Online Procedures for Photophobic Testing

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1. Abstract

The purpose of this project was to create a series of visual tests that could aid in the diagnosis of photophobia in patients who have sustained traumatic brain injury (TBI). Photophobia is a neurological symptom characterized by pain or irritation of the eyes caused by sensitivity to light. As a medical symptom it is not widely understood, thus making conclusive diagnosis difficult. Patients who have experienced traumatic brain injury are also likely to develop photophobia. This link can provide valuable insight into photophobia as a condition.

Research done with rats by one of our clients has shown that TBI negatively impacted the horizontal cells in the retina. Horizontal cells are neurons that interconnect and communicate information from photoreceptor cells. Among other things, they are responsible for acclimating the eyes to different light levels. Deficiencies in horizontal cell capacity cause issues with gain control, contrast response, relative brightness perception, and response range.

The diagnosis of photophobia is generally conducted by relying on anecdotal reports, patient behavior, clinical monitoring, and physical examination. There is no objective metric for measuring a patient's acute sensitivity to light. The current ophthalmological tests, such as the Snellen eye chart and Pelli-Robson contrast chart, do not provide significant enough measurements regarding changes in perception that would be relevant to TBI or photophobia.

As previously mentioned, the primary goal of this project was to develop a series of visual tests to assist in the accurate diagnosis of both traumatic brain injury as well as photophobia. We worked with Dr. Mary Johnson and Dr. Amanda Henderson from Johns Hopkins University and our advisor, Dr. Arthur Shapiro, to create these tools. Dr. Johnson and Dr. Henderson expressed a need for the tests to be embedded in the Qualtrics survey platform. This would allow Johns Hopkins' ophthalmology department to easily distribute the tests to patients and collect relevant data.

The original scope of the project consisted of four diagnostic tests written in javascript that would be hosted on the Qualtrics survey platform. The goal of the tests were to simplify the recognition of TBI and photophobia by ophthalmologists. Although all four tests were successfully implemented, due to time constraints and unpredictable complications (see 7.2) , only two of the original four tests were integrated with the Qualtrics survey.

Each test was written with the p5 javascript graphics framework, and targeted a different perceptual or psychophysical task. After working with Johns Hopkins University to create these tests, we received institutional review board (IRB) approval from American University to distribute the survey via Amazon Mechanical Turk and collect data.

2. Introduction

The problem we are addressing with our capstone is one expressed to us by our clients who are doctors of ophthalmology at Johns Hopkins University. They have expressed frustration with the fact that there is no concrete tool for medical diagnosis for photophobia, a common symptom/consequence of traumatic brain injury. Because of this, diagnosis of photophobia in patients with TBI relies heavily on subjective measures such as patient reports, long-term observation of patients, or other anecdotal strategies. Oftentimes, the only way to diagnose photophobia is to test for all other mal-effects associated with traumatic brain injury. All of these methods are extremely time consuming, cost-heavy, and frustrating for both the patient and doctor involved.

With this, we set out to remedy these frustrations and eliminate wastefulness of both time and money for patients who have photophobia and for the doctors involved in diagnosis. In order to do this, we have developed, tested, and analyzed data from many iterations of two tests with the goal of producing data that could accurately predict whether the user experienced photophobia or not.

We were given a skeleton of the software from our advisor, Professor Arthur Shapiro, that served as a demonstration of what our deliverables should look like. We worked closely with him, meeting at minimum once a week to seek approval on implementations and make subsequent improvements in order to prepare for our bi-weekly meetings with our clients.

2.1 Project Overview

Current visual tests in the field of ophthalmology focus mainly on aspects of visual acuity. The primary example of this is the Snellen eye chart, which is the standard chart used when administering most eye exams. The chart consists of several rows of letters that progressively get smaller in size. The test is performed on each eye and ophthalmologists can use it to determine the sharpness of a patient's vision. Another common test is the Pelli-Robson test, which measures contrast sensitivity, or how well one can discern between multiple different objects. The test includes multiple rows of letters, similar to the Snellen chart, but these letters are all the same size, only their color becomes progressively lighter. Again, it is performed on each eye separately and is concluded when the participants can no longer distinguish the letters from the background. While the Snellen chart and Pelli-Robson charts work well for diagnosing various vision issues related to visual acuity and contrast, there are many other characteristics that define good vision.

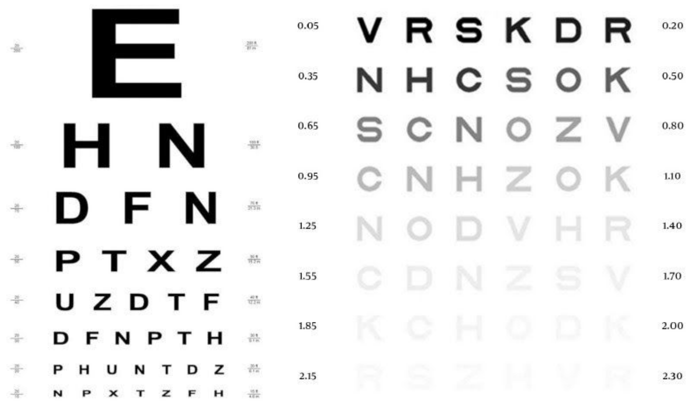


Figure 1. Snellen eye chart (left) and Pelli-Robson contrast sensitivity chart (right)

Photophobia is another factor that can contribute to a person's vision. When a person develops photophobia, also known as light sensitivity, they experience discomfort when exposed to light. In some cases physical inflammation of the eye may also occur. Photophobia can be caused by many different underlying conditions, but Dr. Johnson and Dr. Henderson had an interest in photophobia experienced by patients who had traumatic brain injury. A traumatic brain injury (TBI) is a disruption of traditional brain functionality, usually brought about by physical injury to the head. Some symptoms of TBI include blurry vision, difficulty concentrating, and general confusion or irritability. Many patients with TBI experience photophobia. The Snell eye chart and Pelli-Robson contrast sensitivity chart are not effective tests for measuring and diagnosing photophobia. Patients are usually diagnosed with photophobia through physical examination or subjective patient anecdotes.

The objective of this project was to create a series of visual tests that could be used by Johns Hopkins University to accurately diagnose photophobia in patients who have experienced traumatic brain injury. The purpose was to ease the frustrations experienced by ophthalmologists caused by the lack of diagnostic tools. We programmed four interactive tests to be used by Johns Hopkins University. Each group member needed to learn the intricacies of Qualtrics in order to proceed to the testing phase. Once we successfully did this, we could proceed to the testing phase.The first step was receiving IRB approval. Each group member completed an ethics training course that is required by the IRB to gather data on human subjects. We then submitted our document detailing the purpose of our study and methodologies of data collection in a document consisting of thirty pages. After two revisions, we received approval (9.1).

From there, we published (9.2) our survey on Amazon's Mechanical Turk (9.3), a platform that allows researchers to pay respondents to take online surveys. After various adjustments, we analyzed our data collected from the platform.

2.2 Report Structure

This report will start with summarizing some of the existing academic and medical research that has been conducted regarding traumatic brain injury and photophobia. The literature review will also encompass the various perceptual and psychophysical tasks being utilized in our tests. The literature review will be followed with a description of the project's design and final implementation. The results of the project will then be evaluated to determine the success of the project. Finally, the limitations of the project as well as any issues that arose during development will be discussed, ending with possible subsequent future work.

3. Review

3.1 Advisors and Clients

According to Dr. Mary Johnson (one of our clients for the software), TBI patients are photophobic. Mary has evidence that TBI rats have deficits in horizontal cells. Poor horizontal cell function is likely to produce deficits in gain control, contrast response, relative brightness perception and response range.

According to our advisor (Arthur Shapiro), diagnosis of photophobia tends to rely on patient reports, other anecdotal behavior, or in clinic observation; there are no objective tests that measure acute sensitivity to light (this is the problem we are going to address). The situation is familiar to most ophthalmologists for a wide variety of conditions: a patients complains that their vision has deteriorated or substantially altered, and while it is likely that there is substantial change, the current battery of functional tests (snellen; pelli robson, etc) are too insensitive to measuring patient's sensitivity along a dimension that is not relevant for the change in perception that they are perceiving.

In short, the issue is that there is no tool to diagnose photophobia in patients. Our two clients (Dr. Mary Johnson and Dr. Amanda Henderson) have *expressed a serious need for something that can diagnose these conditions*. When a patient experiences traumatic brain injury, the resulting issue is commonly photophobia. Patients with TBI who experience visual problems are referred to opthamologists, who struggle with the fact that there is not much they can do due to an absence of a proper test to diagnose their condition (this is the problem we are addressing and the tool we are building).

3.2 Diagnosis, Pathophysiology, and Treatment of Photophobia

The paper, *Diagnosis, pathophysiology, and treatment of photophobia*, written by Bradley J. Katz and Kathleen B. Digre, details the issues discussed above. It starts off by giving an overview of photophobia. They explain that Photophobia, an intolerance to light and is associated with a number of ophthalmic and neurologic conditions. The most common conditions associated with photophobia are migraines, blepharospasm (involuntary closure of the eyelids), and traumatic brain injury (TBI).

The article highlights that there is a lack of knowledge surrounding photophobia: “Our understanding of the photophobia “pathway” is in its infancy and much of its neurochemistry remains unknown”. More important to our project though, these scholars detail the issues surrounding not having proper tools for diagnoses when they remark: “Many patients with a chief complaint of photophobia will have a normal eye exam”.

3.3 Shedding Light on Photophobia

Another paper, *Shedding Light on Photophobia*, by Kathleen B. Digre, MD and K.C. Brennan, MD echoes the same sentiments as the last paper. After a series of small studies were done to diagnose photophobia, they concluded: “These data are not conclusive, and they speak to the need for more precise ascertainment of both photophobia and headache symptoms after TBI”.

However, the paper does discuss the optimisation surrounding the understanding of photophobia. Over the past few years there have been significant advances in the understanding of this. This paper reviews the characteristics and disorders associated with photophobia, discusses the anatomy and physiology of this phenomenon, and concludes with a practical approach to diagnosis and treatment. They have found plenty of effective treatments to attack the root issue causing photophobia. For example, patients can try dilating eye drops, tinted sunglasses, different medications, and even eye procedures. This article found that there needs to be an effective diagnosis of what is causing photophobia in order to effectively treat the patient - which again highlights the importance of our project. Below is a diagram that illustrates how doctors go about diagnosing photophobia. It also highlights how this is very complex and there can be a plethora of reasons why someone is experiencing. *This article stresses how treating photophobia starts with accurate diagnosis.*

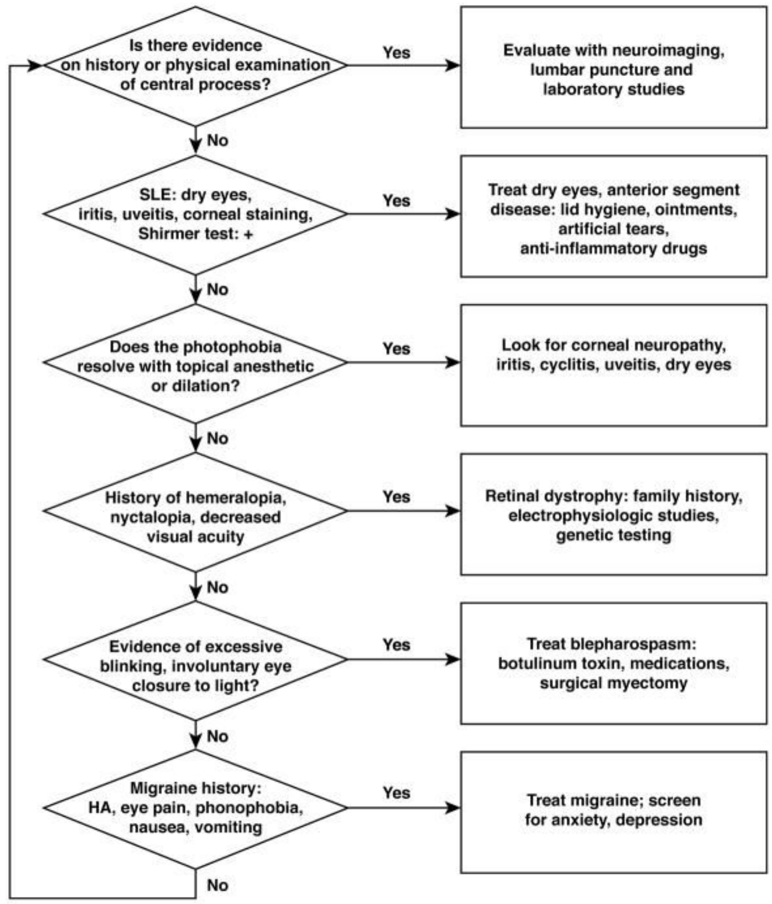


Figure 2: How doctors go about diagnosing patients who experience photophobia

3.4 Action Spectrum for Photophobia

The paper *Action Spectrum for Photophobia* by James M. Stringham, Kenneth Fuld, and Adam J. Wenzel researches why patients experience photophobia as a symptom of many different incidents. They also highlight how so much about the neurology of photophobia is unknown, however studies like this are starting to shed light on it. They talk about how a more studied phenomenon similar to photophobia is discomfort glare. Many researchers draw upon discomfort glare to try to understand photophobia but often find they are pretty different. In discomfort glare studies, subjects are rarel, i f ever, exposed to lights that are subjectively judged as intolerable. However, photophobia involves an acute intolerance to light, typically marked by some sort of behavioral aversion (squinting or closing the eyes).

This paper ultimately found that thresholds for photophobia (light-induced discomfort) were determined at wavelengths from 440 to 640 nm for three subjects. Photophobia was assessed by measuring subjects' level of squinting. Subjects' functions showed a trend of increasing sensitivity with decreasing wavelength. They propose that the corrected function is due to increased sensitivity to potential retinal damage by short-wavelength light. They found that photophobia serves a function of biological protection. The results also suggest that photophobia is significantly mitigated by macular pigment in the short wavelengths.

4. Design Requirements

4.1 Feasibility Discussion

Economic

The overall economic cost for our project is very low. At our stage we just made a survey on Qualtrics which is why there is little to no economic cost. That being said, if we wanted to scale up our project we can use a different software to make our project to be more widely used. For example, we could use a different software for more thorough data analysis. We used excel to find the R^2 values but can take that a step further. If we sent out this survey to many more people to take, calculating the R^2 values on excel would be incredibly inefficient and using a different software, like Tableau, would be necessary.

In terms of the economic / monetary impact of our project, there really is none. Since this is a survey for doctors to use, the goal of our project is not to make a profit. It's to help doctors diagnose patients suffering from photophobia. The only way for this to make money would be to sell our survey to Doctors to use.

Environmental

While creating the project itself has very little environmental impact (only real impact is the energy our computers are using while we create and work on the survey), online tests like these can have positive effects on the environment. For example, this online test would limit the amount of face to face contact between doctors and patients. This would bring down the carbon footprint of an individual because they would be saving a trip from the doctor's office - not driving or using a different form of transportation to get there. An online survey is also really fitting in today's world with the pandemic going on. With the current pandemic, limiting face to face communication is one of the best ways to stop the spread of the virus.

Manufacturability

There are no physical materials needed for this project. It's purley an online survey with data analysis happening online too.

Technical

There is also not a lot of technical risk occurring with this project. Our survey doesn't ask or need much information from the user. The biggest risk would be a patient's confidential information about photophobia being stolen. This however is a very low risk and isn't a real threat.

The technical challenges of this project is how to best create a test that *accurately* diagnoses photophobia. This involves a lot of medical research and neuroscience to figure out. That is why we were working with doctors at John Hopkins to assist us with this information and knowledge.

Another technical challenge is how to effectively analyze this data to see how accurate our results are. While using the R^2 value is great, there is always more ways to look at the numbers to ensure our survey is as accurate and useful as possible.

Ethical

Our project is based around helping doctors effectively test phototrophic patients. We want to help make doctors and patients' lives easier. So our project is based around very ethically sound ideas however, that doesn't mean there are areas where some ethical issues can arise.

One way that we can potentially make an ethical mistake is to charge a lot of money for our survey. Hypothetically, if our survey is exceptional at diagnosing photophobic patients, we would have an opportunity to charge doctors and patients a lot of money to take or use our test. This could potentially limit who can take this survey because of a monetary barrier.

