# Implementing Double Flash Illusion (DFI) for Online Data Collection

*Ruchira Sakalle*

Master of Science

School of Informatics

University of Edinburgh

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# Abstract

Our senses play a pivotal role in shaping our understanding of the environment, creating a compelling field for investigation. Every day, we are immersed in a sea of multisensory information, yet the intricacies of how these experiences converge remain elusive. Notably, there are scenarios where visual cues enhance our auditory perception. On the flip side, our senses can sometimes deceive us, as demonstrated by the double flash illusion. This illusion not only serves as a touchstone for exploring multisensory coordination but also offers insights into the brain's approach to determining causality from sensory data. Such insights become particularly significant when studying groups with distinct sensory integration behaviors. Acknowledging the importance of comprehensive data in this area, our study presents an online instrument, tailored for The University of Edinburgh, to examine the Double Flash Illusion. Our primary goal is to create a dynamic tool for data gathering, paving the way for subsequent studies, particularly in comparing multisensory coordination and causal deductions in individuals with Autism Spectrum Disorder to those in the general population.

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# Chapter 1

# Introduction

Our perception of the environment and events around us is a fascinating aspect of our existence. Each day, our senses are exposed to countless stimuli, from the things we see to the sounds we hear and the textures we feel. Yet the intricate mechanics of how we process and integrate these multisensory experiences remain a mystery. It's an established observation that our senses can often complement and enhance each other. A renowned illustration of this phenomenon is the 'cocktail party effect' as highlighted by Zion-Golumbic (2013) [11]. Imagine being at a bustling cocktail party, where amidst the cacophony, you're trying to focus on a conversation with a friend. The auditory environment might be overwhelming, but by observing the lip movement : the visual cue, comprehension becomes clearer. Here, the visual sense augments the auditory experience, showcasing the marvel of multisensory integration. This process, where our brain synergizes data from varied sensory channels like sight, sound, and touch, empowers us to construct a comprehensive and coherent interpretation of our surroundings. Such integration not only refines our perception but also optimizes our response speed and bolsters our learning capabilities. However, the relationship between our senses isn't always straightforward. At times, the input from one sense can distort or create illusions in another. A pivotal study by Shams et al. (2000)[26] sheds light on this. In their experiment, participants were exposed to a consistent white disk flashing on a black background, offset from their direct line of sight. Each flash was followed 50 milliseconds later by another, and they were accompanied by beeps spaced 57 milliseconds apart. Despite the controlled visual stimuli, participants often reported seeing multiple flashes when just one flash was paired with several beeps. This illusion not only challenges the dominance of visual perception in multisensory experiences but also prompts us to question: 1) Does a sensory input always amplify another? and 2)

Does visual perception overwhelmingly overshadow other senses?

The perception of double flash illusion is often used to test multisensory integration. But the illusion is also used to investigate causal inference processes as it demonstrates how our brain infers the cause of sensory events. When the brain receives information from multiple sensory modalities (in this case, auditory and visual), it attempts to make sense of this information by determining whether they came from the same source or different sources. In the double flash illusion, the brain seems to infer that the two beeps must have been caused by two separate visual events (flashes), leading to the perception of two flashes even when only one occurred.

This illusion serves as a tool to explore how the brain integrates information from different sensory modalities and makes inferences about the external world based on this information. Understanding these processes can provide insights into how the brain makes decisions about causality in more complex real-world scenarios.

Such findings carry profound implications, especially when considering populations like those diagnosed with Autism Spectrum Disorder (ASD), where the nuances of multisensory integration come under scrutiny and recent studies have suggested that individuals with ASD may have impaired causal inference abilities (Noel, Shivkumar, et al. 2022) [21]

In this study, I delve deeply into the Double Flash Illusion (DFI) and its variations. My primary objective is to amass a robust dataset to validate this intriguing sensory phenomenon, comparing fresh insights with established findings. Additionally, I aim to develop an exhaustive framework tailored for future research, especially to assess individuals with ASD and contrast their sensory perceptions with neurotypical counterparts.

The following document outlines the journey of transitioning the DFI experiment to an online platform, the meticulous testing of the tool, the methodologies for data collection, and our consequential discoveries. Chapter 2 lays the groundwork for our study. Chapter 3 details the methods and techniques employed, Chapter 4 delves into data and its subsequent analysis, and Chapter 5 unravels the results derived from this analysis.

# Chapter 2

# Background

In this section, I will discuss the previous work that motivated this project and JsPsych framework used, a tool to design behavioural experiments and host it online and statistical tools we will use to interpret the participant responses and understand it better.

## 2.1 Challenging Visual Supremacy

Historically, vision has been considered the most prevalent sensory modality, as evidenced in numerous studies[23] [6] [22]. Even research exploring the interplay between vision and other senses often underscored this visual supremacy [9]. However, Shams et al.'s groundbreaking research challenged this established belief [26]. Their study revealed that an auditory cue could dramatically alter visual perception. Specifically, when participants were presented with a single flash paired with two quick auditory beeps, they frequently perceived two visual flashes. Interestingly, the opposite scenario, where two flashes were paired with a singular beep, resulted in the perception of just one flash. This pivotal discovery reshaped our understanding of the dominance of vision in multisensory experiences.

In the paper *What you see is what you hear*[26] participants were presented with a white disk flashing on a black screen, positioned slightly away from their direct gaze. Simultaneously, they heard a series of beeps with a brief 57-millisecond gap between them. During the experiment, they were tasked with counting the number of times the disk flashed in each session. To ensure a comprehensive assessment, the experiment was designed with varied rounds, mixing up the combinations of flashes and beeps multiple times. (Figure 1)

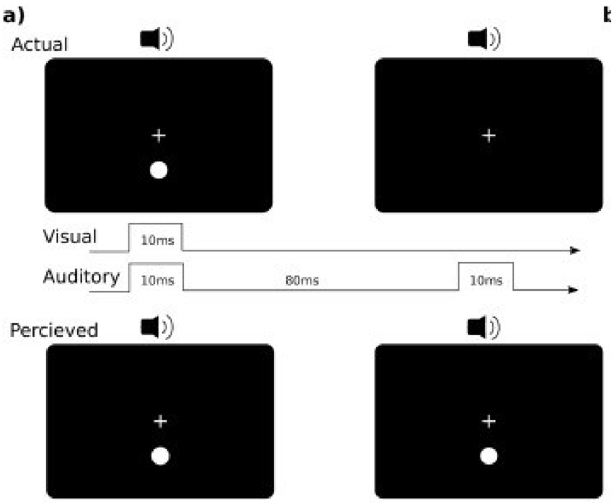



Figure 2.1: Inspired from Shams et al., 2000

So far we have only discussed the fission illusion where a single flash is accompanied by multiple beeps, there is another variant of the same known as fusion illusion where multiple flashes occur with single beep it often leads to the perception of single flash. [1][33][27][34]. But it still remains uncertain whether the underlying mechanism for fission and fusion illusion are the same. [18]. In McGovern et al., 2014 they investigated age-related differences in multisensory integration using the "sound-induced flash illusion" (alternate generic name for Double Flash Illusion when there are multiple beeps or flashes). They found that distinct patterns emerged when examining the two illusion variants. Older individuals were more prone to the fission illusion under extended stimulus onset asynchronies ( refers to the temporal difference or interval between the onset or start of two stimuli) than their younger counterparts. Yet, both age groups showed similar responses to the fusion illusion. The study suggests that while these illusions seem related, they are governed by separate neural pathways.

It is important to note that DFI is also used to understand causal inference processes. Causal inference and DFI are related in a way that explains the brains ability to infer from various sensory input, thereby resulting in perception of two flashes. The underlying principle is that the brain integrates sensory information in a way that it deems most probable based on prior experiences and the current context. In the case of the double flash illusion, the brain infers that two auditory beeps likely have two corresponding visual events, even if only one is actually presented. In the work, Shams et al., 2005 [27], they discussed that double flash illusion can be understood using optimal percept, which is based on bayesian causal inference, they made use of the ideal observer model.

