IMPROVING THE ACCESSIBILITY OF MOTION PERCEPTION TASKS

By

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Abstract

Web-based experiments have become increasingly popular over the last decade. While historically lab based software systems, such as MatLab, have been favored due to their technical sophistication and ability to precisely control experimental procedures, their reach has been limited. To engage in more inclusive research, it is often necessary to bring research tools to participants where they live. Tools such as Inquisit are beginning to fill this gap, providing the ability to run research grade experiments on participants' own devices. However, to date, there have been limited tools that can measure basic visual functions such as motion processing. Here we introduce a new procedure using random dot motion that we co-developed with Inquisit that aims to measure people's ability to discriminate motion direction in noise. This software implements similar parameters, controlling dot size, coherence levels, speed, and density dots as MatLab. Further, we present data to validate the software by collecting parametric measures of motion direction sensitivity at different noise levels and different motion speeds. Our data show very similar measures between the traditional lab-based and the new web-based systems suggesting that the new tool is valid and reliable and potentially appropriate to collect experimental data in participants' home environments.

Keywords: MatLab, Inquisit, coding, laboratory research

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INTRODUCTION

The ability to detect a moving object in the environment is a key part of everyday living. Motion perception occurs within the brain, specifically the visual cortex. The dorsal stream is responsible for the detection of motion within the visual cortex. First, the brain extracts whether what is being seen follows first or second-order motion perception. First order motion perception occurs when an absolute image feature is moving, such as a bright bar on a dark background, Second order, on the other hand, is when a relative image feature is moving such as a feature being defined by contrast, texture, or a flicker. Once that is completed, the visual system integrates individual local motion signals at various parts of the visual field into a 2D representation of moving objects and surfaces. The ability to detect coherent motion is what Random Dot Motion paradigms are usually used for.

Researchers have used Random Dot Motion stimuli as paradigms to detect and estimate one's motion perception. Random Dot Motion stimuli are done on a computer screen and involve the movement of dots in different directions on the screen, with a specific percentage of those moving in one direction. While fixated on a focal point, subjects must distinguish the direction in which the coherent group of dots are moving. The focal point is placed directly in the middle of the screen so that participants have a full view of the dots as well as a field of vision from the same angle. This also works to limit error between participants since they all maintain the same point of view.

Peripheral vision can also be assessed using Random Dot Motion. Random dot motion tasks are usually done in black and white which is a great advantage for peripheral vision. One's peripheral vision is dominated by rods, and therefore it is easier to see the white dots across the screen. Rods are responsible for vision under low light, whereas cone cells are responsible for the vision under higher lights. Had the dots been a different color, participants would most likely have a harder time deciphering direction with these dots.

Notably, many questions have been raised on why Random Dot Motion works and works well within the capacity of the work it completes. First, the question arises of why researchers choose to use dots as circles rather than any other shape such as squares. The reason for this is that the brain processes and preferes shapes with smoother sides and surfaces when interpreting motion. Sharp edges or lines would require the brain to use extra cells to extract those specific characteristics and decipher the direction of the motion. Another issue with the use of shapes with straight edges is the aperture problem.The aperture problem is the fact that the motion of a 1 dimensional structure can not be determined if viewed at a small aperture in which the the ends of the stimulus are not visible (Binder et al., 1970). This means that when looking at any shape with edges such as bars or squares, the brain has the ability to perceive it under an optical illusion like mindset. For these reasons, random dot motion studies are usually done using the simplest shape, circles as the dots.

There are certain concerns that lie in the utilization of Random Dot Motion to assess motion perception. Previous literature has raised questions about different features of a Random Dot Motion (RDM) algorithm and how they influence the perception of dot motion. It has been understood that the smallest differences in algorithm layouts across studies impact motion perception (Watamaniuk and Sekuler, 1992). In addition, performance on tasks has also been shown to be impacted by certain parameters such as duration, dot density, and speed (Williams & Sekuler, 1984; Scase, et al.; Pilly and Seitz, 2009). There occurs a vast majority of types of movement in RDM, all having the ability to influence motion perception. Pilly and Seitz (2009) experimented with these ideas and tested four main types of paradigms in an attempt to indicate the changes each parameter makes on motion perception.