Another potential ethical issue is cyber security and how we handle the data. Our survey asks basic questions like age, gender, IP address, their survey response (potential whether or not they have photophobia), and a few other crucial characteristics to the observer. It is important that all of this information stays only with the doctors. Even when we do data analysis it is most ethical for the analyst to not know who these patients are as that is highly confidential information. It is also important to not sell this data. Down the road if this becomes successful, we could have the opportunity to sell survey data to companies for various reasons. This is highly unethical and should be avoided at all costs.

Political

Photophobia is not necessarily a political issue, but like mentioned in the last section there are lots of politics about data collection and how we interact with people online.

There are many different laws that cover data privacy and it is important that we follow all of them. There are also different laws in every US state country so our for what we do with the data we collect from this survey need to follow these laws. For example, Public Law 104 -

191 - Health Insurance Portability and Accountability Act of 1996 is a bill that governs the collection of health information (govinfo.gov).

Data privacy is also a hot topic in today's political climate and there are lots of new bills being introduced today. The best we can do is to stay up to date on the laws so we can make sure our data collection is done so ethically and legally.

5. Final Implementation

As already stated, technologies used included p5, javascript, Qualtrics, and Excel. The tests were created with javascript using p5, an interactive graphics framework. The tests were then embedded within the Qualtrics survey platform, for easy dissemination. Data analysis after the fact was done in Excel.

5.1 Relative Brightness Images

Our first test consisted of various images with dots of the same color placed on different parts of the photos (9.5). All photos were presented with dots of three different sizes With direction from Professor Shapiro and our clients, we adjusted the image contrast and dot color to get results reflective of our objective to differentiate participants with photophobia from those without. Participants were asked to rank the dots on the image from lightest to darkest.

Perhaps the largest part of this task was ranking the dots from brightest to darkest. Professor Shapiro taught us a methodology on photoshop to accomplish that. By applying high pass filters to each image, you can imitate the naturally occurring filters of the human eye.

To achieve unambiguous accuracy with these rankings, a filter size equivalent to the radius of the dots in each filter is applied to the images. In order to accommodate for variations in participants individual filters, we applied this filter with its original size (9.6), half the size (9.7), 75% of the size (9.8), 1.25 the size (9.9), and 1.75x the size (9.10). The gradient image showed little to no variation with different filters applied so the original size filter was used for all analysis of these responses. When analyzing the data, we considered all filter sizes. Although the actual ranking showed minimal change between filters, it explains responses that switch the order of dots that rank closely or appear similar in color. Because of this, we were able to accept a much lower r^2 value than we originally anticipated as an acceptable baseline for the tests.

5.2 Maloney and Knoblach Contrast Response

The Maloney and Knoblach contrast response test was our second test. The test presents participants with a series of random pairs of circles. The participant is presented with a third circle they must compare to the previous pair of circles by judging which circle is more similar.

The test has two variants, a light variant where the circles are being compared against a white background, and a dark variant where the circles are being compared against a black background.

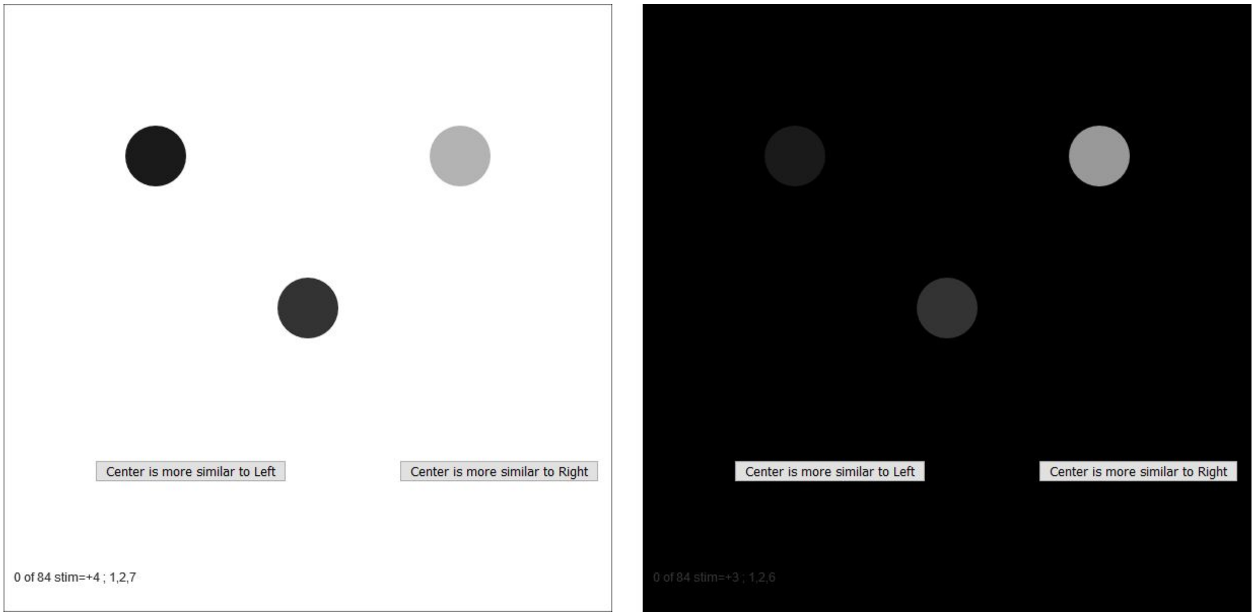


Figure 3. Maloney and Knoblach Contrast Response Test, Light (left) and Dark (right)

The participants' choices and the order of the circles are analyzed using the Maximum Likelihood Difference Scaling (MLDS) algorithm. The MLDS algorithm uses difference scaling to estimate perceptual differences along a scale. A curve is generated consisting of the various stimuli, by recursively applying a linear model function to the data. The likelihood estimation is defined with the following equation:

$$L(\Psi, \sigma) = \prod_{k=1}^{n} \Phi\left(\frac{\delta\left(\mathrm{q}^k\right)}{\sigma}\right)^{1-R_k} \left(1 - \Phi\left(\frac{\delta\left(\mathrm{q}^k\right)}{\sigma}\right)\right)^{R_k}$$

Figure 4: Maximum Likelihood Estimation

The generated MLDS graph can be used to determine if a participant has likely experienced traumatic brain injury or photophobia. This test is not a definitive answer, but is aimed as more of a diagnostic suggestion. Below is a graph of a participant with normal vision as well as a graph of a participant who has experienced traumatic brain injury.

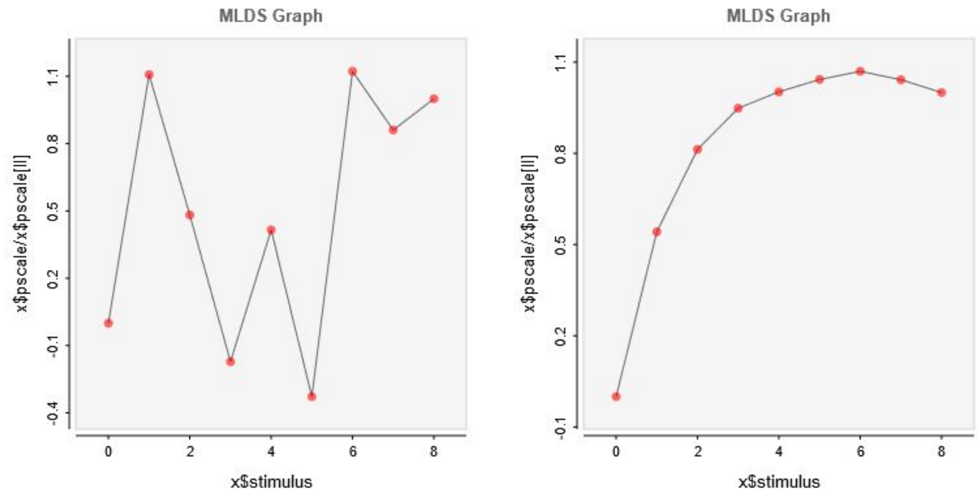


Figure 5: MLDS algorithm results, participant with TBI (left) and participant without (right)

5.3 Qualtrics

Qualtrics is an online survey platform that can be used to administer survey research as well as data accumulation. Qualtrics was chosen as the platform because it is the standard that is used by Johns Hopkins' ophthalmology department when collecting data due to its security features. Qualtrics is also the most developer friendly and customizable survey platform in comparison to other popular tools like survey monkey and google forms. By reworking our code to mimic the qualtrics survey engine, we were able to directly embed our javascript into survey questions

Our clients requested that we only analyze answers that were taken on computers and throw out data that was taken on mobile devices. To achieve this, we used javascript to capture metadata that provided us with metadata on the participants operating system, screen dimensions, and browser (9.12).

In order to stay in line with IRB standards, we needed to add a consent form to our survey. We added logic to the Qualtrics survey flow, to automatically end the survey if the user chose not to give their consent after reading the form.

Finally, in order to actually gather responses from our survey, we needed to design a way to embed our data into custom collection fields. Because our tasks were interactive, coded in javascript, and not a standard multiple choice or fill-in-the-blank response type provided by qualtrics, we needed to do this all manually. We did this by giving each question an embedded data title and adding/embedding that title in the survey flow (9.14). For every question, the data was submitted at the end of the survey. For Test 1, respondents were given the option to start over if they were not satisfied with their rankings. If they chose to start over, we programmed a reset feature to clear the data and the collection process was restarted.

Implementing the actual javascript tests on Qualtrics was relatively straightforward. p5 has the ability to run code in two modes, "global" mode, and "instance" mode. Global mode is easier to use but puts everything in the global namespace. Instance mode lets us encapsulate all of our code into separate objects, but it is slightly harder to implement. The first step to integrating the tests was to convert from global mode to instance mode. Qualtrics has the option to embed javascript code directly in a question. The question's HTML can then be altered to link the embedded javascript to the specific question.

We also used javascript embedded in the survey to control how and when a participant could proceed. We wanted to disable the participant prom proceeding in the survey unless they had completed the javascript test. Since the javascript was not natively part of the Qualtrics engine, we had to hook into their exposed javascript API. With the exposed javascript API you could do things like enable and disable buttons, send data from the test to the Qualtrics backend, and register things like click or move events.

5.4 Mechanical Turk

In order to gather unbiased data that reflects the general population, we used Amazon's Mechanical Turk. The platform uses real money to incentivize test takers to spend the appropriate amount of time taking the survey in order to produce meaningful data.

Because the amount of funding we could secure from the department to use this tool was limited, we tested our surveys over 100 times using ourselves and peers around us (9.4). We then uploaded (9.2), designed (9.3), and ran our survey on respondents from Mturk. Each participant was awarded .35 cents for their participation.

In order to audit the responses and only accept those that were completed, we implemented a random ID feature on Qualtrics. Only participants who completed the entirety of the survey were given a random ID, which we embedded (9.11) into the survey. At the end of the survey, the ID was presented to respondents and they were instructed to paste that value into Mturk. This way, when we received results, we could distribute payment only to users who took the entire survey by checking that the random ID they entered was present in our data. Respondents were warned that they would only receive compensation if they provided the correct random ID on MTurk and told that the ID would be given at the end of the survey. All respondents provided proper IDs so we did not need to reject any responses on this basis.

6. Results

6.1 Data Analysis

A comprehensive view of our final data is located in 9.16

To assess how accurate our data was we mainly used the R^2 value or the coefficient of determination. R^2 is a statistical measure that represents the proportion of the variance for a dependent variable that's explained by an independent variable or variables in a regression model. R^2 explains to what extent the variance of one variable explains the variance of the second variable. In our project, we measured the variance between the correct picture answers for test 2 to the observer answers. So, if the R^2 value is 0.50, then approximately half of the observed variation can be explained by the model's inputs. The closer the R^2 value is to 1 or -1 the better. We were aiming for a .9 score for observers not experiencing photophobia taking the test.

For every observation, we would find the R^2 value in excel. Here is a screenshot from one of the files. In excel, we used the function **=RSQ(variable1, variable2)**. The example below is from an observer with visual problems which can explain why there is such a low R^2 value.

Correct values	**Observer value**
5	3
4	1
3	2
2	5
1	4
R2 value	**0.36**

Figure 5: Example of how we calculated R^{22} values

After we found the R^2 value of each observer and of each picture, we averaged the total R^2 values for every picture and would separate them by visually impared and not visually impared people. Below is a screenshot of an example of us comparing the average R^2 values from different observers. You can see that normal observers had an average R^2 value of .47 whereas visually impaired people had a R^2 value of .29 - significantly worse.

VIS PROBLEMS

Question	Average r2
Kings	0.32
Wheel	0.10
Grad	0.35
Checker	0.17
Checker 2	0.17
Wheel 2	0.37
Kings 2	0.11
Grad 2	0.72
Average	**0.29**

NORMAL

Question	Average r2
Kings	0.38
Wheel	0.38
Grad	0.64
Checker	0.40
Checker 2	0.43
Wheel 2	0.44
Kings 2	0.41
Grad 2	0.68
Average	**0.47**

Figure 6:Example of R^2 values for each picture for normal and visually impaird observers

6.2 Completed Objectives/Accomplishments

In order to objectively evaluate our success of the project, we asked our advisor, Professor Shapiro, to provide a short reflection on our performance:

"The team worked on a collaboration with researchers in the Departments of Ophthalmology at John Hopkins University and University of Maryland, Baltimore. The project consisted of developing online experiments for testing photophobia; there were two tests: a brightness test and test of maximum likelihood difference scaling. They were able to 1. Translate the MLDS procedure from R to JavaScript; 2. complete several feed loops for correction of both tests, 3. Complete interrelations to get the project approved through the IRB and 4. a preliminary version of the test was run on qualtrics and integrated with Amazon's mechanical Turk."

Although we did not ask for a written response from our clients, they expressed to us that our progress on these tests were an overwhelming success. They noted that they were very pleased by the work accomplished in a short window of time and expressed that they have been trying to actualize a standard test for photophobia with no viable progress in the past. We are excited to continue development with them in the future to help them achieve this goal.

6.3 Variants from Original Goals/Timeline

As the software engineers, not the medical experts, it was our task to explicitly follow the instructions of our clients at Johns Hopkins University. We successfully met all requests to their standards and delivered each iteration on time. Deliveries were made on a bi-weekly basis where during zoom calls with Professor Shapiro and both doctors at Johns Hopkins. The reason that we integrated two out of the four tests was due to the fact that many iterations of our data for the first test did not match the predicted outcome. Our clients concluded that the reason for these issues was due to the fact that we were asking a general population to perform tasks that were too confusing to fully understand without in-person instruction by a medical provider. Patients typically have many questions about tasks like these that are answered in-clinic but due to current circumstances, everything needed to be done virtually.

To remedy this, we knew we needed to take measures to predict as many of these questions as possible and provide answers for them prior to and during the survey. We worked together to solve these issues by implementing various features not limited to but including a tutorial video, a button to highlight any remaining or unseen dots on images presented, and various instructional components that served as reminders of the task at hand. After these measures, results were significantly better but just shy of having medical value.

After testing our survey around 100 times and evaluating the subsequent data, the group decided that without making the tasks easier, we would not get results close enough to the expected outcome. With permission from our clients, we set out to actualize our idea. By essentially re-working the code from scratch for test 1 to make it easier for the participant to provide correct answers, we were finally able to produce data that showed significant discrepancy between participants with photophobia and those without photophobia.

7. Conclusion and Evaluation

The goal of this project was to work with Johns Hopkins University to prototype and develop tests to assist in the diagnosis of photophobia in patients with TBI and we achieved that goal. We successfully implemented all features requested from our clients and made all changes they asked for based on the data we secured after every 2 week period. All requests were completed to satisfaction and delivered on time.

We had a very active role in this project because of our bi-weekly meetings with our client and weekly meetings with our advisor. With these meetings keeping us on track, there was not a week in the semester, and rarely even a few days, that went by without us putting work into the project.

We implemented these tests on the Qualtrics survey platform using the p5 javascript graphics framework. We were able to receive IRB approval to distribute this survey on the internet and collect data via Amazon Mechanical Turk. Based on our data analysis and usage of the MLDS algorithm, we could show that there was a distinction between participants who had experienced traumatic brain injury or photophobia, and those with normal vision.