This model was also used in future research. [15].

Another variant of DFI that has been tested is by alternating the temporal window, i.e changing the inter stimuli interval between both the auditory cues (beeps). It was observed [26] that the illusion appears to diminish when the interstimuli interval between both the beep sounds exceeds the 70 ms mark. Yet, the illusion persisted if the beep and flash were roughly within a 100-millisecond interval of one another, aligning with the known integration period of multisensory neurons in the brain [19] [32]

## 2.2 Double Flash Illusion and Autism Spectrum Disorder

Double flash illusion is often considered to be an indicator of intact multisensory integration, but such a statement can not be made until the phenomenon is tested amongst diverse clinical subgroups like Autism Spectrum Disorders, schizophrenia,synaesthesia, fall prone adults. (discussed in the review *What you see is what you hear: Twenty years of research using the Sound-Induced Flash Illusion* [12]). In this work we will be primarily focusing on studies comparing the results of people with Autism Spectrum Disorder and typically developing individuals. As we wish to implement this framework in future in ASD research.

There has been an extended research in the testing people with ASD with Double Flash illusion. Some of those suggested that people with ASD are less susceptible to the illusion as compared to neurotypicals. [28] [13]. But some research has also shown that there is no significant difference between ASD and typically developing. [28]

Research revealed that individuals with Autism Spectrum Disorders (ASDs) exhibited a heightened susceptibility to the fusion illusion, while their response to the fission illusion deviated from prior observations.This challenges previously established findings. [3] Some studies also reported that individuals with Austism spectrum disorder have larger temporal window [10] and that there is an inverse relationship between size of temporal window and autistic traits [13]. Furthermore, when considering causal inference, it has been observed that those diagnosed with Autism Spectrum Disorder display compromised capabilities in drawing causal relationships, as highlighted by Noel et al. (2022).[21] However, it's crucial to note that the sample sizes in these studies were insufficient to derive definitive conclusions regarding the role of the double flash illusion in discerning multisensory integration and causal inference among these subgroups. This underscores the significance of deploying the double flash illusion in online platforms, which would facilitate the gathering of more comprehensive data.

Such an approach is pivotal for a deeper comprehension of the neural underpinnings of this illusion.

## 2.3 JsPsych Framework

In the course of this research, I utilized the JsPsych Framework as the foundation for designing the experiment. This library, rooted in JavaScript, is specifically tailored for the development and online deployment of behavioral experiments. Notably, JsPsych comes equipped with specialized plugins, facilitating the collection of responses through various mediums such as keyboards and buttons, enhancing the flexibility and efficiency of the experimental process.

### 2.3.1 Advantages of JsPsych

The flexible JavaScript library jsPsych is skilled at handling a variety of experimental designs, from straightforward tasks to complex ones. Its modular plugin-based structure, which enables easy modification and a variable combination of trial types, is one of its distinguishing advantages. It effectively gathers data after an experiment into a JSON format, facilitating the storage and conversion procedure. Despite the inherent limitations of web browsers, jsPsych enhances the accuracy of stimulus display and response collection. Its connectivity with a range of platforms, including computers and mobiles, increases its reach to a larger audience. Additionally, the open-source nature of the framework fosters community improvements and gives researchers the freedom to modify and improve it.

### 2.3.2 Applications of the framework

jsPsych has been employed in a wide range of research, from cognitive and perceptual experiments to clinical assessments and surveys. Given the increasing interest in online data collection, platforms like Mechanical Turk or Prolific often see jsPsych-based experiments.

### 2.3.3 Limitations

Although jsPsych is a potent tool for online experimentation, it's important to be aware that web-based studies may encounter difficulties, including erratic internet speeds, varying screen sizes and resolutions, or background computer processes that may interfere with the timing and presentation of stimuli. Apart from generic limitations, another difficulty was faced as there are no plugins to simultaneously display the disk and play the sound. To overcome this limitation, another unofficial JsPsych Plugin

### 2.3.4 Overcoming the limitations

The JsPsych-psychophysics plugin offers a dynamic platform for precise control over stimulus presentation. It gives detailed management of stimulus onset asynchronies (SOAs) within a test, supporting the simultaneous display of multiple stimuli. This tool simplifies the task of showing various visual components, such as text, pictures, and shapes, at specific places and durations, measured in milliseconds or frames. While its timing precision is slightly reduced, it can also shift stimuli and play audio files. By leveraging the requestAnimationFrame function, it aligns visual signals with display refresh rates, enhancing SOA precision, as highlighted by Kuroki in 2020 [16].

# Chapter 3

# Experimental Design

Drawing from Chapter 2, specifically Section 2.1, the experiment is structured into three distinct segments: Double Flash Illusion Fission, Double Flash Illusion Fusion, and Double Flash Illusion with a variable temporal window. I will delve into the intricate specifics of the experiment, shedding light on the rationale and inspiration that underpin each segment

## 3.1 Technicalities Involved

The black colour flash/disk is presented on a grey background is preceded by a cross fixation point, both located at the centre of the screen. The disk subtends 2 degree of the visual angle [26]. The size of the disk is variable in pixels based on the participant distance which is calculated using a virtual chinrest plugin[17] available in the JsPsych toolkit. The beep sound was produced using the audacity software [30]. Each beep was 3500 hz [28]. The loudness of the beep sound (measured in decibles) could not be controlled in the experimental setting, although participants were asked to use the headphone and keep the volume at the maximum which was tolerable by them. To control for the screen brightness, participants were advised to keep the brightness of their system to the fullest and not to take the experiment in daylight, which could affect the screen luminosity.

## 3.2 Distance From Screen

To make the experimental framework more robust, participant distance from the screen is calculated using virtual chinrest plugin [17]. This is important to make sure that

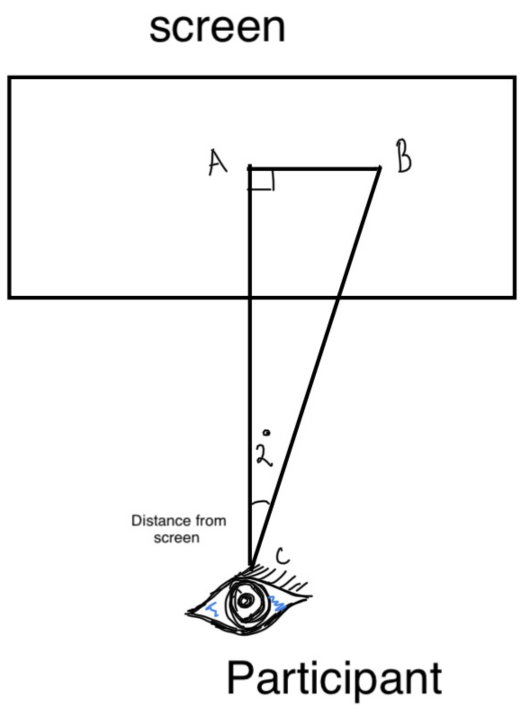



Figure 3.1: Calculating dynamic radii (AB) using tan of 2 degree, tan (2) = opposite side (AB) / adjacent (AC). Participant distance from screen is available (AC), multiplying it by tan of 2 degree gives us the dynamic radii

the disk is subtended at 2 degree of visual angle. This plugin gives the distance of the participant from the screen, this distance helps us determine the dynamic radii of the disk using trigonometric identity of tangent of 2.

The participants viewing distance is calculated using two tasks:

- Card Task: Here esearchers instruct participants to position a credit card or a similarly sized card onto the screen, then modify a slider until the card's displayed image aligns in size with the actual card. This allows the research team to determine the display's logical pixel density (LPD) in pixels per inch, facilitating distance estimations as illustrated in Fig. 3.2.

- Blind Spot task: Participants receive instructions to focus on a stationary black square with their right eye covered. As a red dot moves continuously from the right side to the left, participants must hit the spacebar upon noticing the red dot's disappearance. The research team subsequently computes the distance spanning the center of the black square to the red dot's center at the moment it vanishes from vision.