Notably, questions asked and answered in previous studies mainly focused on parameters and algorithmic features. There are questions that delve even deeper into RDM as a standard form of measurement, including if the program the algorithm is running on is suitable for a study. Traditionally, these random dot motion tests are administered in the lab on well founded coding softwares. If we are able to repeat the study and find another generator valid for the same tasks and results, these tests may be administered in non-traditional ways such as at home or without the investment of millions of dollars in resources.

Typical Paradigms

A typical RDM paradigm is usually conducted on a high end coding software, specifically MATLAB, and consists of randomized coherence, white noise, and signal. Randomized coherence includes dots that are moving in the specified direction. White noise are dots that are moving in random directions, and the term signal is used to describe the dots that follow the coherency. There are some commonly used algorithms for Random Dot Motion. These algorithm templates include White Noise, Movshon/ Newsome, Limited Lifetime, and Brownian Motion.

In white noise, a new set of signal dots are randomly chosen to move in the signal direction from each frame to the next, and the remaining (noise) dots are randomly relocated. Furthermore, in this type of algorithm, each noise dot is given a random direction and speed.

The next algorithm, Movshon/Newsome has three uncorrelated random dot sequences generated and frames from each are interleaved to form the presented motion stimulus. Third, there is Limited Lifetime which is similar to Movshon/ Newsome, however, the dots with the longest lifetime as signal are the first to be chosen to become noise dots, and are then randomly relocated. Lastly, there is the Brownian motion. In Brownian motion, all dots move with the same speed, but only noise dots are given random direction.

Softwares

Psychophysics research studies that involve coding are often done on one of three coding softwares- Psychtoolbox, Inquisit Millisecond, or PsychoPy. Psychtoolbox is built upon the programming language MATLAB, while PsychoPy is built upon Python. In our lab, we tested the validity of previous studies under this topic using two coding softwares, Psychtoolbox and Inquisit. We aimed to determine whether or not Inquisit Millisecond could perform just as well as the widely used MATLAB.

When performing Random Dot Motion studies, specifically in laboratory settings, researchers usually use Psychtoolbox. MATLAB is a highly sophisticated software and is used primarily by mathematicians and engineers. While Psychtoolbox is free, MATLAB is very costly, ranging slightly over $2,000 per person. For this reason, not many companies are able to afford this license for all their employees.Though it is mainly created for numeric computing, they have engines that allow for symbolic computing abilities. Code generation on MATLAB has commands in the center, while also having a variable explorer on the right and directory listing on the left. Because it is mainly created for commercial purposes and MATHWORKS, its base is quite limited.

Inquisit, created by the company Millisecond, is an online platform that is much cheaper than MATLAB, averaging slightly over $2,000 annually for departments. It has pre-generated codes, as well as professional programmers that can help researchers to program their specific needs. In comparison to MATLAB, Inquisit Millisecond, is relatively new, and as a result, has not been validated as a good generator yet.

Python is similar to MATLAB, meaning it can be used in the lab, however, it is free. In similarity to MATLAB, Python is also a highly sophisticated programming language (Educba, 2022). Python treats everything as a general object, in comparison to MATLAB which treats everything like an array (Thorat, 2020) . Python, unlike MATLAB, requires that users pick an integrated development environment (IDE) that fits their needs. Essentially, MATLAB is already an IDE on its own, whereas Python has multiple that users can pick from. Python also has libraries that contain modules for different programming necessities and frameworks, unlike MATLAB which does not have a host of libraries, rather a toolbox.

Overall, these coding softwares are all excellent tools in the lab. MATLAB is designed for specific tasks specially the mathematics field, whereas Python and Inquisit are for more general tasks. Since we only tested MATLAB and Inquisit in our lab, I would believe that Inquisit would be just as good as the other programs. This is because the task we are analyzing is slightly more general and not insanely difficult to the extent of needing professional programming or coding that only focuses on analytics and mathematics.