Our job was to follow the instructions of our clients to provide them with exactly what they asked for. As we lack any medical expertise, we had no room to get creative or stray from their instructions. Of course, it would be impossible to develop a tool in one semester that would be ready for deployment by medical facilities so there is still much work to be done on the project.

With the data provided and tests developed, our clients are now able to seek their own IRB approval to run these tests on actual patients. The IRB process for testing on actual patients rather than a general population is vastly different and far stricter. Thankfully, our clients were aware of this, and gave us exact instructions that kept us in line with those guidelines while we programmed our project. This way, we minimize work on their and future developers' ends.

7.1 Performance/Scalability

Because these tests were developed to be virtual due to COVID-19, the scalability is vast. When in-person visitations are no longer considered a health risk, doing these tests in-clinic can provide official diagnosis of photophobia.

Moreover, as these were developed to be deployable online, people who suspect they might have photophobia can evaluate this for themselves at home by taking the tests and then decide whether they would like to seek a medical diagnosis.

Even more, those who can't afford a medical diagnosis would be able to take these tests at home. Although not directly comparable to an official medical diagnosis, some evaluation is better than none and can allow people to research steps on their own they can take to alleviate symptoms.

7.2 Maintainability

This project was designed and implemented with maintainability in mind. The complete source for all of the tests as well as instructions for how to implement them within Qualtrics is being provided to our clients at Johns Hopkins University. Our javascript code is also written in a modular and concise fashion, using the newer ES6 javascript standard. Writing the code using ES6 allows the code to be adaptable in the event that Qualtrics core engine environment changes. The modularity of our tests also allows for our code base to be easily modified if test requirements were to change or if Johns Hopkins wanted additional features.

7.3 Reusability

Although we designed this project specifically for our clients at Johns Hopkins who expressed the issue to us, it could be used by any medical providers who experience the same frustrations.

7.4 Usefulness

These tests are useful for both doctors and patients. By addressing a specific problem expressed by medical professionals, we can be certain our progress has real world application.

The usefulness of diagnosing photophobia can be seen in the lives of patients who struggle with it themselves. Patients might spend thousands of dollars and both doctors and patients often spend countless hours testing for other conditions with the same symptoms. It is frustrating on both ends when a photophobia diagnosis is achieved because it often only comes when all other possibilities have been ruled out.

These tests will alleviate frustration for those involved in the diagnosis. If symptoms of photophobia are present, these tests can be the first straight-forward tool to diagnose the condition.

7.5 Future Work

Future works will include integrating, testing, and analyzing data from tests 2 and 3. It will also include future improvements on the first two tests. In order for something to be approved as a medical tool, many years of development are needed, significant amounts of money will likely be spent, and hundreds to thousands of data sets must be analyzed. Future work should also include adding components to automate the data analysis that we have performed manually.

One of our group members, Isabella Sims, will continue to work with Professor Shapiro and the clients at Johns Hopkins over break and throughout the Spring semester. In this timeline, future progress will be made to work towards the goal of standardizing these tests as a medical tool to diagnose photophobia.

8. References

Citations
Bradley J. Katz, Kathleen B. Digre,
Diagnosis, pathophysiology, and treatment of photophobia,
Survey of Ophthalmology, Volume 61, Issue 4,2016,
Pages 466-477, ISSN 0039-6257,
https://doi.org/10.1016/j.survophthal.2016.02.001.
(http://www.sciencedirect.com/science/article/pii/S0039625715300072)

Shedding Light on Photophobia
Kathleen B. Digre, K.C. Brennan
J Neuroophthalmol. Author manuscript; available in PMC 2013 Mar 1.
Published in final edited form as: J Neuroophthalmol. 2012 Mar; 32(1): 68–81. doi: 10.1097/WNO.0b013e3182474548
PMCID: PMC3485070

James M. Stringham, Kenneth Fuld, and Adam J. Wenzel, "Action spectrum for photophobia," J. Opt. Soc. Am. A 20, 1852-1858 (2003)

(n.d.). Retrieved from https://www.govinfo.gov/app/details/PLAW-104publ191/summary

9. Appendix

9.1

IRB #: IRB-2021-180
Title: Measuring Color Perception and Light Sensitivity
Creation Date: 10-21-2020
End Date:
Status: Approved
Principal Investigator: Arthur Shapiro
Review Board: IRB

9.2

Measuring Color Perception and Light Sensitivity	Measuring Color Perception and Light Sensitivity	October 29, 2020	November 24, 2020	Publish Batch	Edit	Copy	Delete

9.3

Measuring Color Perception and Light Sensitivity
Requester: Isabella Sims **Reward:** $0.35 per task **Tasks available:** 0 **Duration:** 1 Hours
Qualifications Required: None

Survey Link Instructions (Click to collapse)

All mobile responses will be discarded. Please do not use a mobile device.

The survey consists of 2 short studies:

The first study measures brightness response in observers over the internet. The method is based on a novel extension of a psychometric technique for estimating response response function (maximum likelihood difference scaling). The study serves two different purposes:

1. It lays the foundation for a potential method for calibrating monitors for internet studies,

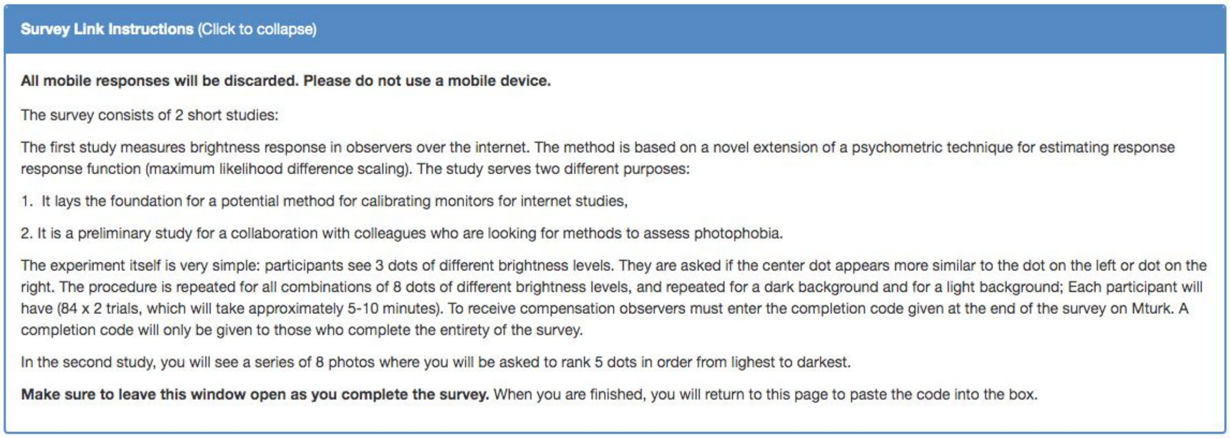
2. It is a preliminary study for a collaboration with colleagues who are looking for methods to assess photophobia.

The experiment itself is very simple: participants see 3 dots of different brightness levels. They are asked if the center dot appears more similar to the dot on the left or dot on the right. The procedure is repeated for all combinations of 8 dots of different brightness levels, and repeated for a dark background and for a light background; Each participant will have (84 x 2 trials, which will take approximately 5-10 minutes). To receive compensation observers must enter the completion code given at the end of the survey on Mturk. A completion code will only be given to those who complete the entirety of the survey.

In the second study, you will see a series of 8 photos where you will be asked to rank 5 dots in order from lighest to darkest.

Make sure to leave this window open as you complete the survey. When you are finished, you will return to this page to paste the code into the box.

Survey link:	https://american.co1.qualtrics.com/jfe/form/SV_9ugbgeRCtwiPA6F



Survey Link Instructions (Click to collapse)

All mobile responses will be discarded. Please do not use a mobile device.

The survey consists of 2 short studies:

The first study measures brightness response in observers over the internet. The method is based on a novel extension of a psychometric technique for estimating response response function (maximum likelihood difference scaling). The study serves two different purposes:

1. It lays the foundation for a potential method for calibrating monitors for internet studies,

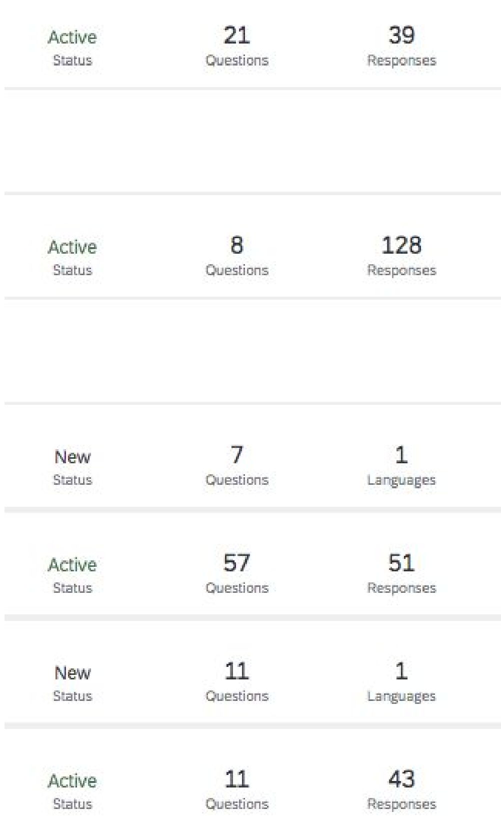
2. It is a preliminary study for a collaboration with colleagues who are looking for methods to assess photophobia.

The experiment itself is very simple: participants see 3 dots of different brightness levels. They are asked if the center dot appears more similar to the dot on the left or dot on the right. The procedure is repeated for all combinations of 8 dots of different brightness levels, and repeated for a dark background and for a light background; Each participant will have (84 x 2 trials, which will take approximately 5-10 minutes). To receive compensation observers must enter the completion code given at the end of the survey on Mturk. A completion code will only be given to those who complete the entirety of the survey.

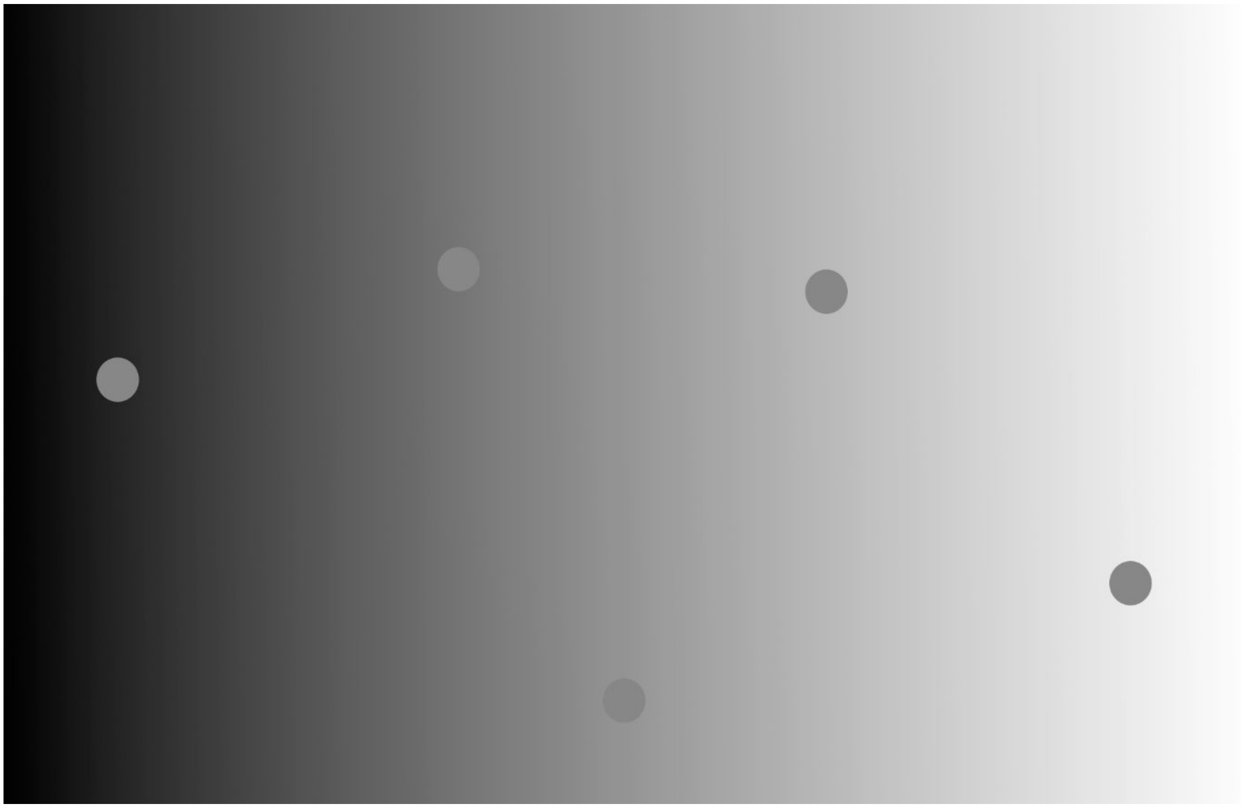
In the second study, you will see a series of 8 photos where you will be asked to rank 5 dots in order from lighest to darkest.

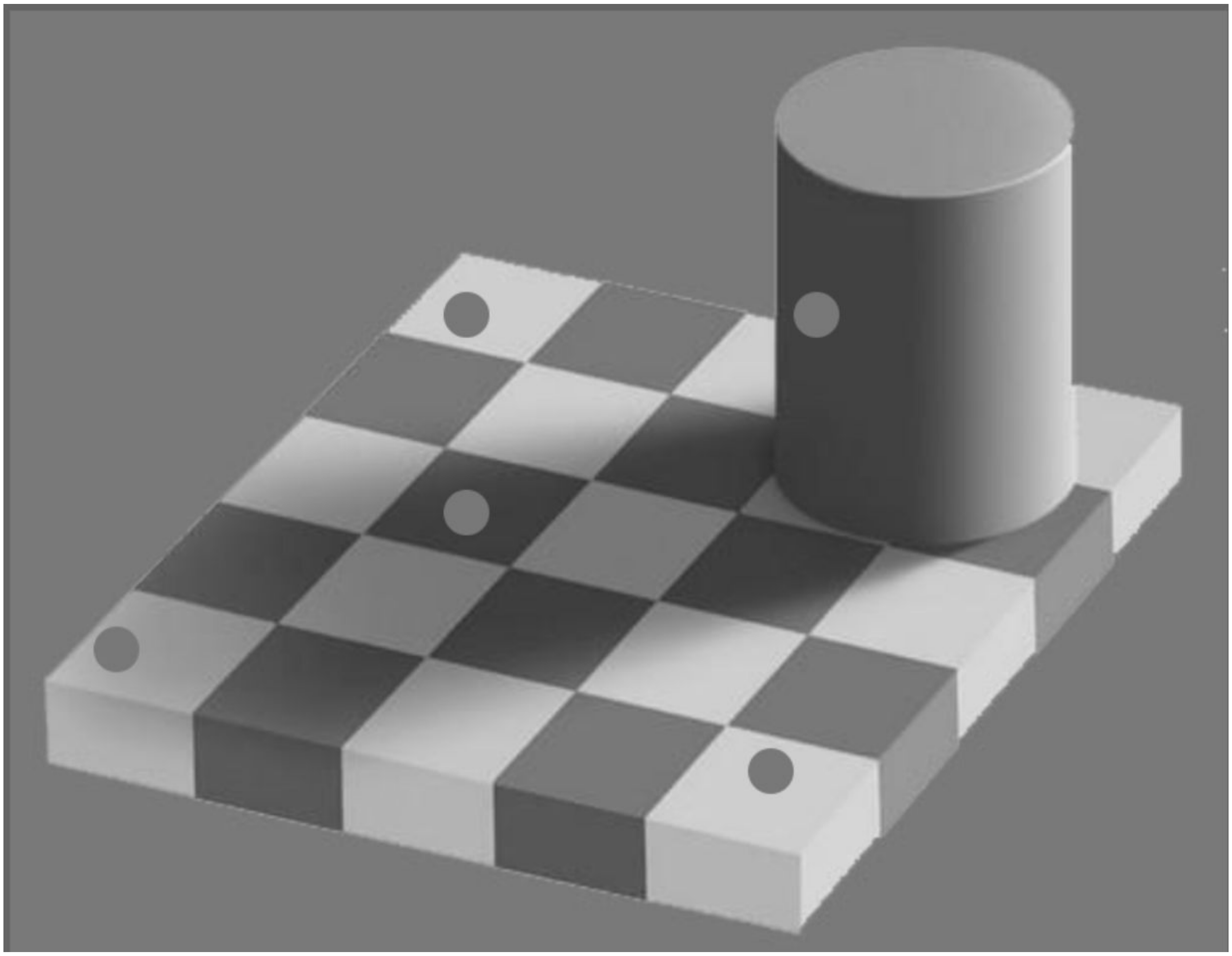
Make sure to leave this window open as you complete the survey. When you are finished, you will return to this page to paste the code into the box.