Before diving into the primary segment of the experiment, participants were prompted to undertake a preliminary trial to familiarize themselves with the experimental procedures.

## 3.3 Double Flash Illusion Fission

Four unique test conditions were presented: a singular flash with one beep (1F1B), a single flash with two beeps (1F2B), a flash without a beep (1F0B), and a scenario with no flash but one beep (0F1B). Notably, the 1F2B setup is the one that induces the illusion, while the rest act as benchmark controls. Specifically, the 1F0B and 0F1B setups were designed to ensure participants' continuous focus and engagement, cementing their importance as true control conditions.

The visual disks were programmed to flash for 30 ms, a change from previous research durations. This shift was necessitated by issues encountered with the JsPsych psychophysics plugin. Specifically, when the flash was set for durations of either 17 ms or 10 ms alongside a 10 ms beep, the illusion failed to manifest. The beep's duration, however, remained consistent at 10 ms. The creators of the jsPsych psychophysics mention this limitations of the plugin in their paper. As a trial commenced, a central cross appeared on the screen. After a 100 ms delay, the disk and beep were presented. In the 1F2B setup, an additional beep followed 80 ms later [12]. For the 0F1B and 1F0B setups, both the beep and flash were initiated 100 ms post the display of the cross, enduring for 10 ms and 30 ms, respectively.

Participants were instructed to use the keys 0, 1, or 2 to indicate their perception. Each test scenario was presented in a randomized sequence, ten times each. Subsequent to each trial, a query assessed participants' confidence in their response, offering five graded options from "Not at all confident" to "Completely Confident". Responses were recorded via keys 1 through 5, correlating to their confidence levels.

## 3.4 Double Flash Illusion Fusion

In the fusion scenario, only three tests were conducted: 1 flash with 2 beeps (1F2B), 2 flashes with 1 beep (2F1B), and 2 flashes with 2 beeps (2B). This setup included two illusion-inducing conditions (1F2B and 2F1B) and one control (2F2B). The 1F2B setup remains consistent with the details provided in Section 3.3. For the 2F1B scenario, two disks are shown for a duration of 20 ms, with a 50 ms interval between them, accompanied by a 20 ms beep. These adjustments were introduced to effectively induce the illusion, since the parameters outlined in the prior study [3] weren't successful in producing the desired illusionary effect. Tweaking the established methodology also offers insights into the implications of modifying the temporal window.

Since this block only had three conditions each condition was repeated 14 times randomly followed by the confidence question as discussed in section 3.3. The idea is to have 40-50 trials in each block followed by confidence question so that it is not overwhelming for the participants.

## 3.5 Double Flash Illusion with Variable Temporal Window

In this segment of the experiment, the characteristics of both the beep and disk duration are consistent with those detailed in Section 3.3, with the exception of the initiation timing of the secondary beep. While the commencement of the first beep and the disk coincide, the subsequent beep is introduced at various intervals: 25 ms, 50 ms, 80 ms, 100 ms, 150 ms, 200 ms, and 300 ms. These intervals were based on previous work [10]. The purpose of this specific block is to investigate the maximum interstimulus interval that can be tolerated before the illusion ceases to manifest effectively. For each specific interval, the condition was showcased seven times, arranged in a randomized sequence. After each presentation, participants were prompted with a query to gauge their confidence in their perceived experience.

## 3.6 Experiment Break

Following each experimental segment, participants were presented with their average response duration, serving as an incentive for heightened alertness. To enhance the experiment's structure, a minimum of a 1-minute pause was allotted after each trial. Participants had the flexibility to either proceed with the experiment after this 1-minute interval or wait until they felt at ease. This approach was adopted to ensure participants weren't inundated by the continuous beeps and flashes. For their convenience, a 1-minute countdown timer was displayed on the screen, allowing participants to monitor the break duration.

## 3.7 Feedback

Upon concluding all three sections of the experiment, participants were prompted to provide feedback. The intent behind posing these questions was to gauge the participants' satisfaction and understanding of the experiment. The questions included:

- Was the experiment easy to understand?
- What changes could we make to the experiment to make it easier for you?
- How did you like the interface? Any suggestions to improve it ?
- Did you feel that the sound alter the perception of flashes ?

# Chapter 4

# Implementation and Data Collection

In this chapter we will discuss how the experiment was implemented online and how the data was collected. The primary focus will be on the tools and technologies used for the implementation, steps for hosting the experiment online and how the data was collected.

## 4.1 Creation of the interface

To create the interface JsPsych framework was used [8]. In jsPsych, plugins determine the types of trials or events in an experiment. While some plugins handle basic tasks like showing instructions or playing sounds, others cater to specific stimuli or tasks, such as the implicit association test. Designing an experiment with jsPsych means identifying the right plugins for desired tasks.

These plugins offer a framework for specific trials but come with ample customization options. For example, the audio-keyboard-response plugin lets you play an audio and collect a keyboard reaction. Users can define the image, allowed key presses, display duration, response time, and more. Despite numerous parameters, often only the main stimulus, like the audio, needs specification. Each plugin is accompanied by its own guide detailing its functions, available settings, and collected data.

In this work we make use of the following JsPysch official plugins.

- Instructions: Helps in showing the instructions before starting the main experimental block. This plugin was used to brief participants about the experiment i.e what keys need to be pressed. Multiple pages can be added within the instruction trial.

- HTML Keyboard Response: This plugin is used to display text as stimulus and record response from keyboard. This was used between experimental block to display the average response time and then to proceed participants can press the space bar. This is also used to collect the participant confidence score of each trial.

- HTML Button Response: This is used to display text as stimulus and provide a button on the screen which can be clicked to proceed. This was used after each experimental block to show the timer for the next experimental block.

- Survey: This plugin is used to display various type of survey like questions like drop-down, likert, multi-choice, multi-select, text etc. In this work text attribute was used to collect the feedback from participants on successful completion of all experimental blocks.

- Fullscreen : The fullscreen plugin facilitates transitioning the experiment into or out of fullscreen mode. Due to security constraints in all browsers, initiating fullscreen mode must be prompted by a user's action. Therefore, this plugin prompts users to click a button to access fullscreen. However, leaving fullscreen mode can be executed without any user intervention.

- Virtual Chin rest [17]: The plugin was employed to determine the distance between the participant and the screen, subsequently adjusting the disk radius accordingly. This feature was crucial in emulating the controlled environment of a lab experiment in an online setting. In lab experiments, participants' distance from the screen is easily managed, but this becomes a challenge online. By incorporating this tool, researchers can account for and adjust based on the variable distance of online participants, ensuring more accurate and comprehensive analysis.

Another essential addition to the experiments was the JsPsych psychophysics [16]plugin. Unlike the standard plugins that come bundled with the main JsPsych package, this particular plugin isn't automatically included. To leverage its functionalities, one must download it separately and then embed it into the experimental script.

One standout feature of the JsPsych psychophysics plugin is its capacity to present multiple stimuli synchronously within one trial. In the context of the described experiment, this allowed for the simultaneous presentation of a disk and the emission of a beep sound. This combined visual and auditory stimulus delivery is pivotal in many psychological studies, particularly when exploring the interplay between various sensory perceptions.

### 4.1.1 Stacking the trials

In the JsPsych framework, the timeline variable stands out as an essential element. It serves as a repository where all the individual trials of the experiment are systematically lined up. The arrangement of these trials is of paramount importance since it dictates the flow and progression of the entire experiment for the participants.

The structure of the experiment in this study is meticulously crafted. It kicks off with the inclusion of the instructions in the timeline, ensuring that participants have a clear understanding of what's expected of them. Once they've been oriented, the virtual chinrest plugin comes into play. This tool is crucial for gauging the distance of the participant from the screen, which in turn informs adjustments to the disk radii, ensuring consistent visuals across varying viewing distances. With these measurements taken, the experiment transitions into a fullscreen mode, immersing participants further.