Our Aim

Our aim in this specific study was to test the validity of the Random Dot Motion task under the same conditions on two platforms- MATLAB and Inquisit Millisecond. This is done to demonstrate whether or not we are able to introduce Inquisit in an at-home environment, with the first step being validating it in laboratory environments to see if it can perform similarly to the higher-end coding softwares such as MATLAB. The reason for this is that companies usually invest thousands of dollars into known softwares such as MATLAB for their research and coding. They choose MATLAB because of its sophistication as well as how widely known and trusted it is, in comparison to Inquisit which is fairly new and not as popular. In addition, the demos on Inquisit Millisecond are free and are excellent tools for teaching and learning. If it is proved valid that Inquisit Millisecond achieves the same results as MATLAB, companies will no longer need to invest this amount of money on programming and can redirect it towards other investments.

It was hypothesized that Inquisit will perform as well as MATLAB and be able to be introduced to different settings and environments. Expected properties include an outcome in which as coherence levels increase, so does one's ability to detect the direction of the dots. The more signal dots there are going in the same direction, the less likely that the noise dots are able to distract from the correct dot path. In these paradigms, a single dot moving in a particular direction does not create any directional interpretation within the brain, however, when it is a group of dots, direction mechanisms in subjects get tricked and therefore incoherent cells that mainly focus on noise directions become active (Seitz & Pilly, 2009). This is a main reason that low coherence, meaning less signal, often leads to misinterpretation of directional perception.

In addition, we hypothesized a learning curve as runs increased. Meaning, the highest performance should be during participants' fourth run. For example, participants may have not performed their best on the first run, but as the task went on in the following runs, their performance increased. This is due to the learning effect in the brain which states that there is a positive or negative correlation with tasks as time (t) passes (Learning Center, 2020). For this reason, longer duration of studies are highly recommended for the greatest results. Past research shows that learning curves will be steeper during the initial stages of any task, and then flatten out as time passes.

Methodology

I. Subjects

A total of 44 participants were tested in this study, with a slightly higher ratio of female to male participants. Participants were undergraduate students, recruited from the Psychology Department population from the University of California, Riverside through the Psychology Research Participation System (SONA Systems). Course credit was awarded as compensation for participation.

Upon arrival, participants were told that they must maintain the same visionware essential, if necessary, throughout the duration of the study. For example, if a participant came in wearing glasses to the first session, they were instructed to wear the same glasses to the second session to reduce any form of error that could occur.

II. Methods

Design

Subjects underwent two separate sessions on separate days. Each session utilized either MATLAB or Inquisit, and each subject was considered complete when they performed the task on both programs. Overall, the sessions were counterbalanced across subjects. Even numbered subjects would begin the study on Inquisit, whereas odd numbered subjects would begin on MATLAB as their first session. Regardless of the program, each session contained 4 runs, which consisted of 160 trials per run (640 trials total per session).

Task Conditions

Each trial in the task contained three conditions that were randomized across the session. These conditions included coherence, direction, and duration. Coherence determined the percentage of dots moving in a single direction and was randomly selected from a pool of predetermined levels (2%, 4%, 6%, 8%, 10%, 15%, 20%, 25%, 30%, and 50%). Each level was presented four times throughout each run of the session. Direction determined the course at which the dots moved coherently and was also randomly chosen from a predetermined pool (45, 135, 225, and 315 degrees). Duration established how long the stimuli were presented on-screen (either 200ms or 800ms).

Set-up

Participants were asked to place their belongings in a separate room and then directed to the testing room, which was a small room with the lights off for the best view of the screen. The set-up in the testing room included a chair, a fixed chin rest, and a ViewSonic PF817 screen.

They were then asked to sit in the chair and bring it in as close as they comfortably can to the chin rest facing the screen. The chin rest was not allowed to be adjusted as it was fixated as the same level of the focal point that appears on every run. Participants were required to sit with uncrossed legs and feet planted on the ground. During the first session, all participants ran through a practice run before beginning the tasks to ensure complete understanding of what must be done.