9.4



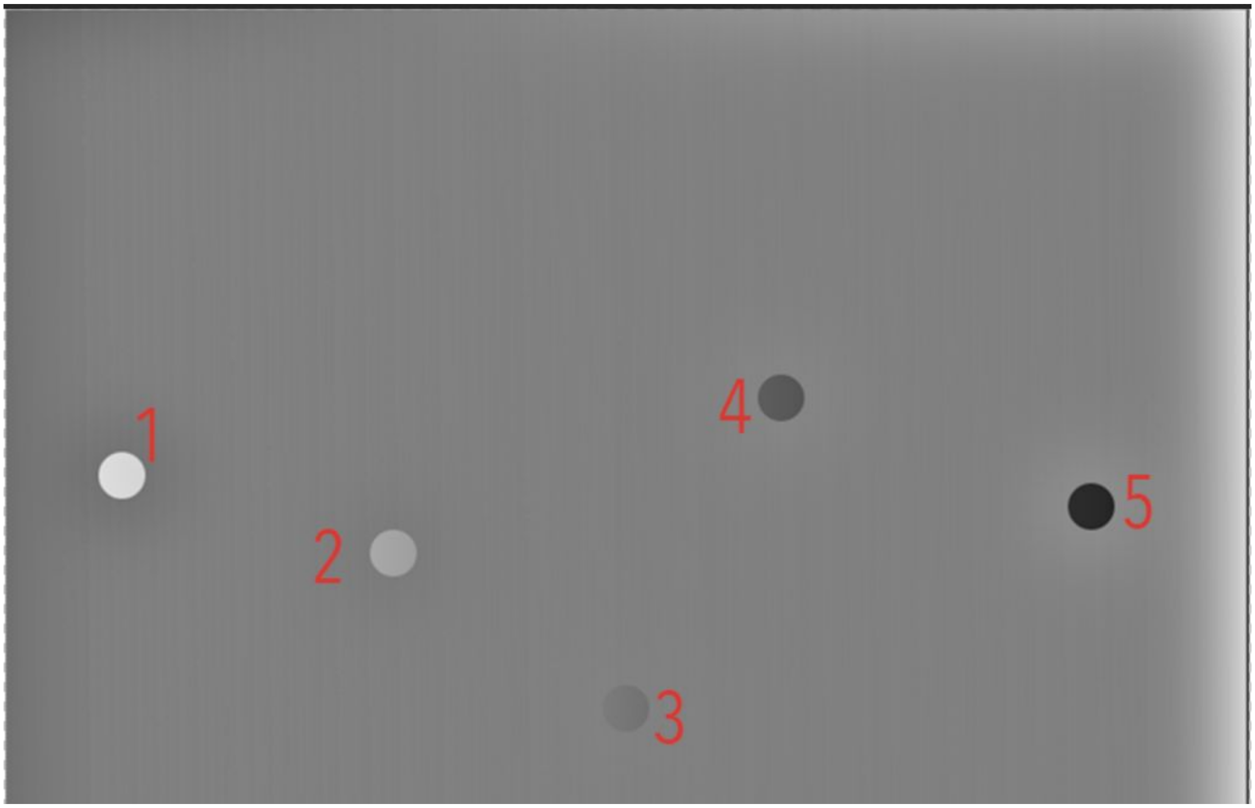
9.5





9.6

5
3
4
2
1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3
4
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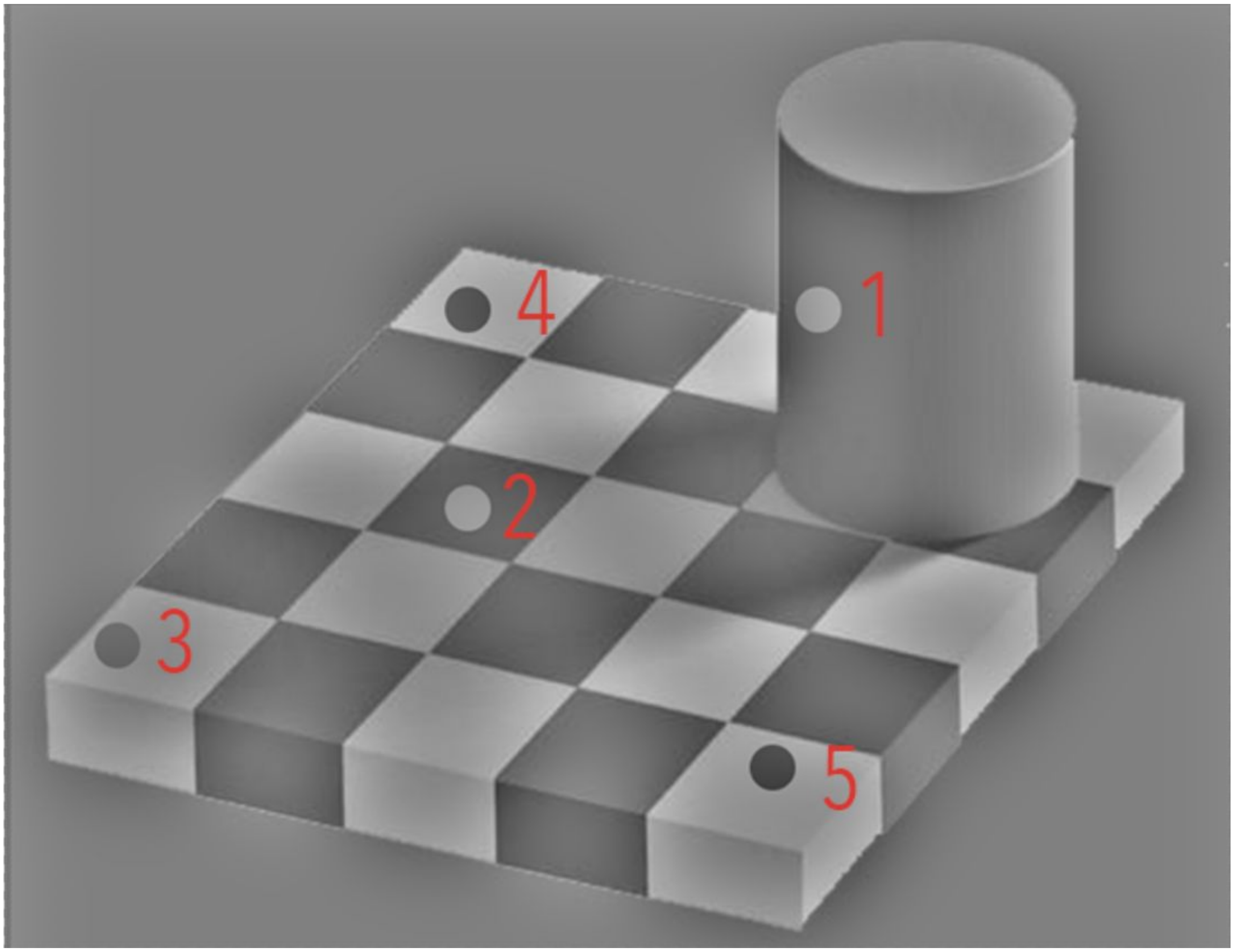
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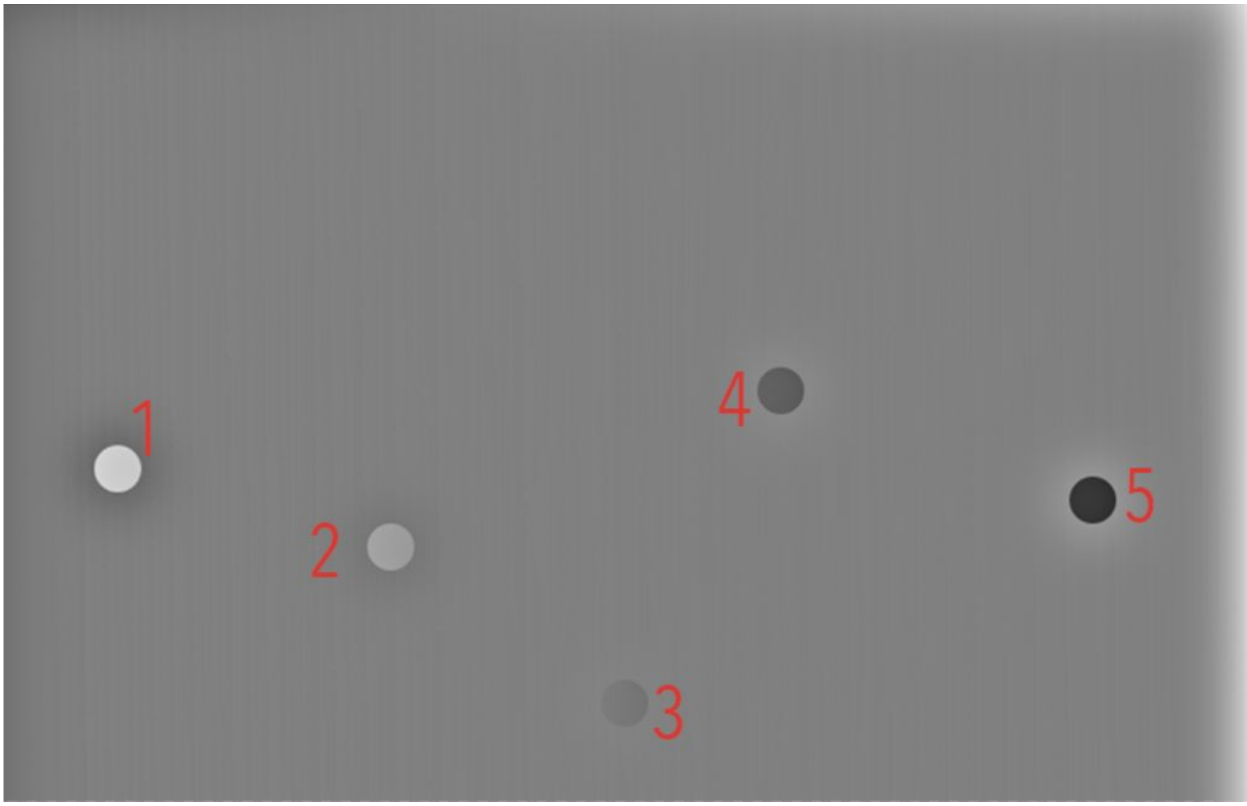
1
2
3
5

9.7


5
3
4
2
1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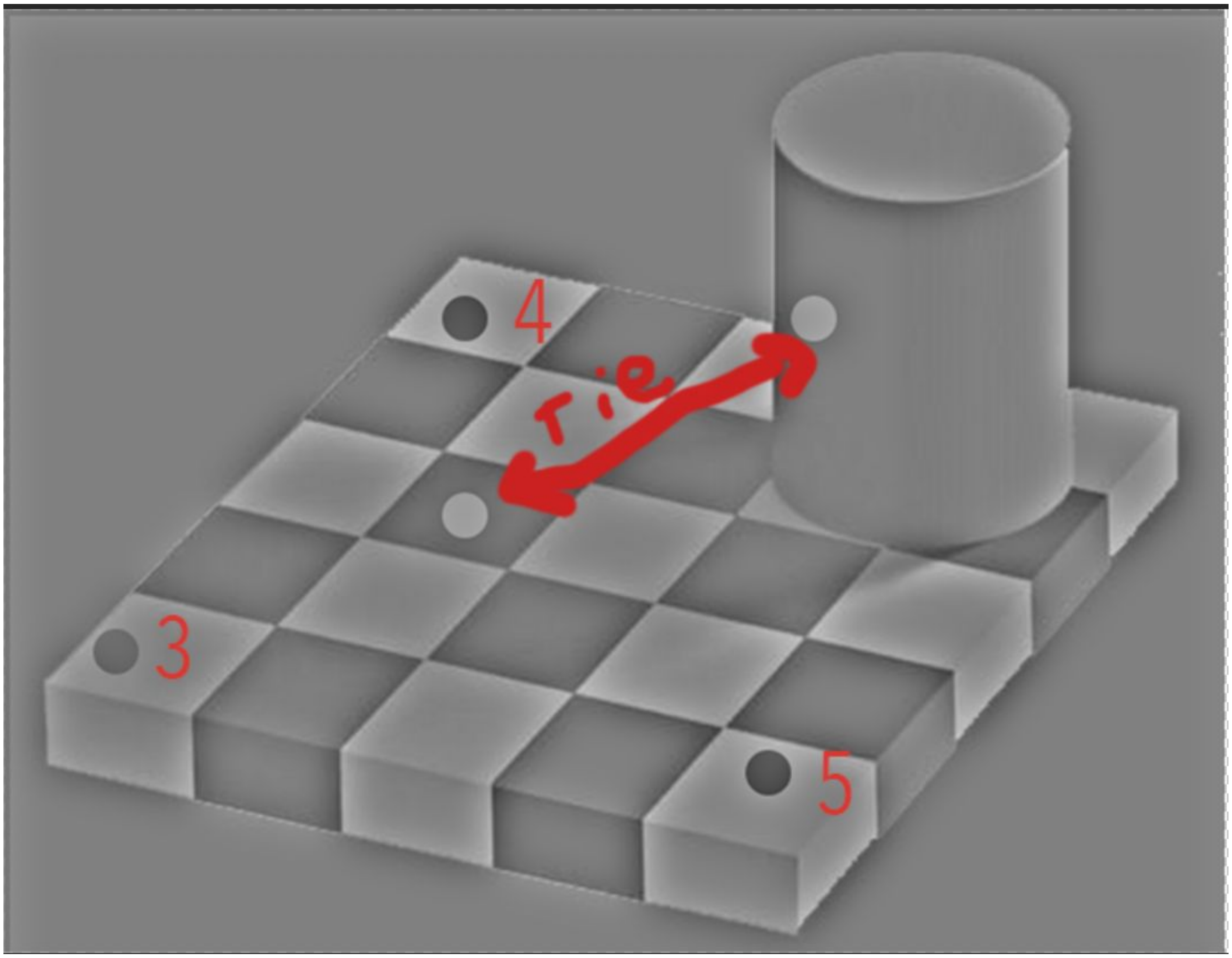
3
4
5