Subsequently, a test block is launched. This segment acts as a dry run, helping participants familiarize themselves with the nuances of the experiment and what they'll encounter. Once they've navigated this introduction, the core phase of the experiment commences. At its conclusion, participants are given a snapshot of their performance metrics, showcasing their average response time. A timer then cues them into the next segment. This pattern, which encompasses the primary experiment block, performance feedback, and intermission timer, is consistently mirrored in the subsequent two blocks.

As the experiment draws to a close, it pivots towards gathering feedback. Participants are encouraged to share their thoughts, experiences, and suggestions. This feedback becomes a treasure trove of information, offering insights that can steer refinements and improvements for the experiment's future renditions.

## 4.2 Participant Information Sheet and Consent Form

According to the guidelines set forth by the School of Informatics' Ethics Committee, it is imperative to provide participants with a comprehensive information sheet and obtain their explicit consent before initiating any experimental activity. To fulfill this ethical requirement, a digital HTML form was meticulously crafted. This form not only detailed all pertinent information regarding the experiment but also served as a platform to garner participant consent.

To record the consent, a checkbox was incorporated into the form, bearing the statement, ”I have read and agree to the terms above.” Participants were mandated to actively acknowledge and accept the provided information by ticking this checkbox. Furthermore, a ”proceed” button was placed below, acting as the gateway to the experiment. Only upon marking their agreement and opting to proceed could participants gain access to the experimental content. This layered approach ensured both adherence to ethical standards and clarity of communication with the participants, making them fully aware of their involvement and rights in the study.

It should also be noted that no personal information is asked from the participants and a unique random number is generated for each participants. The data is anonymised for data protection.

## 4.3 Storing the Participant Data

Up to this point, our focus has primarily been on the user interface, but it’s crucial to recognize that before launching, a robust backend system is indispensable for data storage. Without this backend support, the interface would remain static, and valuable participant responses would vanish without a trace. To address this challenge, we employ Hypertext Preprocessor (PHP). As a server-side scripting language, PHP ensures that any modifications made on the server are instantly mirrored on the user’s end. In the context of this study, rather than opting for a traditional database setup, we’ve chosen a streamlined approach: each participant’s responses are meticulously captured and stored as individual CSV files. This method ensures data integrity while simplifying data retrieval and analysis processes.

## 4.4 Hosting the experiment Online

The experiment is hosted using XAMPP on Google Compute Engine using a virtual machine. We will breifly discuss what is XAMPP and Google compute engine is and how it is used to host the experiment.

### 4.4.1 What is XAMPP?

XAMPP is an open-source web development tool that combines several essential components: Apache (a web server), MariaDB (a database developed from MySQL), PHP (a server-side scripting language), and Perl (a web development programming language). The acronym ”XAMPP” stands for Cross-Platform, Apache, MySQL, PHP, and Perl. This package allows developers to set up a local server environment on their computers, enabling them to test and validate web projects before deploying them to a live server. In essence, XAMPP offers a convenient environment to trial and refine web applications built using technologies like Apache, Perl, PHP, and MariaDB, ensuring they function smoothly before public release.

### 4.4.2 Google Compute Engine

A part of Google Cloud Platform (GCP), Google Compute Engine (GCE) offers users scalable and affordable virtual machines that run within Google's extensive network of data centres. GCE uses Google's powerful infrastructure to provide a consistent experience while being designed for maximum speed. It has outstanding scalability, allowing customers to modify resources in accordance with their requirements. The fact that GCE supports a wide range of operating systems, machine setups, and easily connects with other GCP services like Google Cloud Storage and BigQuery further highlights its excellent adaptability. The pricing structure, which uses a pay-as-you-go method with additional reductions for continuous usage, is also user-friendly.

### 4.4.3 How was it hosted?

When setting up our experiment using XAMPP on Google Cloud's Compute Engine, our first step was to initiate a new Virtual Machine (VM) instance via the Google Cloud Console. After the successful establishment of the VM, we accessed it using the in-built SSH (Secure Socket Shell) feature available on the Google Cloud Console. Alternatively, one could employ an SSH client, making use of the VM's designated external IP (Internet Protocol) address. The subsequent move was to procure the XAMPP installer tailored for Linux, which, once downloaded, was rendered executable to facilitate the installation of XAMPP. With the platform in place, we proceeded to transfer crucial elements for our interface, encompassing a myriad of plugins, HTML files, and designated folders for images and sounds, to the VM's default XAMPP directory, typically found at /opt/lampp/htdocs/. To guarantee our website's external accessibility, we dove back into the Google Cloud Console to tweak the VM's firewall settings, granting passage for traffic via ports 80 (HTTP) and 443 (HTTPS). With every configuration in place and XAMPP fired up, our website was smoothly operational, ready for access through any browser using the VM's external IP.

## 4.5 Data Collection

Before commencing the data collection process, we secured Level 1 ethics approval from the Ethics Committee at the School of Informatics. Our participant pool comprised 16 dedicated Masters students from The University of Edinburgh. To facilitate participation, we disseminated the website link through communication channels like email and WhatsApp. In our outreach, we also provided participants with a comprehensive overview, alerting them about possible technical glitches they might encounter and offering solutions to ensure the uninterrupted flow of the experiment. It's imperative to note that in our commitment to data privacy, all the gathered data has been anonymized and is securely stored on our server.

# Chapter 5

# Understanding the Data

In this chapter, we will discuss some simple data analysis of the data collected. The analysis will be discussed experiment block wise. There are three experimental block as discussed in Chapter 3. This is just to understand simple trends in data using data visualisation.

## 5.1 Experimental Block 1: Fission illusion with controls

In the experimental setup, we tested four distinct conditions:

- A single flash accompanied by one beep (1F1B)
- A single flash followed by two beeps (1F2B)
- A flash in the absence of any beep (1F0B)
- An instance where there was no flash, but one beep was presented (0F1B).

It's crucial to highlight that the 1F2B combination is the primary condition responsible for creating the perceptual illusion. The other scenarios serve as comparative benchmarks to gauge the effect of this illusion.

In the subsequent analysis, we consolidated the data from all participants and determined the percentage of correct responses for each individual. This approach provides a comprehensive view of how participants reacted across different conditions. We have also considered the effect of average response time and participant distance from the screen to understand if it influences the illusion or accuracy of the responses in any way.

### 5.1.1 Percentage of 2 flashes response when there was 1 flash

To determine the percentage of correct responses, we began by analyzing how often participants mistakenly perceived two flashes when, in reality, there was only one. Specifically, we divided the total number of times ”two flashes” were reported by the number of trials under the illusion-inducing condition (1F2B).

Interestingly, some anomalies emerged even in non-illusory conditions. For instance, in situations where there was clearly just one flash paired with a single beep (1F1B), certain participants still reported perceiving two flashes. This indicates that there might be other factors or cognitive biases at play, influencing participants' perceptions even outside the designated illusory scenarios. One explanation would be the lack of attention. A study asserted that without focused attention, features can be incorrectly combined, leading to ”illusory conjunctions.” [31] (Refer to the Figure 5.1) But for some participants the illusion did not work at all. Five out of twenty participants did not get affected by the illusion. When we aggregate the participant response in all the illusory conditions, it is observed that on an average the illusion works 49 per cent of the times and as reported by previous study by Keil et al., 2020 [14] the typical probability of experiencing the illusion in audiovisual scenarios has frequently been noted to be approximately 50 per cent. There is a huge variability in the responses (standard deviation of 42 per cent), high variability in responses has also been reported in previous studies.[7]

### 5.1.2 Relation Between Participant Distance from the Screen and Percentage of Incorrect Response

In the online experimental setup, measuring the distance of the participants from their screens presented challenges. Despite these challenges, our observations revealed a significant positive correlation between the distance a participant was from the screen and the percentage of their incorrect responses. Specifically, for this analysis, we focused solely on the non-illusory condition. Our statistical analysis yielded a Pearson correlation coefficient of 0.68, signifying a notable correlation.