Task Procedure

Participants were shown a Random-Dot Kinematogram (RDK) moving in multiple directions and were tasked with determining the general direction the dots were moving in cohesively. White dots served as the visual stimuli and were presented with a randomized selection of the three conditions listed previously. At the start of each trial, a red fixation point located at the center of the screen was presented against a gray background for 250ms; this fixation point turned white immediately before the random-dot stimuli were presented for either 200ms or 800ms. After the visual stimuli disappeared for 500ms, the participant was granted 4 seconds to respond with an answer. The response screen consisted of four lines that corresponded to their respective directions (in degrees). The subject simply had to click on the correct line (or within 22.5 degrees) to indicate their answer. A screen indicating whether the subject answered correctly or not appeared within the 4-second response window. If the subject made no answer within the 4 seconds, it was counted as a "wrong" answer. A 400ms intertrial window followed each trial for the entirety of the run.

Results

Software Comparison

MATLAB and Inquisit were compared on the grounds of whether or not they achieved the same, or similar results. Our data showed that these softwares did result in similar results. One can reach this conclusion based on the graphs displaying similar curves and effects as well as the statistical tests that were conducted.

Graphs show that under the same conditions, the results did not show differences between MATLAB and Inquisit. There was, however, an effect of viewing duration. MATLAB seemed to have a very slight advantage over Inquisit when it came to the longer viewing duration time. In comparison, when it came to the smaller viewing window duration, Inquisit took the lead. Although these differences were not major, they may speak as to whether or not the software is able to handle this duration or intensity of task.

Performance as a function of Coherence

Performance was calculated based on the number of average correct trials for each coherence level. Graphs agreed with what had been hypothesized regarding the correlation between coherence levels and ability to accurately perceive motion direction. It was seen that as coherence levels increased, participants' ability to correctly differentiate the direction of the signal dots also increased. Another interesting fact seen through the graphs is in the factor of viewing screen duration. The 200 ms viewing screen had a steeper incline in performance, whereas the 800 ms screen had a more exponential increase in shape. Overall, the longer the viewing screen was, in this case 800 ms, the better participants performed, with more gradual increases in performance. As the graphs confirmed, there is no observed significant difference in performance according to software.

Statistical analysis consisted of doing a two-tailed t-test of performance for the two independent variables of software. The p-value for the 200 ms viewing screen was determined to be 0.504 (*P*=.504), which shows no significant difference in softwares and performance. The p-value at the 800 ms viewing screen was determined to be 0.689 (*P*=.689), which also shows that there was no significant difference between the two softwares regarding participant performance. Based on these values, the null hypothesis failed to be rejected. In our case, the null hypothesis is that there will not be a difference in performance between the two softwares. Since the null is not rejected, then our statistical analysis proved that there is no difference between the two softwares, or that the difference was too small to be picked up by the tests that we ran.