9.8


3
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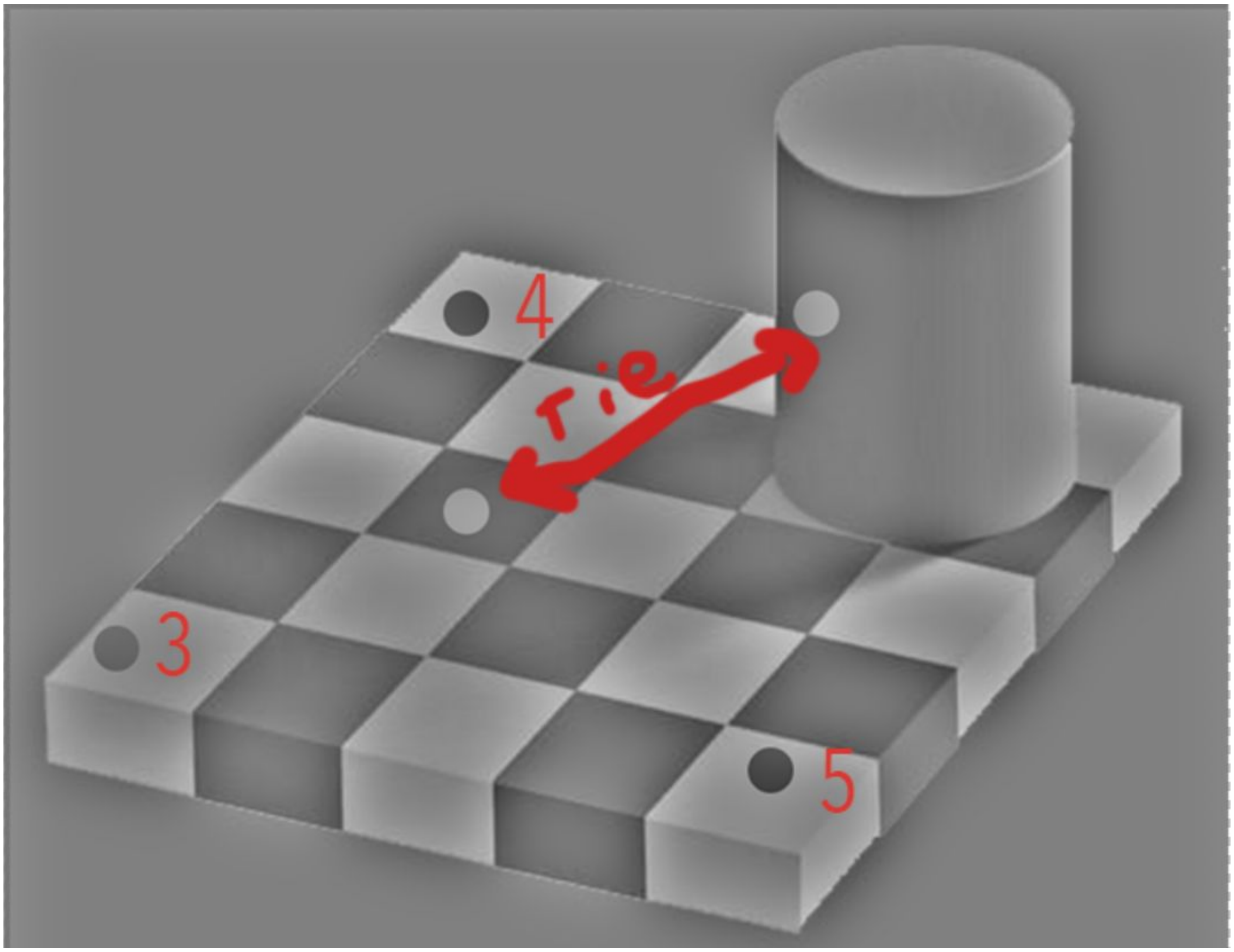
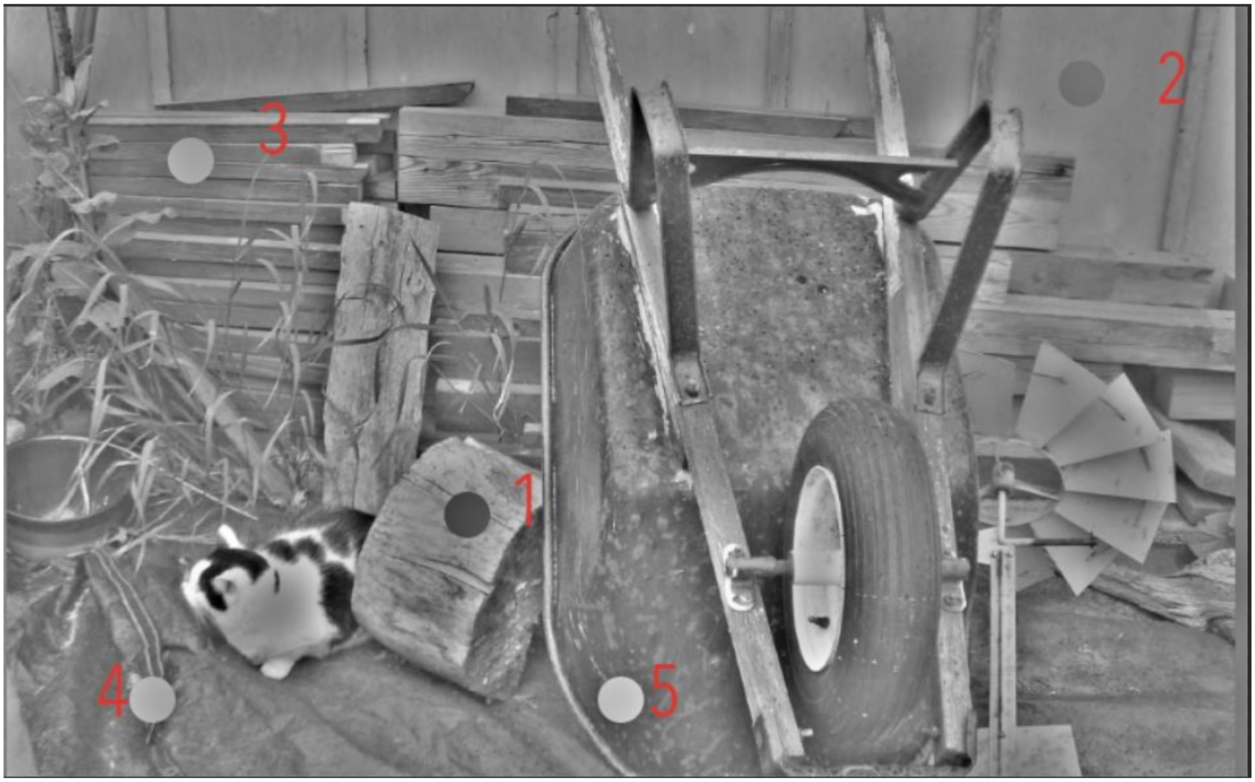
5
2
1

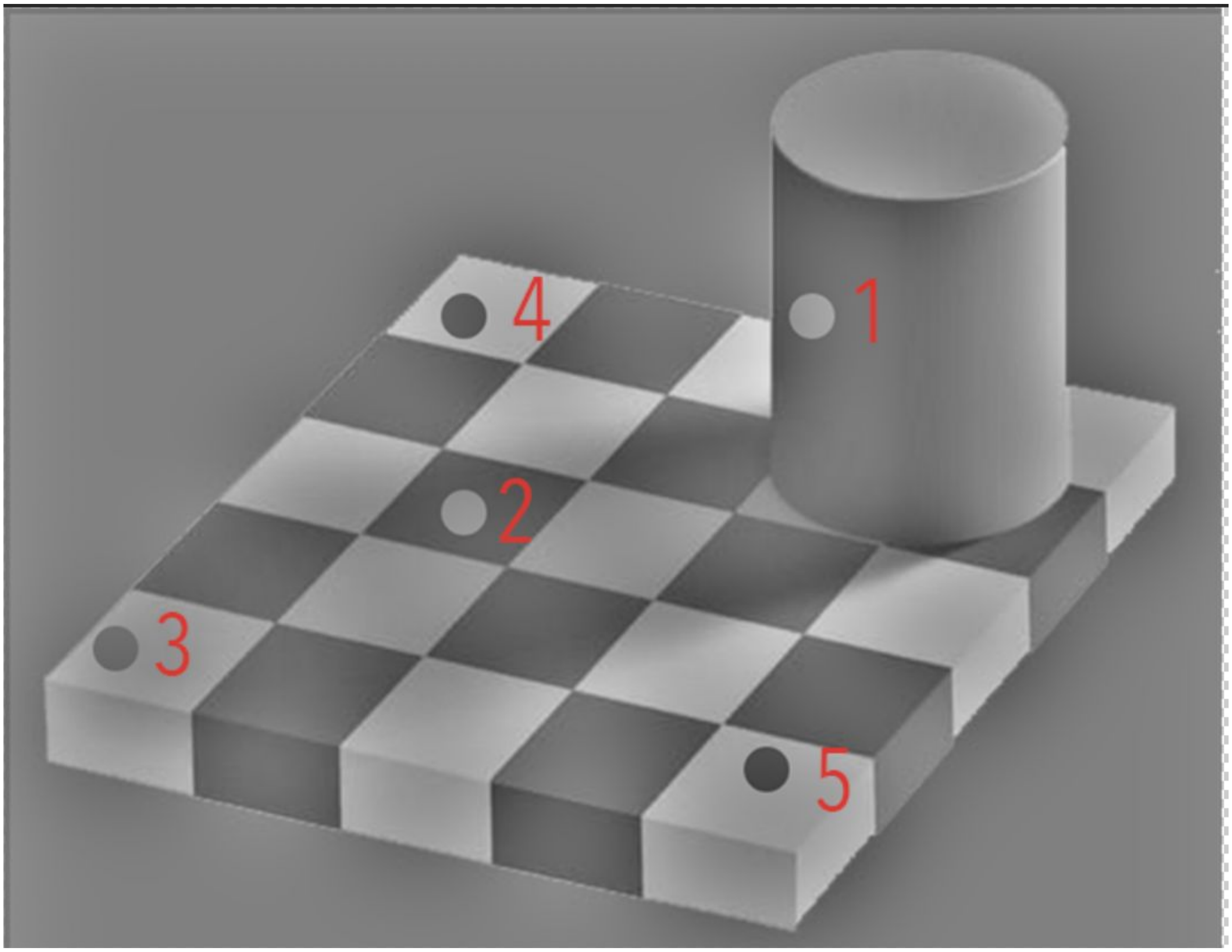

5
3
4
2
1



9.9


1
2
3
4
5


5
3
4
2
1



9.10


3
2
1
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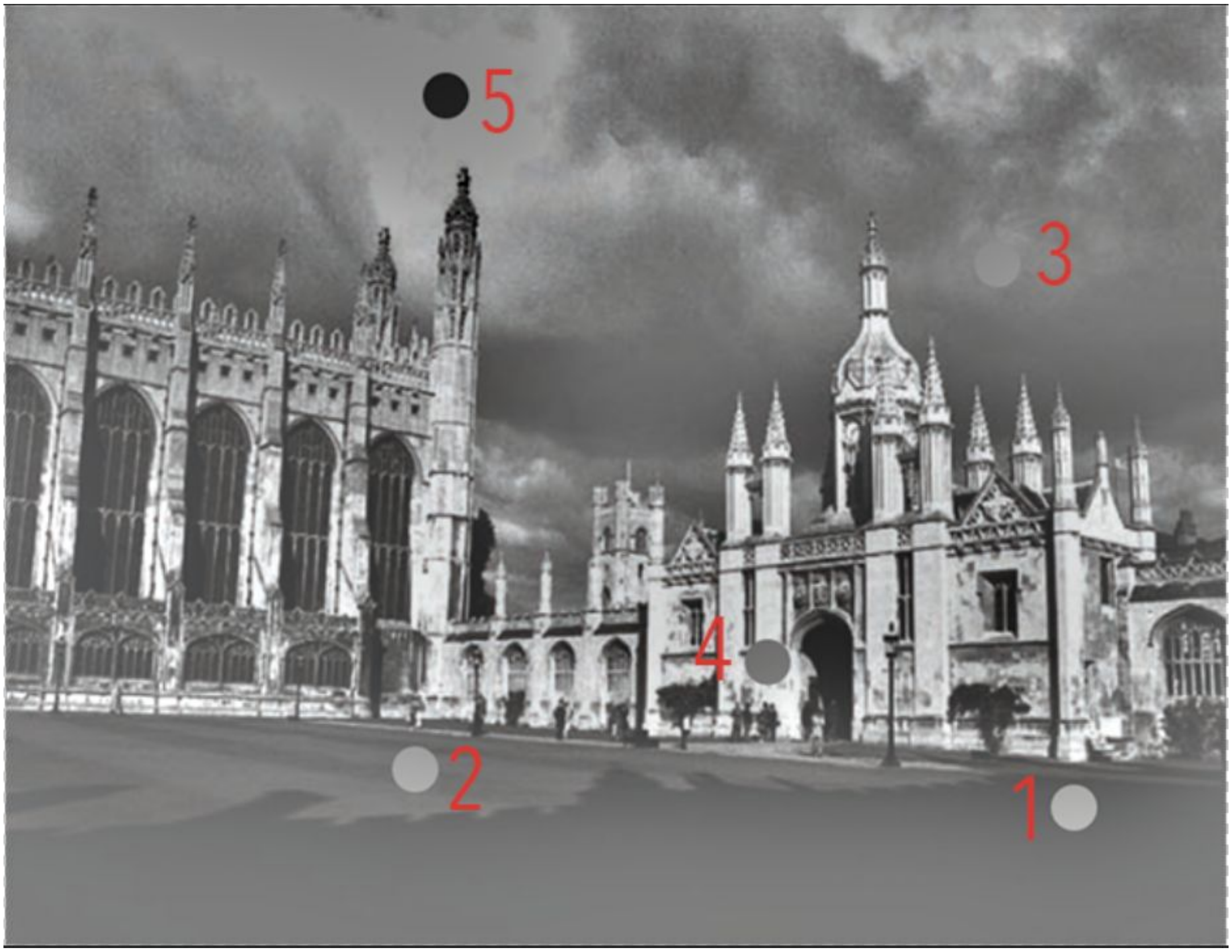
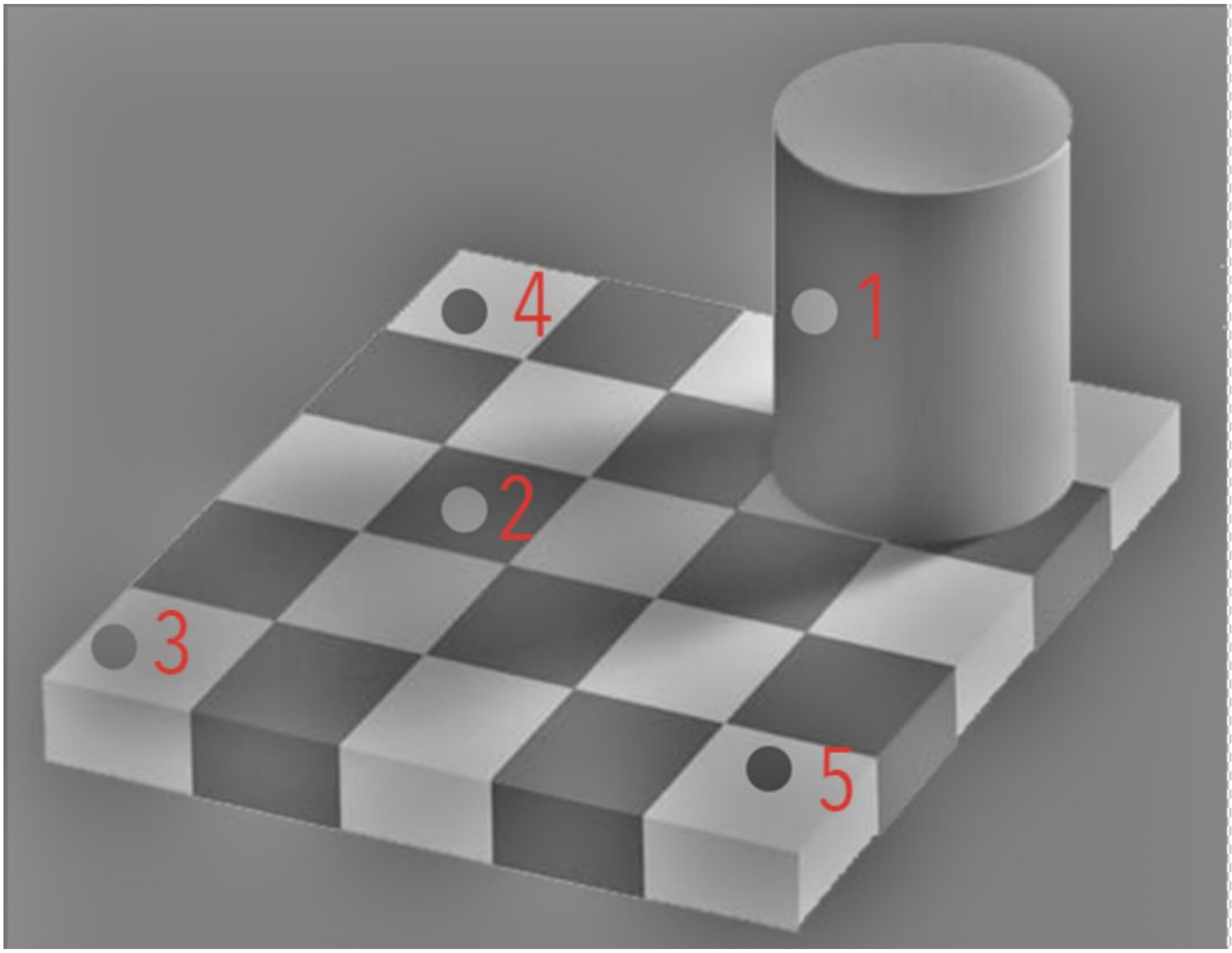
5