To delve deeper into this phenomenon, we undertook a comprehensive visualization approach. We plotted the distribution of participant distances, measured in millimeters, and also constructed a scatter plot juxtaposing participant distance against the percentage of their incorrect responses. As illustrated in Figure 5.2, the data clearly indicates that the participant situated furthest from the screen recorded the highest percentage of

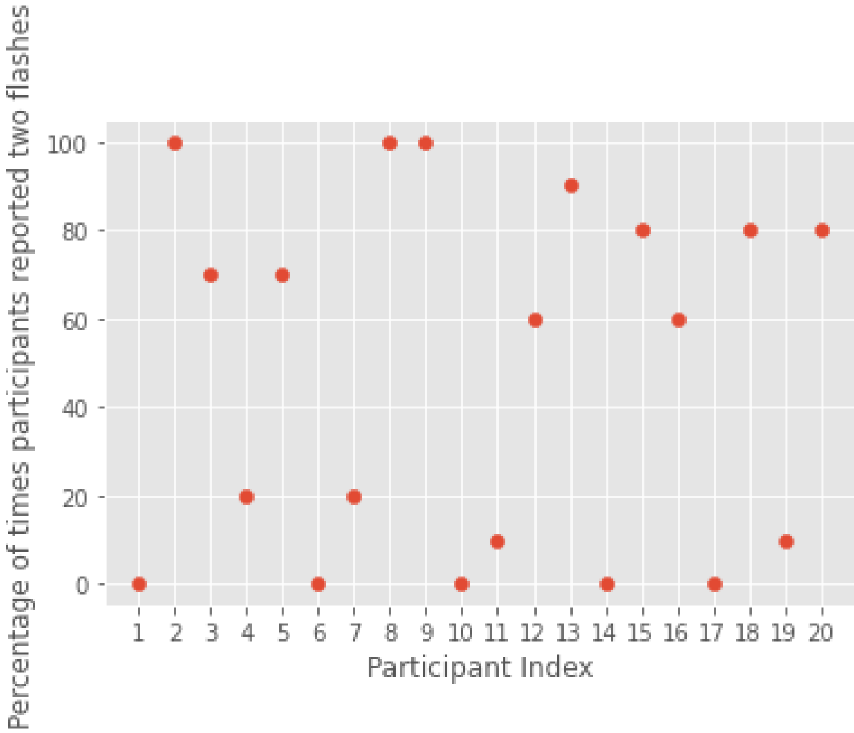



Figure 5.1: Percentage of times participants reported 2 in fission condition

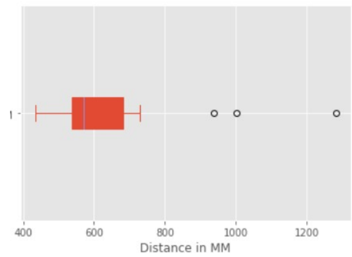
incorrect answers. This observation underscores the importance of controlling for screen distance in such experiments.

A discernible linear trend was evident in the data, which provides a plausible explanation for the elevated correlation coefficient. However, it's crucial to acknowledge that outliers, particularly participants situated exceptionally far from their screens, might have also influenced this high correlation. This suggests that while distance is a significant factor, it's also essential to consider the role of outliers in the overall data interpretation.

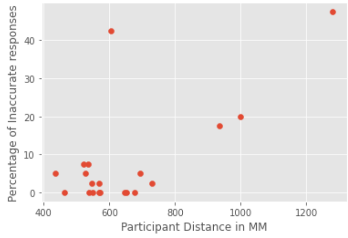
### 5.1.3 Taking Confidence into Account

After each response in our study, we gathered information regarding the confidence levels of participants. To ascertain the average confidence percentage for each participant in every condition, we summed their confidence scores and then divided the total by the maximum possible confidence score—equivalent to the number of entries in that specific condition.

Figure 5.3 visually presents this data, plotting the derived confidence percentages against two metrics: the accuracy of responses and the frequency with which the illusion

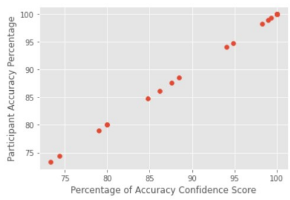



(a) Distribution of Participant Distance

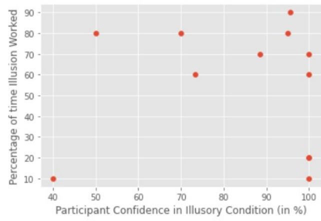



(b) Participant Distance v/s Percentage of Incorrect Response

Figure 5.2: Understanding the variability in participant distance from screen and its relationship with percentage of inaccurate responses



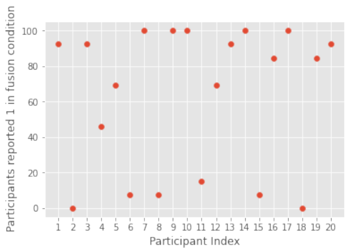

(a) Participant Accuracy v/s Confidence in response




(b) Percentage with which participants were deceived by the fission illusion v/s Confidence in response

Figure 5.3: Comparing the participant performance with the confidence response provided by them

was effective. A clear observation from Figure 5.3a is that participants who answered with greater accuracy also exuded higher confidence in their responses. Conversely, in scenarios where the illusion was successful, a significant majority of participants displayed elevated confidence levels (5.3b). Interestingly, for those participants who were only deceived by the illusion 10 per cent of the time, there was a noticeable dip in confidence. Yet, participants who consistently saw through the illusion and weren't deceived exhibited strong assurance in their responses, as evidenced by their high confidence scores. This suggests that not only accuracy but also the susceptibility to the illusion played a role in the confidence levels displayed by the participants.




(a) Frequency with which participants were deceived by the fusion illusion.


(b) Percentage with which participants were deceived by the fusion illusion. v/s Confidence in response

Figure 5.4

## 5.2 Experimental Block 2: Fusion Illusion

In this designated segment of the study, we examine three distinct conditions: the two-flash-two-beep (2F2B) scenario, the two-flash-one-beep (2F1B) scenario, and the one-flash-two-beep (1F2B) scenario. While we maintain the 2F2B scenario as our benchmark or control, the 2F1B and 1F2B scenarios are treated as the illusory conditions. The inclusion of the 1F2B scenario is particularly strategic; it allows us to juxtapose the outcomes obtained from the two illusory conditions. Our primary objective here is to ascertain the frequency with which participants succumb to the fusion illusion, specifically within the 2F1B scenario. To achieve this, we closely monitor instances where participants mistakenly report witnessing a single flash when, in reality, they were presented with two flashes accompanied by a singular beep. In figure 5.4 a) It can be observed that there is a high variability in participant response. (mean= 63.07, standard deviation = 39.34), but in this case participants seem to be more susceptible to fusion illusion as opposed to fission, which has not been observed in previous studies. [1] This could be due to smaller inter stimuli interval between both flashes as compared to both beeps. In the next experimental block, we see the effect of fission illusion at variable temporal windows.