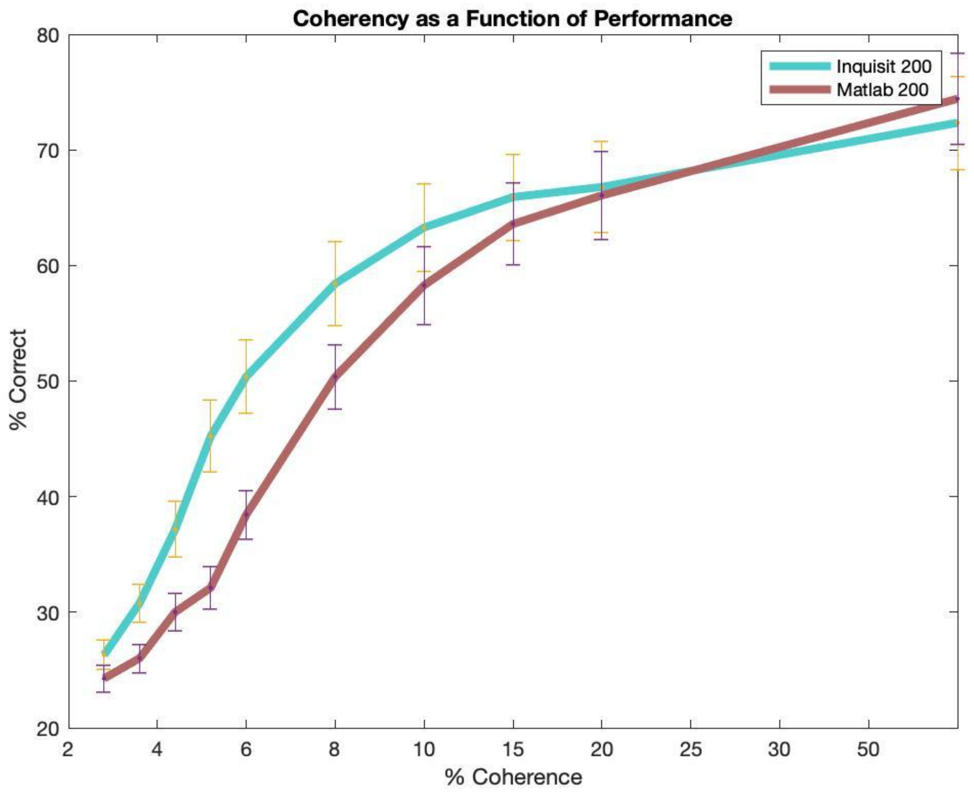


Figure I: Figure I shows performance as a function of coherency at the 200 ms viewing screen duration in correspondence to both softwares. Both softwares seemed to perform similarly. The 200 ms viewing screen had a steep incline in performance as coherency increased.