5
3
4
2
1


4
1
2
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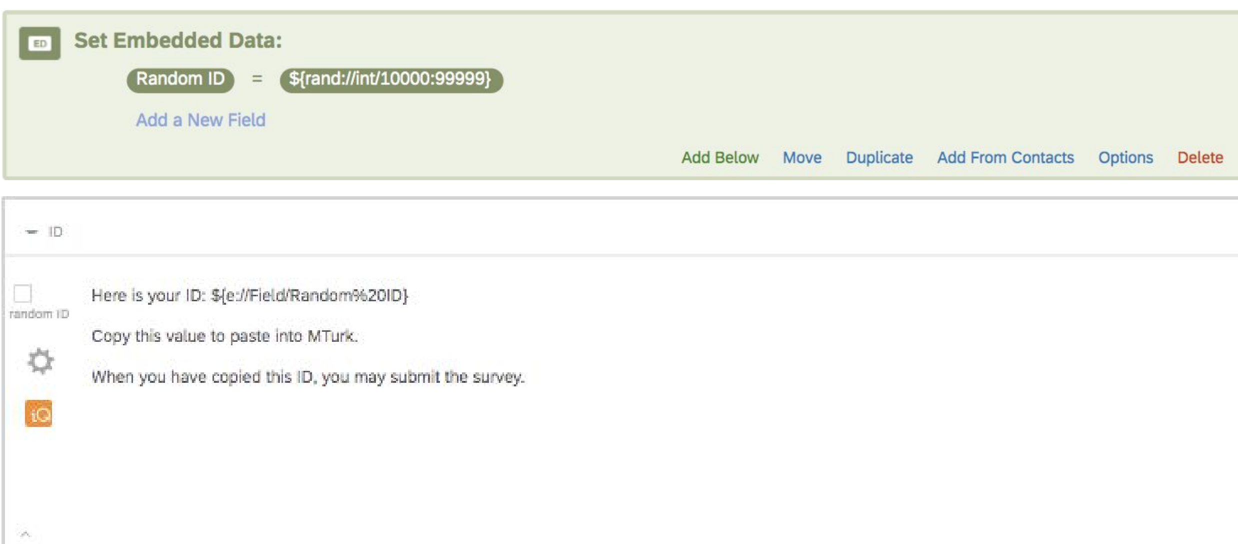
5

9.11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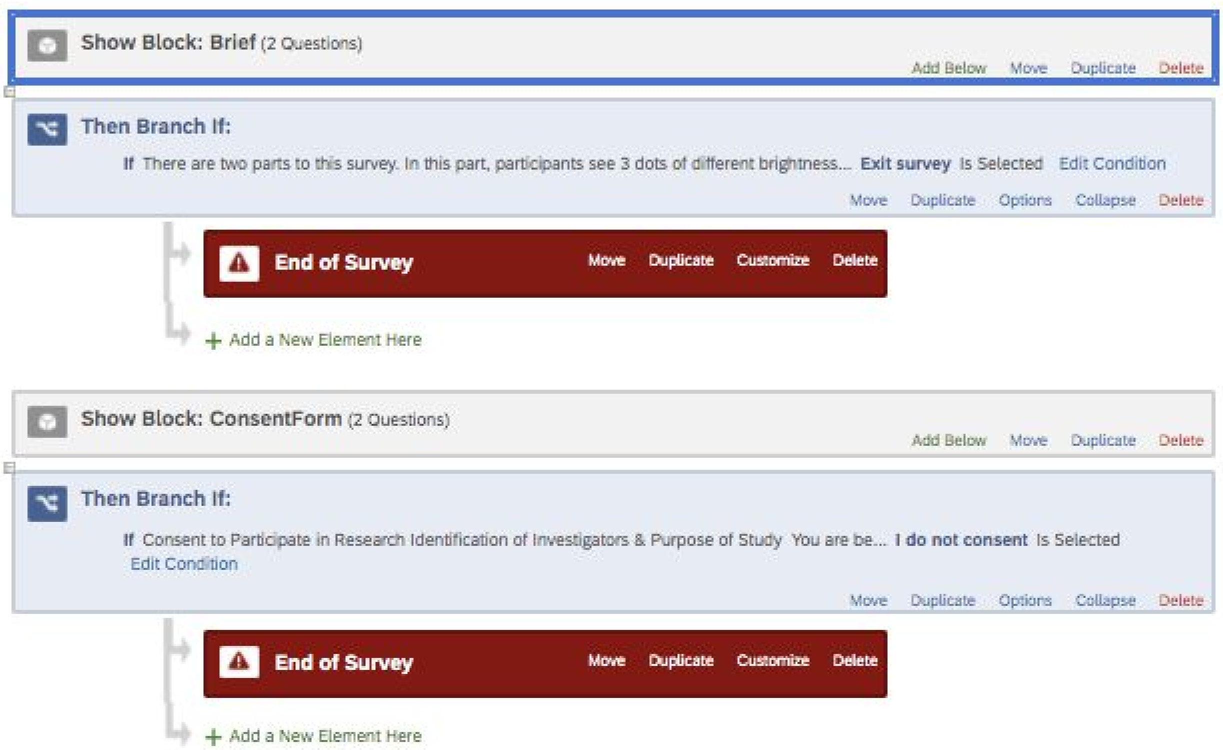
Random ID
=
${rand://int/10000:99999}
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
ID
random ID
Here is your ID: ${e://Field/Random%20ID}
Copy this value to paste into MTurk.
When you have copied this ID, you may submit the survey.

9.12

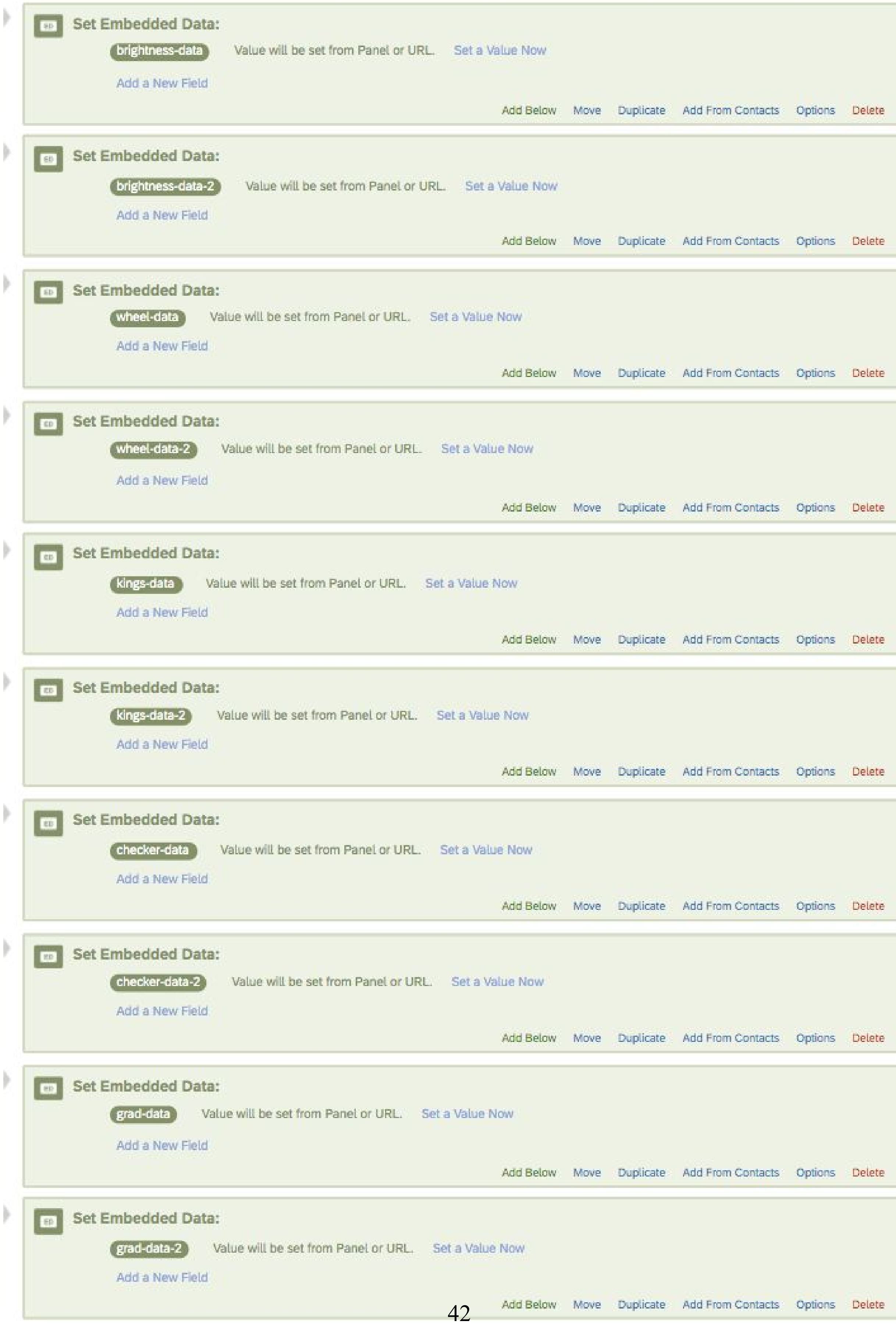
browser data_Browser	browser data_Version	browser data_Operating System	browser data_Resolution
Click to write the question text - Browser	Click to write the question text - Version	Click to write the question text - Operating System	Click to write the question text - Resolution
Chrome	86.0.4240.198	Windows NT 6.3	1024x768
Chrome	86.0.4240.198	Windows NT 10.0	1920x1080
Chrome	86.0.4240.198	Windows NT 6.3	1920x1080
Chrome	87.0.4280.66	Windows NT 6.3	1366x768
Chrome	86.0.4240.198	Windows NT 6.3	1920x1080
Chrome	87.0.4280.66	Windows NT 6.1	1366x768
Chrome	87.0.4280.66	Windows NT 10.0	1536x864
Chrome	87.0.4280.66	Windows NT 10.0	1364x768
Chrome	87.0.4280.66	Windows NT 6.1	1366x768
Chrome	86.0.4240.198	Windows NT 6.1	1366x768
Chrome	86.0.4240.193	Windows NT 6.1	1366x768
Opera	72.0.3815.320	Windows NT 10.0	1366x768
Chrome	86.0.4240.198	Windows NT 10.0	1364x768
Chrome	86.0.4240.198	Windows NT 6.1	1366x768
Chrome	86.0.4240.198	Windows NT 6.1	1366x768
Chrome	87.0.4280.66	Windows NT 6.1	1366x768
Chrome	87.0.4280.66	Windows NT 6.1	1366x768
Chrome	87.0.4280.66	Windows NT 6.1	1366x768
Chrome	84.0.4147.125	Windows NT 6.3	1366x768

9.13



9.14

```
const PARENT_ID = 'wheelbarrow';
const filter_applied = 90;
const EMBEDDED_DATA = 'wheel-data-2';
```


Set Embedded Data:
brightness-data
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
brightness-data-2
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
wheel-data
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
wheel-data-2
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
kings-data
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
kings-data-2
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
checker-data
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
checker-data-2
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
grad-data
Value will be set from Panel or URL.
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete
Set Embedded Data:
grad-data-2
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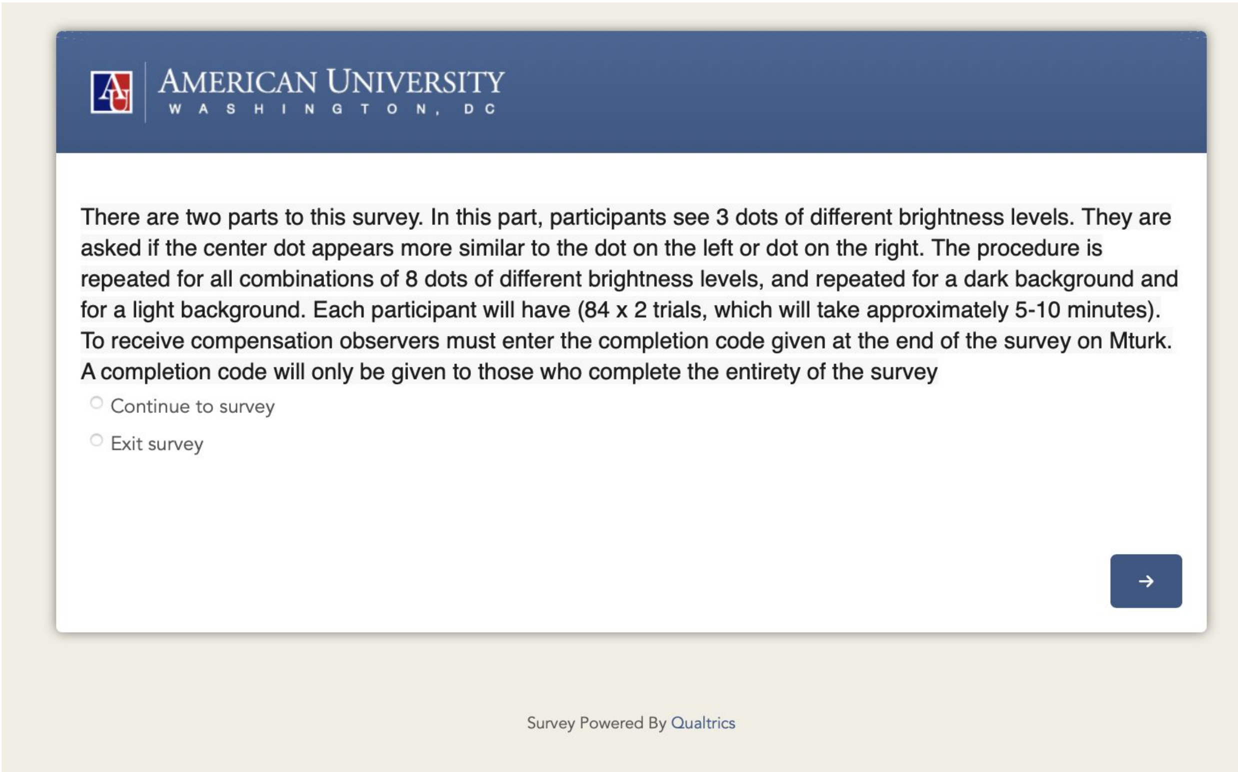
Set a Value Now
Add a New Field
Add Below
Move
Duplicate
Add From Contacts
Options
Delete

9.14



AMERICAN UNIVERSITY
WASHINGTON, DC

There are two parts to this survey. In this part, participants see 3 dots of different brightness levels. They are asked if the center dot appears more similar to the dot on the left or dot on the right. The procedure is repeated for all combinations of 8 dots of different brightness levels, and repeated for a dark background and for a light background. Each participant will have (84 x 2 trials, which will take approximately 5-10 minutes). To receive compensation observers must enter the completion code given at the end of the survey on Mturk. A completion code will only be given to those who complete the entirety of the survey

- Continue to survey
- Exit survey

Survey Powered By Qualtrics

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WASHINGTON, DC

Consent to Participate in Research

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by *Isabella Sims and Professor Arthur Shapiro* from American University. The purpose of this study is to *measure color perception and light sensitivity*. This study will contribute to the student's completion of her capstone project.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. This study consists of a *survey* that will be administered to individual participants via Qualtrics. You will be asked to provide answers to a series of questions related to color and light perception. You will then take a survey where you see three dots, and click one of them based on the prompt.

Time Required

Participation in this study will require 5-15 minutes of your time.

RisksThe investigator does not perceive more than minimal risks from your involvement in this study.

Benefits

Potential benefits from participation in this study include advancements in the fields of perceptual, cognitive, and neuroscience.

You will also be compensated 30 cents for completing the survey via Amazons Mechanical Turk.

Only fully completed surveys are eligible for compensation.

Confidentiality

The results of this research may be published in academic publications. However, none of the information presented can be traced back to an individual.

The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind. You may also refuse to answer any individual question without consequences.