## 5.3 Experimental Block 3: Variable Temporal Window

In this section, only one condition was presented: a single flash followed by two beeps (1F2B). The first beep coincided with the flash, while the second beep occurred at subsequent intervals of 25, 50, 80, 100, 150, and 300 ms. This design drew inspiration

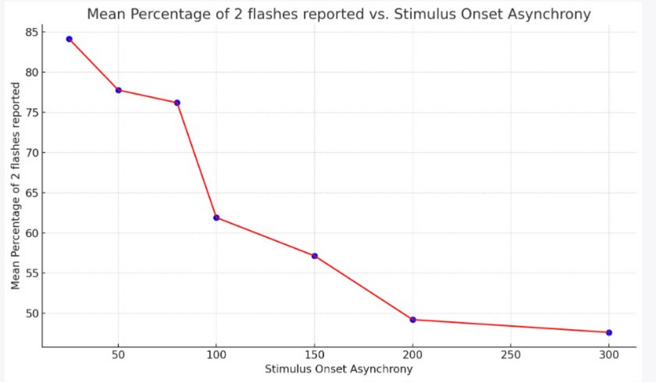



Figure 5.5: Mean Percentage of times participants reported 2 flashes at variable stimulus onset asynchrony

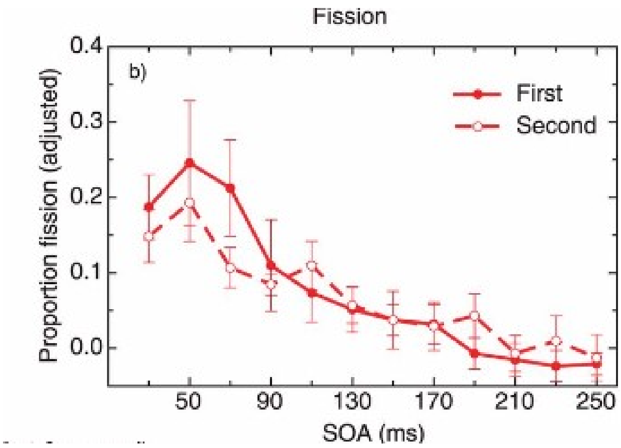



Figure 5.6: Mean Percentage of times participants reported 2 flashes at variable stimulus onset asynchrony Source: Apthorp et al., 2013 (The first and second represents the first and second test flash)([2])

from a previous study by Foss Feig et al., 2010 [10]. Past research has indicated that as the time gap between two stimuli increases, the susceptibility to the illusion diminishes [2]. Unfortunately, the stimulus onset asynchrony (SOA) was not initially recorded, rendering the analysis nonsensical without these SOA values. In our analysis, we illustrate the average proportion of participants who reported seeing two flashes in the fission condition, considering the varying stimulus onset asynchronies, Only 10 participants responses were used for this analysis. In figure 5.5, It can be observed that as the inter stimuli interval increases the percentage of times the illusion is perceived decreases. This is in accordance with previous studies. [2] [10] [35] [24] . To validate this we can have a look at the graph from Apthorp et al., 2013 (figure 5.6). The trend in both the experiments is the same suggesting that increase in temporal binding window can reduce the susceptibility to double flash illusion. Although in this study the mean percentage of times participants reported 2 flashes is quite high when compared to the previous study [2].

## 5.4 Feedback from Participants

In addition to the main components of the experiment, participants were encouraged to share their thoughts regarding various aspects, including the experiment's structure, the user interface, and their perception of how auditory inputs influenced visual experiences. This section delves into the feedback provided by the participants, offering insights into their experiences and suggestions.

### 5.4.1 Understanding of the Experiment

Out of the 20 participants, a vast majority found the experiment straightforward and easy to grasp. However, one individual expressed difficulty in comprehending the experiment's objectives and procedures. Another participant felt that their understanding was only partial. This feedback suggests that while the instructions were clear for most, there remains room for improvement in clarity or presentation.

### 5.4.2 Suggestions for Experiment Enhancement

When asked about potential changes to enhance the experiment's user experience, several participants shared their insights. Three of them pinpointed areas in the user interface that could be enhanced, emphasizing the importance of addressing minor bugs. Another three participants believed that having visual representations or examples of the 0, 1, and 2 disks would have facilitated a clearer understanding. However, the inclusion of such examples was purposely avoided to prevent any unintentional biases. A couple of participants found the confidence range to be a tad extensive and felt that a more concise range might simplify the task. A recurring suggestion was the addition of more detailed instructions to guide participants effectively.

### 5.4.3 Feedback on the User Interface

Participants' experiences with the user interface varied. While one participant encountered issues with the display of average response times, potentially due to browser compatibility challenges, others had suggestions regarding the aesthetics. A couple of participants felt the interface could be more colorful and engaging. Conversely, the simplicity of the design was appreciated by another participant, who believed it allowed for better focus on the task at hand. An intriguing suggestion was the inclusion of a feature that reveals the ”correct” responses post-experiment, catering to participants’ curiosity regarding their performance.

### 5.4.4 Auditory Influence on Visual Perception

A significant portion of the participants, 14 out of 20, felt that the auditory component influenced their visual perception during the experiment. Two participants did not perceive any influence, while another mentioned experiencing the effect occasionally. Some participants provided detailed insights, with one highlighting how the synchronization of sound with visual cues in the second round made it more intuitive. However, the same participant felt challenged by the third round due to the desynchronization of auditory and visual inputs. Another participant’s feedback hinted at an evolving understanding as the experiment progressed, with realization dawning during the initial round. This feedback underscores the intricate relationship between auditory and visual stimuli and how they can modulate perceptions.

# Chapter 6

# Discussion

This study provides an in-depth methodology for conducting the double flash illusion experiment online, capturing participant data, and performing preliminary data analysis to see if the results are consistent with prior research. All relevant code is accessible on GitHub [25], and detailed instructions for online deployment are presented in Appendix A.

Our core aim was to design a digital framework for the double flash illusion experiment. We sought to pinpoint any challenges that might surface when transitioning from a traditional laboratory setup to an online format. To maintain consistent participant positioning and distance from the screen, we employed the virtual chin rest plugin [17]. Furthermore, participants were instructed to use headphones, set their screen brightness to maximum, and avoid conducting the experiment outside in direct sunlight.

While our experimental results did not precisely match prior studies, the overarching trends remained consistent. Specifically, for the fission illusion, participants were susceptible to the illusion about 49 per cent of the time. This closely aligns with a review by Keil et al (2020) [14], which reported an average susceptibility rate of approximately 50 per cent where one flash was perceived as two. A notable variability in responses suggests individual variability, a notion supported by prior research [7].

In contrast, during the fusion condition, participants were more susceptible than in the fission condition. We hypothesize this increased susceptibility may stem from the shorter Stimulus Onset Asynchrony (SOA) between the two flashes and one beep (50 ms) compared to the SOA between the two beeps in the fission condition (80 ms). To investigate further, we designed a subsequent experimental segment focusing solely on fission trials with varying temporal windows. Our observations highlighted that as SOA expands, the average frequency at which participants perceive two flashes as a single flash diminishes. This trend resonates with findings from several other studies [10][2][35][24].

However, a comparison with findings from Apthorp et al (2013), while affirming the inverse relationship between SOA and perceptions, unveiled significant discrepancies in percentage values. In our study, a higher overall percentage was observed, which could potentially be attributed to individual differences or perhaps the limited sample size of our research.

The feedback provided by participants are also crucial for understanding what they make of the experiment and also, helps us understand if the participants were attentive during the trials.

## 6.1 Impact of this work

Experimental Methods in the Digital Age: The facility to perform tests online offers a substantial benefit as the world grows more distant and digital. This work opens the way by showing how to convert an experiment that has traditionally been conducted in a lab to an online platform. This is especially important given the increased need for remote research tools, which might broaden the scope of studies and enable greater involvement across a wider range of locations. This also helps participants to take the experiments at their own comfort, and enables the researchers to have access to more participants and therefore more data.

The double flash illusion offers insights into the way the human brain deciphers sensory information, particularly when reconciling discrepancies between what we hear and see. Our comprehension of this illusion has deepened since it was first identified. Delving deeper into this phenomenon can enhance our grasp of the integration and processing of human sensory perceptions.

Innovative Experimental Approaches: Employing tools such as the virtual chin rest plugin exemplifies creative strategies to uphold the authenticity and consistency of online experimental outcomes. This indicates the potential of executing intricate experiments online without compromising the precision associated with traditional lab-based investigations.

## 6.2 Limitations

While we aimed to create a comprehensive interface and robust study, several limitations emerged during the course of our work.

- Technical Challenges: One significant challenge was a technical glitch that prevented accurate recording of the per-trial SOA during Experiment Block 3. This glitch necessitated an additional round of data collection. Such setbacks underscore the vulnerability of digital platforms and highlight the potential risks of major data loss.