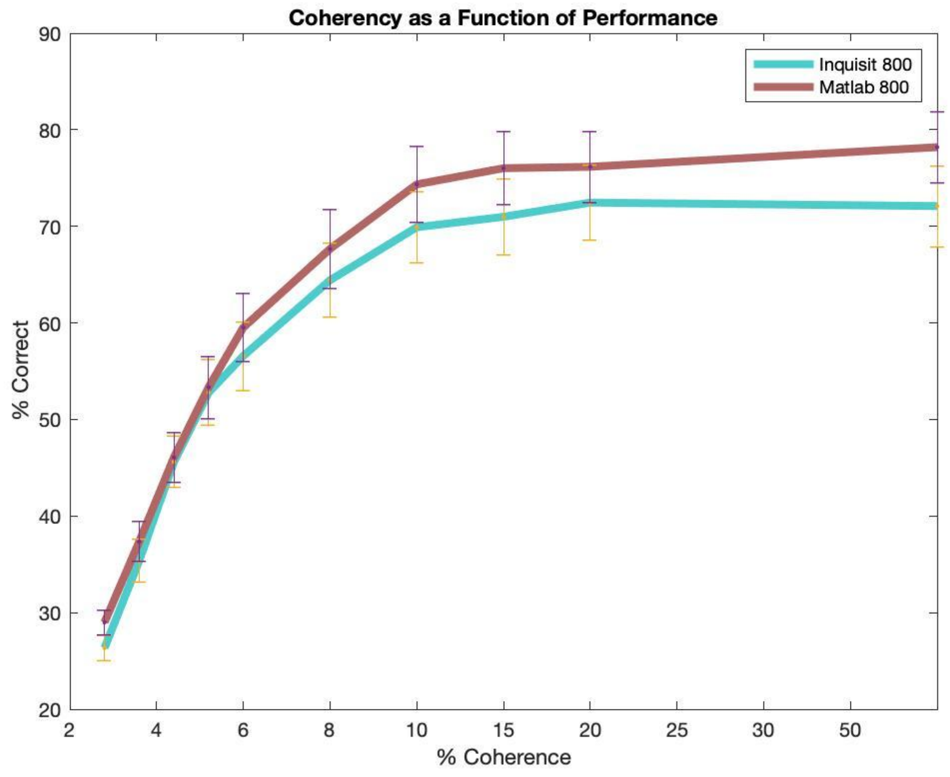
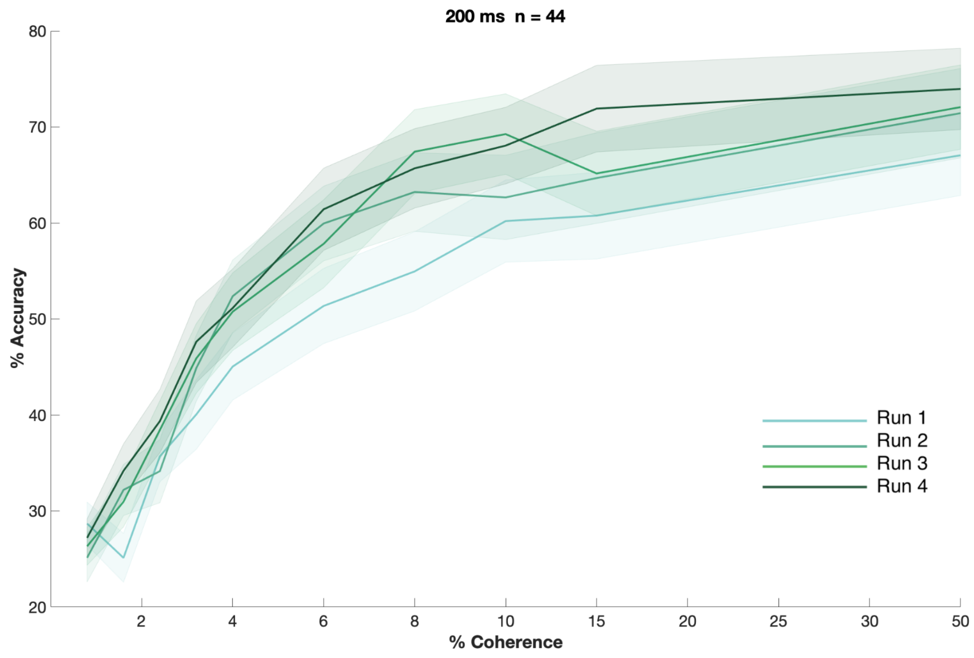
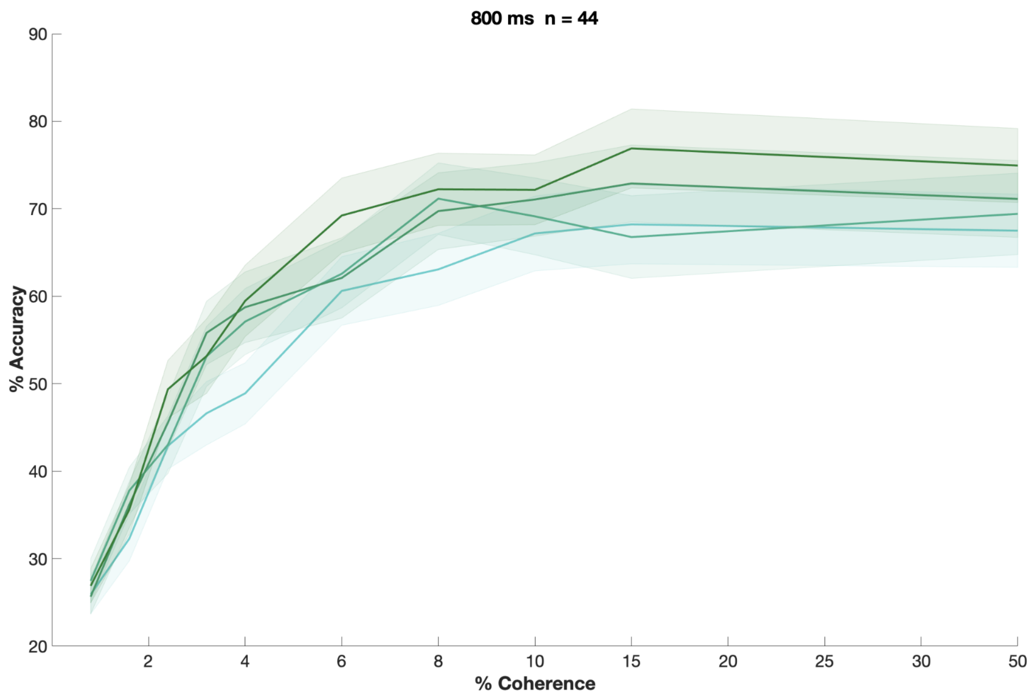