Questions about Your Rights as a Research Subject

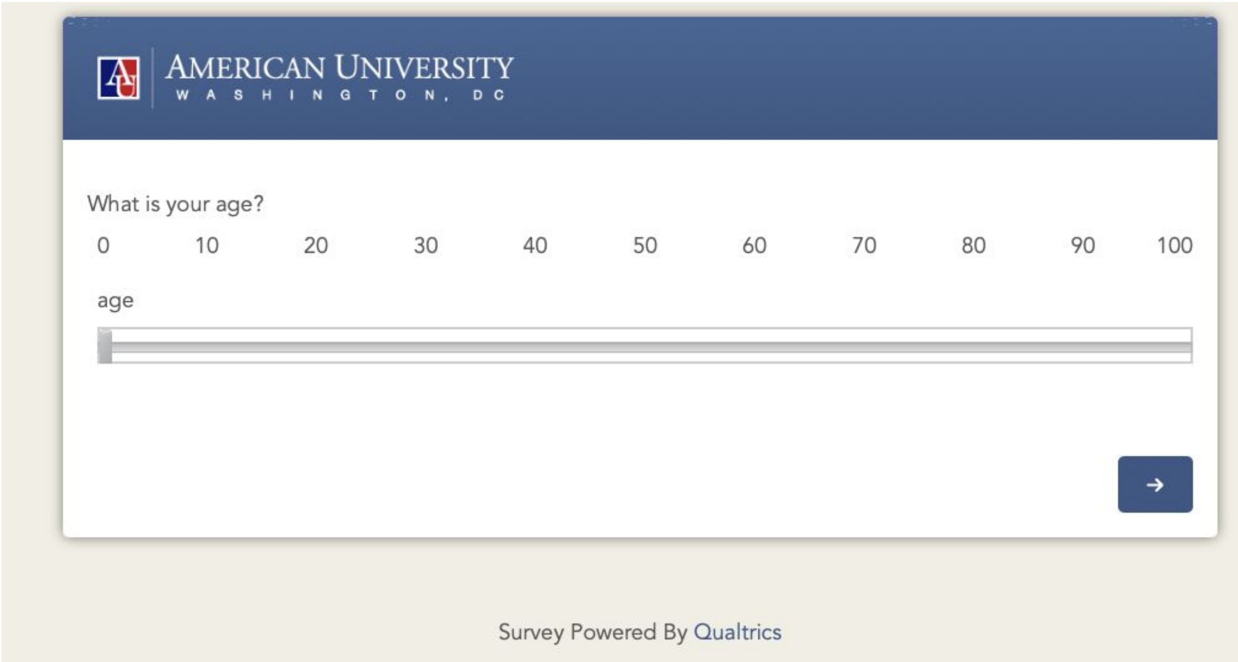
Matt Zembrzuski
IRB Coordinator
American University
(202)885-3447
irb@american.edu

Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

○ I consent

○ I do not consent


AMERICAN UNIVERSITY
WASHINGTON, DC

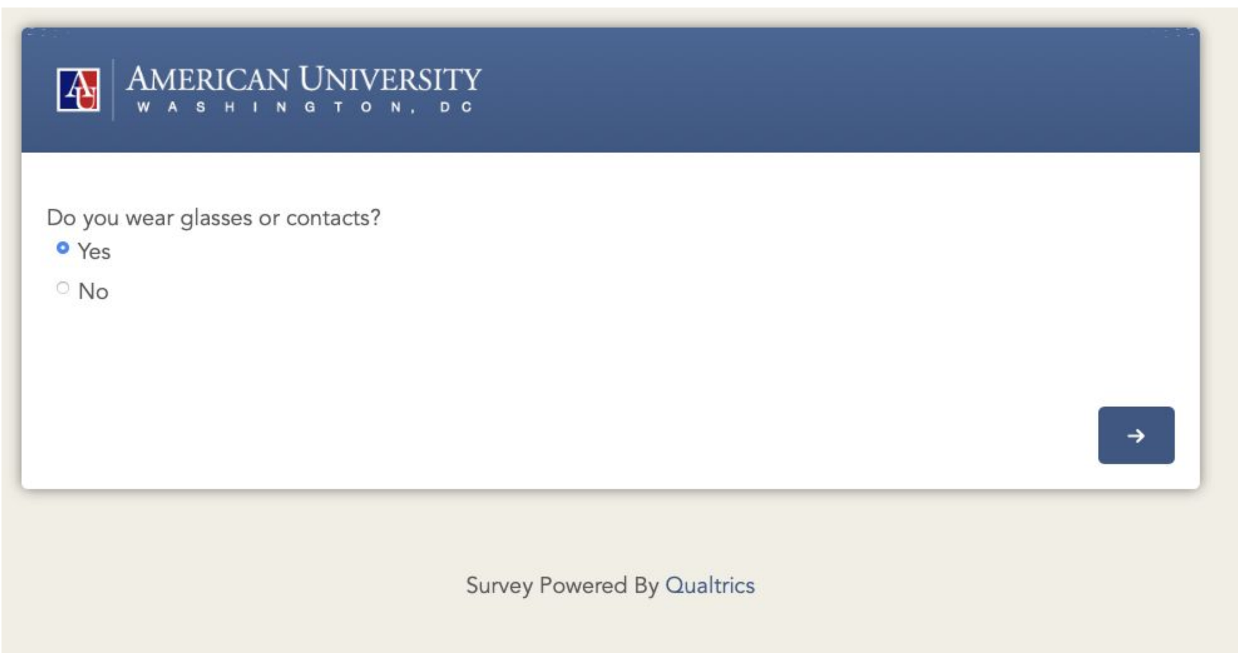
What is your age?

0 10 20 30 40 50 60 70 80 90 100

age

→

Survey Powered By Qualtrics

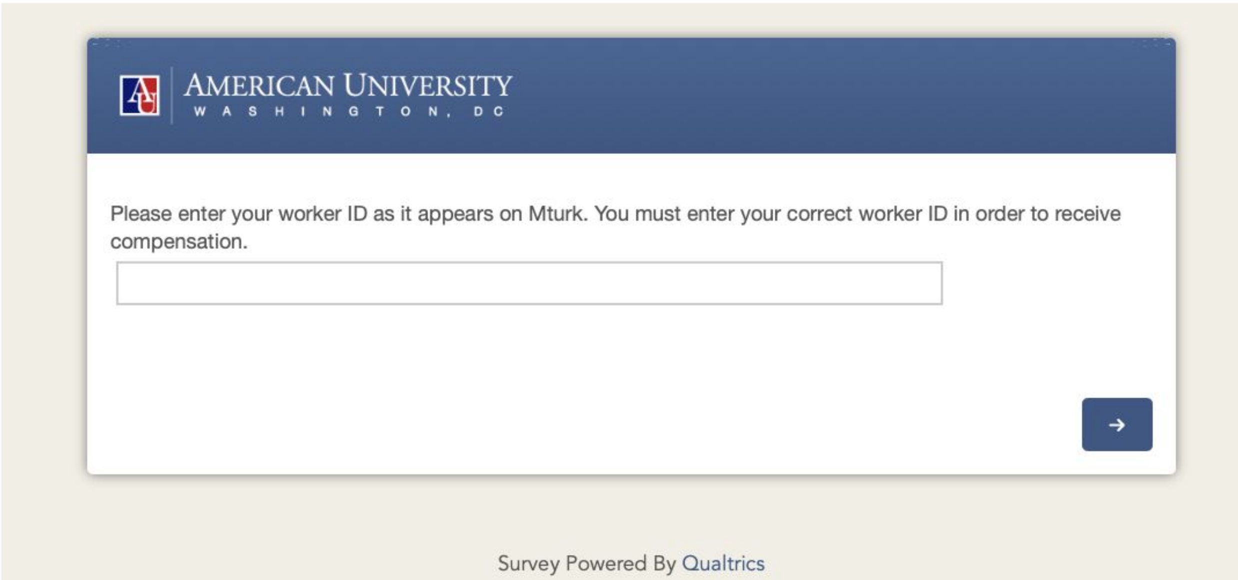

AMERICAN UNIVERSITY
WASHINGTON, DC

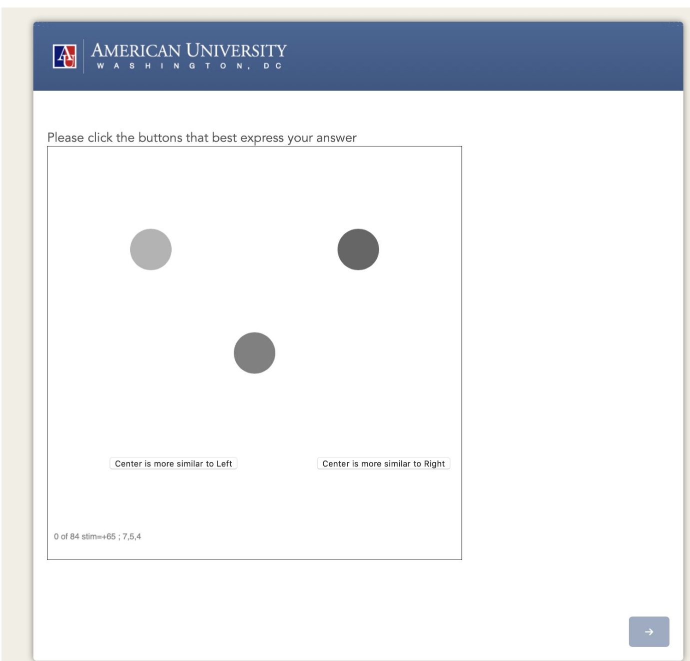
Do you wear glasses or contacts?

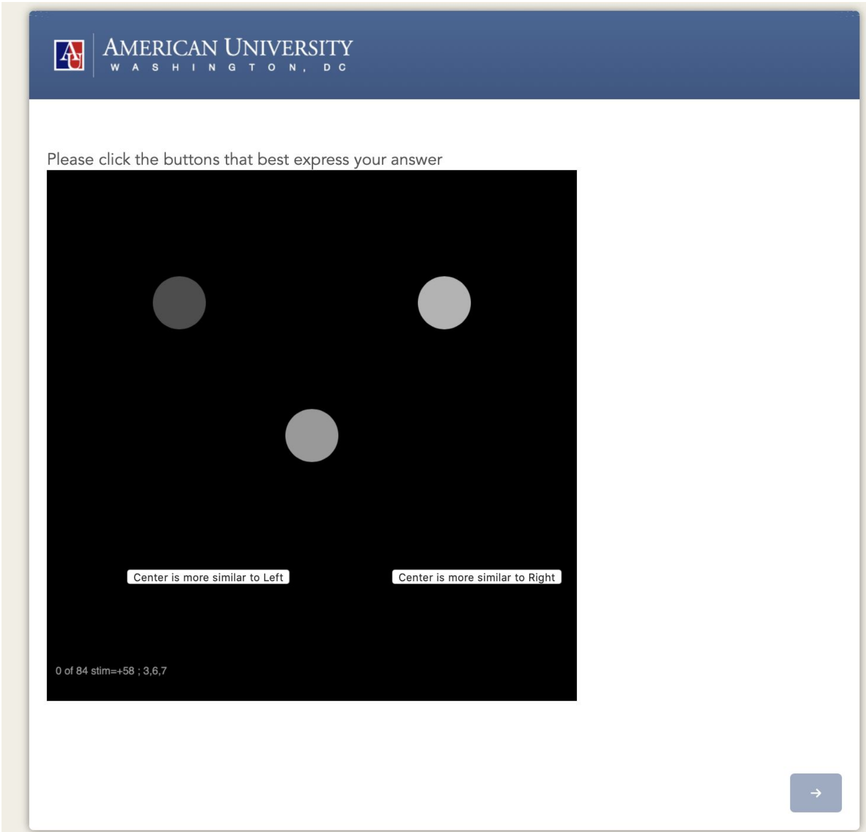
- Yes
- No

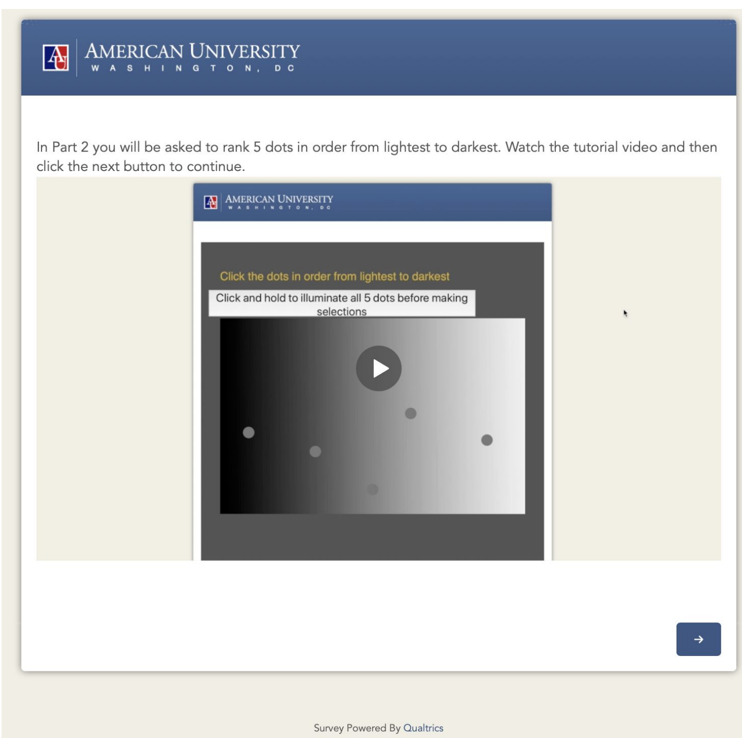
→

Survey Powered By Qualtrics

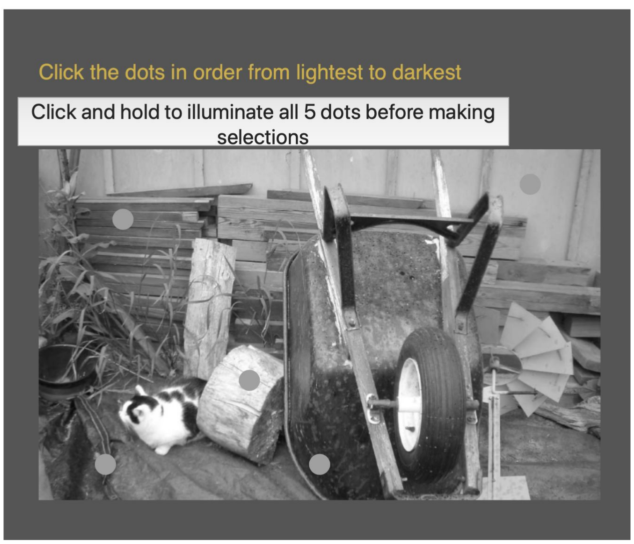

AMERICAN UNIVERSITY
WASHINGTON, DC
Please enter your worker ID as it appears on Mturk. You must enter your correct worker ID in order to receive compensation.
Survey Powered By Qualtrics

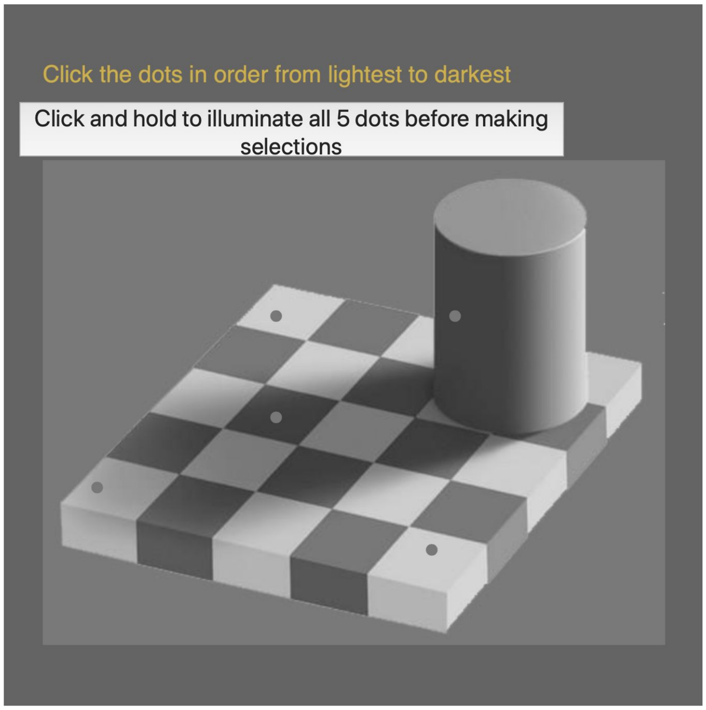

AMERICAN UNIVERSITY
WASHINGTON, DC
Please click the buttons that best express your answer
Center is more similar to Left
Center is more similar to Right
0 of 84 stim=+65 ; 7,5,4