- Website Bugs: The study's online interface experienced occasional bugs like disk not appearing and experiment stalling. While we implemented temporary fixes to facilitate continuous data collection, these solutions are not sustainable in the long run. As we seek to scale the experiment for a broader participant base, ensuring a seamless and bug-free experience becomes paramount.

- Data Analysis Scope: Our data analysis primarily revolved around exploratory techniques. While this provides a foundation, further in-depth analysis can offer a more granular understanding of participant behaviors and patterns.

To advance this research and rectify the above limitations, future iterations should prioritize rigorous testing of the digital platform, incorporate more sophisticated data analysis techniques, and broaden the participant criteria to ensure a diverse and representative sample.

## 6.3 Future work in Autism Spectrum Disorder Research

Exploring the double flash illusion in the context of autism spectrum disorder (ASD) has the potential to shed light on aberrant sensory processing and pave the path for focused therapies.

The Foundations of Autism Spectrum Disorder and Sensory Integration:

ASD is a neurodevelopmental disease distinguished by difficulties with social interaction and repetitive activities. Beyond these distinguishing characteristics, many people with ASD also show unusual sensory sensitivity and abnormalities in their cognitive processes [32]. These can appear as extreme sensitivity to sensory inputs (hyper- or hypo-reactivity) or extraordinary interest in sensory components of the surroundings.

Given that the double flash illusion highlights the brain's capacity to integrate auditory and visual cues, it offers a tangible medium to understand sensory integration in ASD, a population where such processes might be distinctly atypical.

**Altered Multisensory Integration in ASD**: Research has provided substantial evidence of altered multisensory processing in ASD. [28] showcased how individuals with ASD possess different temporal binding windows, suggesting an expanded time-frame for integrating multisensory stimuli. Furthermore, Foss-Feig et al. (2010) [10] found that children with ASD can integrate multisensory stimuli across longer temporal disparities than neurotypical children. Such findings indicate that those with ASD might experience the double flash illusion in a markedly different manner, potentially perceiving the illusion over broader auditory-visual intervals.

**Importance of Exploring the Double Flash Illusion in ASD** Diving into the intricacies of the double flash illusion in the context of ASD is paramount for several reasons:

**Demystifying Sensory Experiences** By comprehending how individuals with ASD perceive this illusion, researchers can glean insights into their sensory world. This can help bridge the gap between the lived experiences of those with ASD and the external observations made by caregivers, educators, and therapists.

**Informed Therapeutic Approaches** An understanding of sensory processing can lead to the development of more tailored therapeutic strategies. By accounting for multisensory integration peculiarities, interventions can be fine-tuned to better align with the unique sensory profiles of those with ASD.

**Enhancing Social and Communication Skills** Sensory processing abnormalities can indirectly influence social interactions and communication. For instance, the over- or under-integration of auditory and visual cues might affect an individual's ability to interpret non-verbal cues, gestures, or even the nuances of spoken language [5]. Thus, by addressing sensory integration challenges, one might also ameliorate some social and communicative difficulties faced by those with ASD.

**Extending the Research** The exploration of the double flash illusion in ASD shouldn't be seen in isolation. Other multisensory illusions, such as the McGurk effect, where an auditory syllable is paired with the visual motion of a different syllable, leading to the perception of a third, distinct syllable, could also be explored in the context of ASD [20]. Such phenomena together can create a comprehensive understanding of multisensory integration in ASD.

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[1] [2] [30] [3] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [21] [22] [23] [26] [27] [29] [28] [31] [32] [33] [34] [24] [35] [25] [4] [28] [20] [5]

# Appendix A

# User Interface of the experiment

In this section, you will be able to gauge what the interface looks like

## A.1 Interface Images

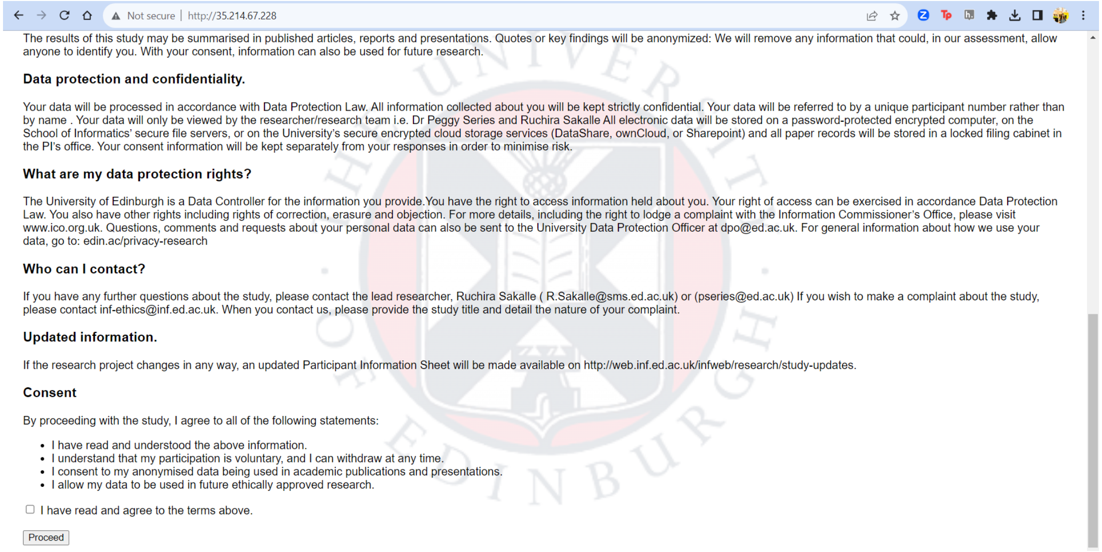


Figure A.1: Participant Information Sheet

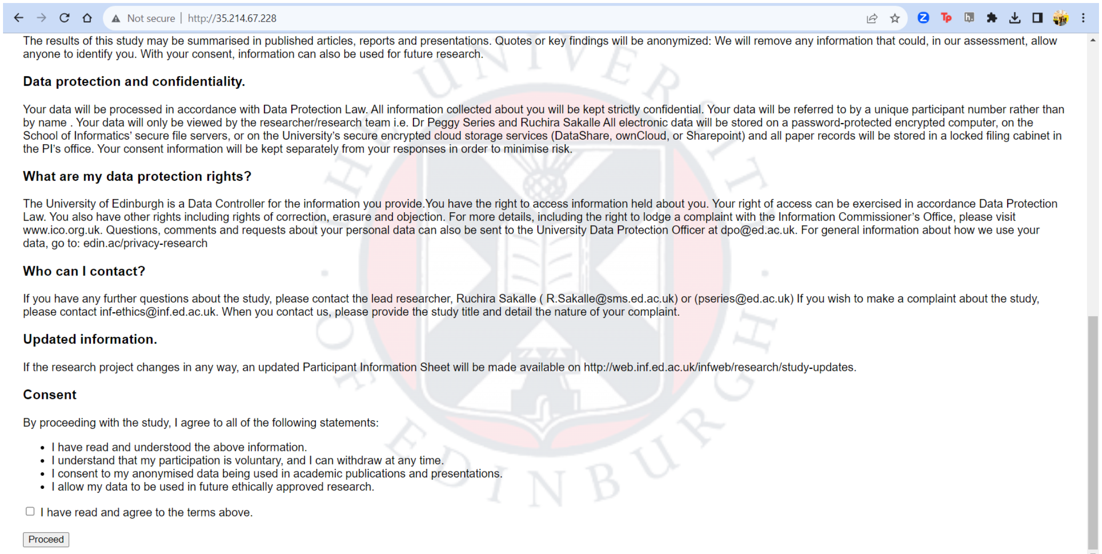
Not secure | http://35.214.67.228
The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research.
Data protection and confidentiality.
Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name . Your data will only be viewed by the researcher/research team i.e. Dr Peggy Series and Ruchira Sakalle All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.
What are my data protection rights?
The University of Edinburgh is a Data Controller for the information you provide.You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk. For general information about how we use your data, go to: edin.ac/privacy-research
Who can I contact?
If you have any further questions about the study, please contact the lead researcher, Ruchira Sakalle ( R.Sakalle@sms.ed.ac.uk) or (pseries@ed.ac.uk) If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.
Updated information.
If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.
Consent
By proceeding with the study, I agree to all of the following statements:
• I have read and understood the above information.
• I understand that my participation is voluntary, and I can withdraw at any time.
• I consent to my anonymised data being used in academic publications and presentations.
• I allow my data to be used in future ethically approved research.
I have read and agree to the terms above.
Proceed