Figure II: Figure II shows performance as a function of coherency at the 800 ms viewing screen duration in correspondence to both softwares. Both softwares seemed to perform similarly. The 800 ms viewing screen had a more gradual increase in performance as coherency increased.

Learning Effect

Learning curves were measured through the plotting of average performance per run number across all participants. Viewing screen durations were plotted separately to reduce observation error. Results showed that participants did, in fact, experience a learning curve. Run one was seen as the lowest performance with run four as the highest accuracy in responses. Both viewing screens had the same trend. An interesting observation seen in the 200 ms viewing screen was a peak at around coherency levels of 8-10% where performance averaged better here during run three than run four.





Figures IV and V Figures IV and V are the changes in performance based on coherency plotted by runs. Viewing screen durations were plotted separately with no difference in observations between both.

This observed trend could be attributed to the duration of the tests. Previous studies mention that learning curves are usually seen through longer tasks or tasks that require reinforcement (Analytics Toolkit, 2022). This task required a practice run at the beginning of the first session as well as an option to have a practice run during the second session. In addition, there were 4 runs within the task itself, each containing 160 trials.

Discussion

This study aimed to answer whether or not Inquisit Millisecond could effectively and accurately provide data that would be validated by sophisticated coding softwares such as MATLAB. Overall, we failed to reject the null. More specifically, this study failed to prove that there is a difference between MATLAB and Inquisit. However, this does not remove the possibility of small differences, rather they were not significant enough to be picked up by the t-test that we ran. The t-test looked to examine the holistic picture of specific variables, but did not go into detail about the smaller relationships between the parameters.

Based on the results, it is believed that Inquisit can begin to be introduced into studies within lab environments with a goal of feasible at-home testing. This software was created specifically for our study, making us the first to use it. This paper also provides support for other groups to use it as well in introducing Inquisit as a primary data collection method. This introduction would allow for the administration of at home testing and possibly in lab testing. It would also allow for the saving of money rather than the billions of dollars companies spend into MATLAB.

Limitations

There are a few limitations in this work that could be considered caveats. Since this study was performed at the University of California, Riverside only, there was not a great variance of age in participants. The sample size compared to the overall goal was very limited, and could therefore have artificially caused an error. Error would be caused by the potential of differences among subjects such as vision differences or focus duration of each individual. In addition, participants did not range greatly in age, making results look reasonable only in college students.

Further work would be needed to understand generalizability to other populations. Finally, if we did not test the extent to which curves are consistent across different computers and screens. If we want to use this program in at home environments, further studies must be done accounting for these technological differences. Technological differences could be comparing performance on this same task between HP and Macbook computers. Differences could possibly arise due to resolution and graphic advantages pre-installed into these laptops.

Take-aways/ Conclusion

As a student who is interested in the field of optometry, tasks that involve the visual cortex are great ways to measure the different jobs of this area of the brain. Random dot motion is a great way to assess motion perception as well as peripheral vision through the usage of the focal point. Through this study, I was able to learn not only how random dot motion paradigms work, but also the overall of how motion perception works. Also learned through this study was the correlation between optometry and neuroscience and the effect one can have on the other. Neuro motion processing is assessed through the usage of tasks that work to involve the specific areas in the visual cortex. These tasks must be precisely coded due to the fact that, as learned, the simplest shift in parameters can alter the entire outcome. My ability to write and read code also improved heavily throughout this study.

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