made above, we replace the angular measurements with the distance measurements, i.e., setting the conditions as having the stimuli 0 cm, 10 cm, or 25 cm away from the center of the screen, respectively. The parameters were also adjusted so visual cues could occur on the screen as desired. For the trials that belong to conditions 10° and 25°, a black dot is implemented in each set of the stimuli and serves the purpose of a focus point, subject to the same eccentricity condition, to help the participants locate the stimuli. Table 3.2 below shows an exemplary row of the data from each of the conditions that were used as the initial trial of the experimental loop respectively. Similar to the previous table, parameters are converted to pixels as units for convenience. The three conditions were counterbalanced in the implementation to avoid biases such as the practice effect.

Figure 3.4 below illustrates the visual display of trials in each of the three conditions. The

Condition	startVal	stepSizes	minVal	maxVal
0	9	1	1	29
10	123	6	1	150
25	189	9	1	230

Table 3.2: Setting of Experimental Trials

general setups for three experimental loops are all very similar to the one illustrated in Figure 3.1, and we would use the condition of 10 cm as an example below. Each trial starts with the two focus points occurring in two quadrants of the screen, indicating the quadrants in which the stimuli would appear. These focus points are visible until the selecting options for each trial appear, and their locations are determined by the eccentricity of the trial. At the same time, an audio clip will be played for 350 ms indicating the start of the trial as well. After a 150 ms interval of blank screen, the two sets of stimuli appear for 100 ms, each consisting of the target T-shape and two distractor T-shape. The stimuli's locations are also determined by the eccentricity, but on the opposite side of the focus points. Other than these differences, the experimental trials are essentially the same as the practice trials.

4 Evaluations and Limitations

4.1 Design Evaluation

As mentioned, this experiment is supposed to be an improvement based on the original experiment done by Green and Bavelier. The design of dividing the screen into four quadrants is a major difference between our experimental setup and the original experiment by Green and Bavelier, as the original experiment has only one set of stimuli appear during each trial. There are certain advantages in this design choice. For instance, this design does eliminate the anticipation effect mentioned in the previous section to some extent, though it is clear that this effect is not completely eliminated. In particular, it eliminates the anticipation of the stimuli size which was an unavoidable issue in the original design since the stimuli size of a particular trial can be based on any one of those four staircases. The design also increases the task difficulty to some extent, which emphasizes the role of the feedback system in the experiment.

However, this design does cause certain problems. For example, the division of the screen limits the range of size of the stimuli, as we faced the issue of having limited space and had to resize the stimuli, which may in turn affect the accuracy of the experiment. Another potential issue is that because of our experimental setting, one set of stimuli is guaranteed to occur on the left half of the screen (similarly, on the right half, the upper half, and the lower half of the screen). Therefore, the participants may focus on half of the screen instead of the entire screen. One potential adjustment corresponding to this issue is adjusting the focus point configuration. Instead of having a focus in each of the two quadrants, we may move the focus to the center of the screen and move the T-shapes correspondingly. This adjustment would increase the response time for the participants to locate the stimuli because the stimuli become less predictable and the recorded time would reflect the speed of response more accurately.

Although the experiment avoids the practice effect by counterbalancing the three trial conditions, other issues may still be present. For example, because of the large number of trials required in the experiment, there is the concern that participants may experience fatigue during the experiment, which consequently affects the overall performance in certain conditions.

4.2 Overall Effectiveness

Although we have witnessed the benefit of the perceptual training typically applied in laboratory settings, it is questionable whether our experimental setting reflects the whole merit of playing actual games. For instance, our experimental settings do not reflect the actual setting when playing games in several ways. First, the experimental task we designed still lacks diversity, and therefore does not provide a comprehensive view of how perceptual training boosts our visual learning mechanism. Second, game-plays often create an automatic visual fixation on the targets that appear unexpectedly, which eliminates the participants' anticipation of the target, and therefore maintains the effectiveness of the experiment in shortening game players' response time. These prominent traits in games do not occur in our experimental settings, as participants may soon be anticipating the stimuli to appear at specific locations, which eases the effort it takes to perceive the "unexpected stimuli". Moreover, many game-plays usually require the synchronicity of different perceptions like vision, hearing, and movements, which is not reflected in typical experimental designs as well. These issues identified above also limit the role of feedback in perceptual learning and its potential in experimental implementation.

It is also hard for laboratory experiments to generalize and accommodate different game genres with different visual skills. Our experimental design leans towards first-player shooting (FPS) games, which helps with shortening response time when encountering stimuli. However, other genres focus on creating mental images, information categorization, and other skills crucial in visual learning. While it should be easy to create different experimental designs that study the effect of video games on these traits, it would be hard to integrate them into one experiment that reflects the diverse visual skills involved in playing games.

References

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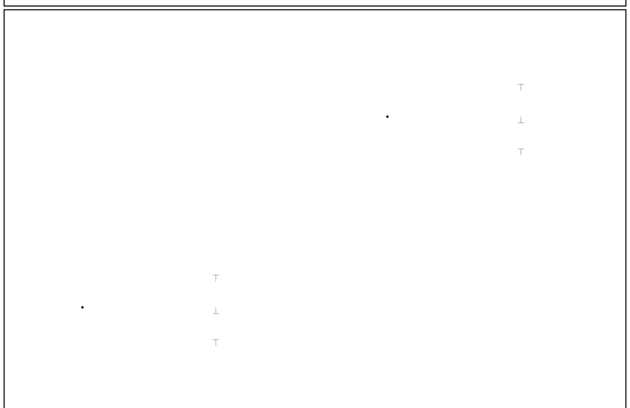
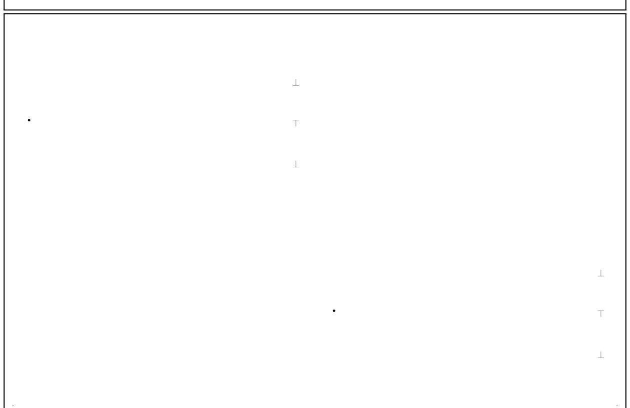
(a) Condition 0



(b) Condition 10



(c) Condition 25

FIGURE 3.4: Visual Display of Experimental Trials