AMERICAN UNIVERSITY
WASHINGTON, DC
Please click the buttons that best express your answer
Center is more similar to Left
Center is more similar to Right
0 of 84 stim=+58 ; 3,6,7

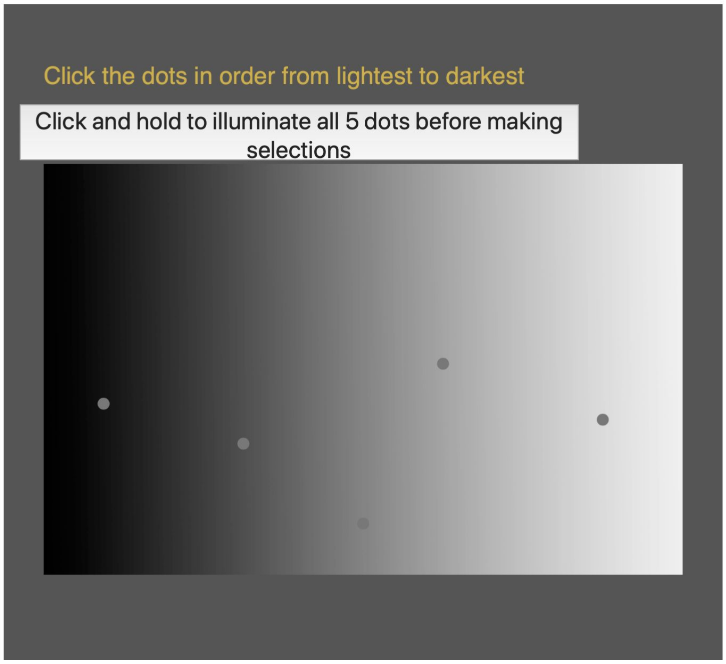

AMERICAN UNIVERSITY
WASHINGTON, DC
In Part 2 you will be asked to rank 5 dots in order from lightest to darkest. Watch the tutorial video and then click the next button to continue.
AMERICAN UNIVERSITY
Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections
Survey Powered By Qualtrics

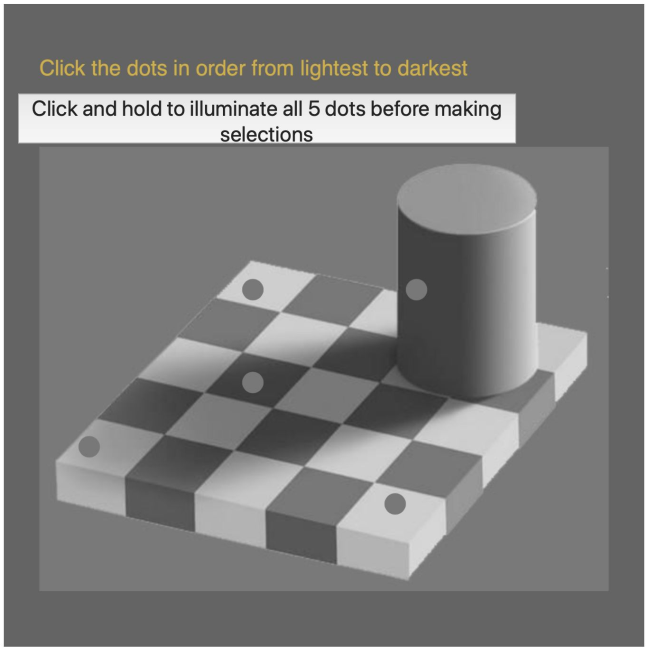

Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections

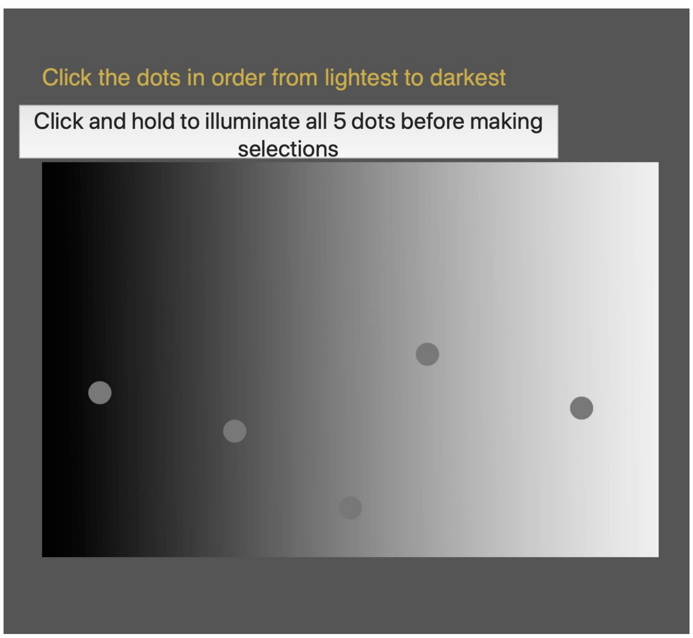

Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections

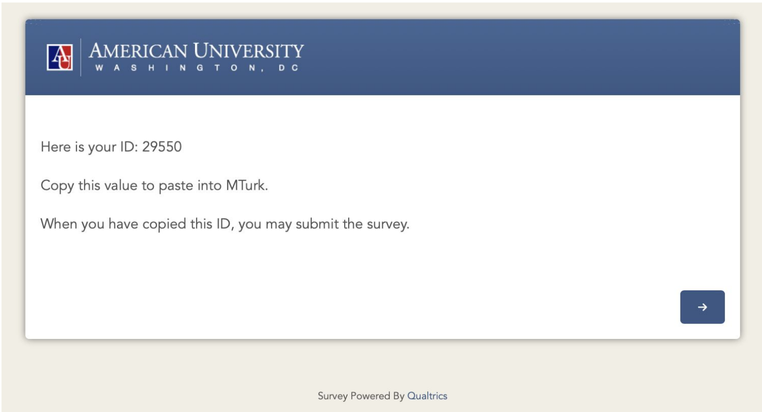

Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections


Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections


Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections


Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections

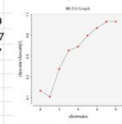
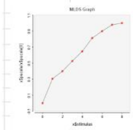
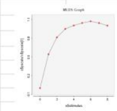
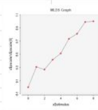
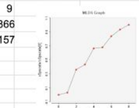
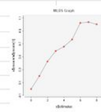
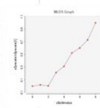
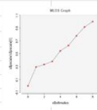
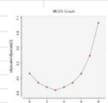
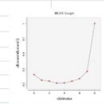

Click the dots in order from lightest to darkest
Click and hold to illuminate all 5 dots before making selections


AMERICAN UNIVERSITY
WASHINGTON, DC
Here is your ID: 29550
Copy this value to paste into MTurk.
When you have copied this ID, you may submit the survey.
Survey Powered By Qualtrics

9.16

fx Random ID:

	A	B	C	D	E	F	G	H	I	J
1	**Random ID:**	81728								
2		1	2	3	4	5	6	7	8	9
3	**brightness:**	0	0.272938818§	-0.990242014	-1.835020309	-2.006180137	-2.506753857	-2.855334489	-3.143854909	-3.150705557
4	**brightness-2**	0	-1.377333217	-1.801530953	-2.376798619	-2.922304048	-3.670954036	-4.060702904	-4.419357833	-4.51569197
9	**Random ID:**	75284								
10		1	2	3	4	5	6	7	8	9
11	**brightness:**	0	293.087265	439.5761821	512.7792417	541.965898	563.8876609	578.4515981	563.4629449	540.6757386
12	**brightness-2**	0	-1.03071901	-0.900970458	-1.398713936	-1.72030368	-2.460912949	-2.71929457	-3.319544296	-3.353341109
17	**Random ID:**	71583								
18		1	2	3	4	5	6	7	8	9
19	**brightness:**	0	-0.130456459	-1.526098213	-1.837043257	-2.814200228	-2.877950606	-3.548624705	-3.956363057	-4.245578866
20	**brightness-2**	0	-0.738383370	-1.566968401	-2.160642281	-2.406013953	-2.813368757	-3.753253829	-3.802891939	-3.673323157
25	**Random ID:**	20118								
26		1	2	3	4	5	6	7	8	9
27	**brightness:**	0	-0.057844952	-0.012737001	-0.60931034	-0.892037395	-1.494976977	-1.715623223	-2.080793255	-2.851748238
28	**brightness-2**	0	-1.23314509	-1.398022799	-1.596475937	-2.282504985	-2.634891387	-3.268043146	-3.843066898	-4.197022937
33	**Random ID:**	55669								
34		1	2	3	4	5	6	7	8	9
35	**brightness:**	0	45.64036569	68.40607424	83.44990616	68.62581108	46.29408128	1.547530456	-88.03005846	-252.1061439
36	**brightness-2**	0	1.274933052	1.476489114	1.920862481	1.887845875	1.501305888	0.921263788§	-0.725375651	-11.6646866

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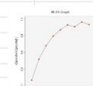
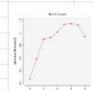
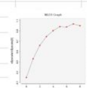
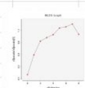
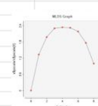
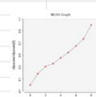
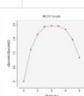
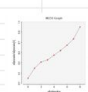
fx vis probs

	A	B	C	D	E	F	G	H	I	J
1	**vis probs**									
2	**Average**									
3		1	2	3	4	5	6	7	8	9
4	**brightness:**	0	-7.84956	-12.934	-16.5186	-18.8713	-20.711	-20.0359	-21.8049	-20.8331
5	**brightness-2**	0	-3.23813	-6.39658	-6.63392	-7.55816	-8.78589	-8.90591	-8.683	-6.78986
10	**Average without outliers**									
11		1	2	3	4	5	6	7	8	9
12	**brightness:**	0	-7.67753	-13.1814	-16.821	-19.2429	-20.9048	-20.7697	-22.0056	-21.2583
13	**brightness-2**	0	-4.06042	-6.88031	-7.61293	-8.22225	-9.58483	-9.83573	-10.405	-8.27962
25	no vis probs									
26	**Average**									
27		1	2	3	4	5	6	7	8	9
28	**brightness:**	0	339.68	504.445	587.2352	596.9506	592.7573	557.8656	449.7791	254.9608
29	**brightness-2**	0	-9.182255331	-14.9112	-17.2262	-21.8083	-26.1416	-31.2951	-36.9531	-48.1027
34	**Average without outliers**									
35		1	2	3	4	5	6	7	8	9
36	**brightness:**	0	339.3634	503.9442	586.4161	596.4108	592.1603	557.1145	448.5092	254.354
37	**brightness-2**	0	-9.450866815	-15.3258	-17.3146	-21.8416	-26.2305	-31.2317	-37.2269	-48.5742

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1			5,4,3,2,1 =	perfect score	all except gradiants			VIS PROBLEMS				NORMAL				
2			5,3,4,2,1 =	perfect score	just for gradiants (grad-data-1 and grad-data-2)			**Question**	**Average r2**		**Question**	**Average r2**				
3								Kings	0.32		Kings	0.38				
4								Wheel	0.10		Wheel	0.38				
5								Grad	0.35		Grad	0.64				
6								Checker	0.17		Checker	0.40				
7								Checker 2	0.17		Checker 2	0.43				
8								Wheel 2	0.37		Wheel 2	0.44				
9								Kings 2	0.11		Kings 2	0.41				
10								Grad 2	0.72		Grad 2	0.68				
11			VIS PROGLEMS					**Average**	**0.29**		**Average**	**0.47**				
12																
13	Correct Score		Correct values	Observer value	#NAME?	Wheel data			Wheel data			Wheel data			Wheel data	
14	5	2.5	5	3		5	3		5	2		5	2		5	2
15	3	3.666666667	4	1		4	5		4	5		4	5		4	4
16	4	1.166666667	3	2		3	1		3	1		3	1		3	1
17	2	4	2	5		2	2		2	3		2	4		2	5
18	1	3.5	1	4		1	4		1	4		1	3		1	3
19		0.4407756813	R2 value	0.36			0.01			0.04			0.01			0.09
20			AVERAGE:	0.10												
21																
22			Wheel data 2			Wheel data 2			Wheel data 2			Wheel data 2			Wheel data 2	
23	5	2.333333333	5	1		5	2		5	2		5	4		5	3
24	3	4	4	3		4	4		4	5		4	5		4	2
25	4	2.333333333	3	2		3	3		3	4		3	3		3	1
26	2	3.666666667	2	4		2	5		2	3		2	1		2	5
27	1	2.666666667	1	5		1	1		1	1		1	2		1	4
28		0.1636363636		0.81			0.01			0.16			0.64			0.25
29			AVERAGE:	0.37												
30																
31			Kings data			Kings data			Kings data			Kings data			Kings data	
32	5	1.166666667	5	2		5	1		5	1		5	1		5	1
33	3	3.333333333	4	3		4	5		4	3		4	3		4	2
34	4	4	3	1		3	4		3	5		3	4		3	5
35	2	2.666666667	2	4		2	2		2	2		2	2		2	4
36	1	3.833333333	1	5		1	3		1	4		1	5		1	3
37		0.3031578947		0.49			0.01			0.25			0.49			0.36
38			AVERAGE:	0.32												
39																
40			Kings data 2			Kings data 2			Kings data 2			Kings data 2			Kings data 2	
41	5	1	5	1		5	1		5	1		5	1		5	1
42	3	3.666666667	4	2		4	3		4	4		4	4		4	4

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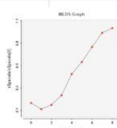
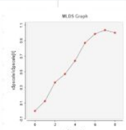
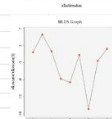
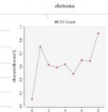
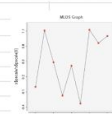
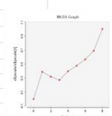
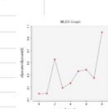
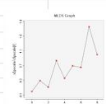
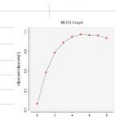
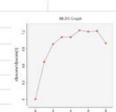
Random ID:

	A	B	C	D	E	F	G	H	I	J	P
1	**Random ID:**	69117									**Impairment types**
2		1	2	3	4	5	6	7	8	9	
3	**brightness:**	0	0.436985647	0.1403064031	-0.540527309	-2.051571778	-2.908327973	-3.967578701	-4.978843699	-5.311222861	color blind
4	**brightness-2:**	0	-0.421721887	-1.220970379	-1.58275906	-2.145815359	-2.914150667	-3.300338089	-3.466453122	-3.351639339	
9	**Random ID:**	26229									
10		1	2	3	4	5	6	7	8	9	photophobia
11	**brightness:**	0	-0.173137219	-0.009155844	0.2593424668	0.2934839834	0.0256829758	0.5545430857	0.0835405560	-0.033385076	
12	**brightness-2:**	0	0.6066665631	0.3966646272	0.3664741325	0.4030882296	0.290630618	0.4517272441	0.439236672	0.7584196495	
17	**Random ID:**	65481									
18		1	2	3	4	5	6	7	8	9	
19	**brightness:**	0	0.3155777426	0.1373519516	-0.048982905	0.118364407	-0.093302432	0.3196968398	0.245119388	0.2847924017	traumatic brain injury
20	**brightness-2:**	0	0.2635942624	0.2165932568	0.1839827499	0.2685434065	0.322238449	0.3837870499	0.4666053826	0.6777416379	
25	**Random ID:**	76659									
26		1	2	3	4	5	6	7	8	9	
27	**brightness:**	0	0.0011071419	0.2565104213	0.0430100895	0.0780986482	0.1681411634	0.1792731288	0.1171693389	0.4585694021	photophobia
28	**brightness-2:**	0	0.2156187815	0.0870623950	0.6125338949	0.2609957326	0.5083087253	0.4780977185	1.282806244	0.7313470569	
33	**Random ID:**	32103									
34		1	2	3	4	5	6	7	8	9	photophobia
35	**brightness:**	0	-8.288627012	-13.47736859	-16.15300605	-17.65498528	-18.3260466	-18.13258807	-18.02033677	-17.30119649	
36	**brightness-2:**	0	-4.007408553	-5.918949317	-6.667810164	-6.655999021	-7.39141154	-7.258985159	-7.324117699	-5.996378605	

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