Figure A.2: Participant Information Sheet

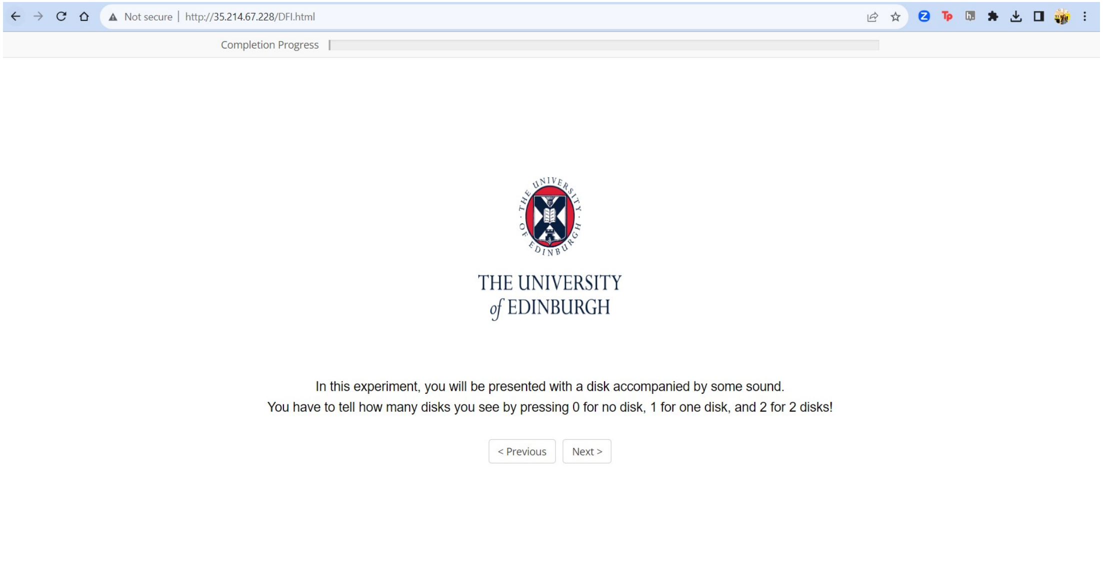


Figure A.3: Instructions Page

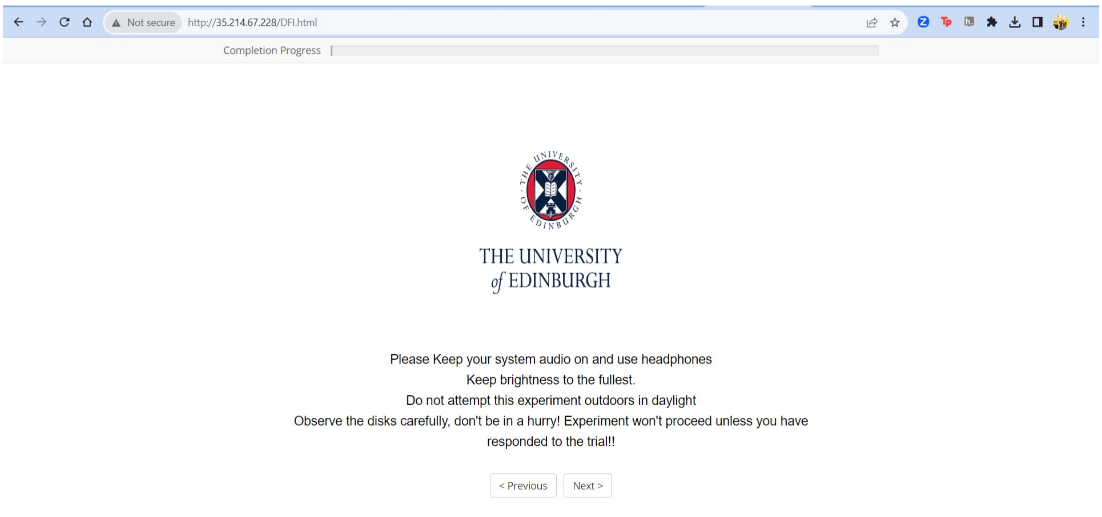


Figure A.4: Instructions Page

# Appendix B

# How to host the experimet on XAMPP using Google Compute Engine

This guide illustrates the steps to set up and host an experiment on XAMPP using the Google Compute Engine platform.

## B.1 Setting up Google Compute Engine

1. Navigate to the Google Cloud Platform Console at https://console.cloud.google.com/.
2. If you haven't already, create a new project.
3. On the navigation menu, click on 'Compute Engine' and then 'VM instances'.
4. Click on 'Create' to create a new virtual machine.
5. Choose a name for your instance and select the desired region and zone.
6. Under 'Boot disk', choose an OS (e.g., Ubuntu).
7. Configure the rest of your VM settings as per your requirements.
8. Click on 'Create' to initialize your VM.

## B.2 Installing XAMPP

1. SSH into your newly created VM instance.

2. Download the XAMPP installer for Linux (assuming you chose Ubuntu as the OS). Use the command:

```
wget https://www.apachefriends.org/xampp-files/VERSION/xampp-linux-*-
installer.run
```

   Replace `VERSION` with the desired version.

3. Make the installer executable and run it:

```
chmod +x xampp-linux-*-installer.run
sudo ./xampp-linux-*-installer.run
```

4. Follow the on-screen prompts to complete the installation.

## B.3 Uploading Your Experiment Files

1. Use `scp` or a similar tool to transfer your experiment files to the VM. For example:

```
scp /path/to/your/experiment-files username@your-vm-external-ip:/path/on
/vm
```

2. Once uploaded, move your experiment files to the XAMPP htdocs directory:

```
sudo mv /path/on/vm/experiment-files /opt/lampp/htdocs/
```

## B.4 Accessing Your Experiment

Now, you can access your experiment via a web browser by navigating to:

`http://your-vm-external-ip/experiment-files`

## B.5 Conclusion

Your experiment should now be hosted on XAMPP using Google Compute Engine and accessible to anyone with the external IP. Ensure that the firewall settings on GCP allow for HTTP and HTTPS traffic.

# Appendix C

# Participants' information sheet and Consent Form

## Participant Information Sheet

**Project title:** An online tool to investigate causal inference processes
**Principal investigator:** Peggy Series
**Researcher collecting data:** Ruchira Sakalle
**Funder (if applicable):**

This study was certified according to the Informatics Research Ethics Process, reference number 346198. Please take time to read the following information carefully. You should keep this page for your records.

### Who are the researchers?

- Dr Peggy Series, Professor in Computational Psychiatry
- Ruchira Sakalle, M.Sc. Cognitive Science Student

### What is the purpose of the study?

Through this project we aim to implement an online tool to investigate causal inference processes. As an initial step, we plan to conduct a pilot experiment involving around 10 healthy participants. This stage aims to validate the task's effectiveness and gather feedback. Additionally, we will perform simple data analysis to compare their behaviour with existing research findings on this particular task.

### Why have I been asked to take part?

You have been asked to participate as your participation is valuable in helping the researchers assess the validity of the experiment and contribute to building a better tool.

### Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

### What will happen if I decide to take part?

If you choose to participate, you will receive an online link to access the experiment. During each trial, you will be presented with visual stimuli for a brief duration accompanied by sounds. Your task will be to indicate the number of disks you perceive by pressing specific keys on your keyboard. The entire experiment is expected to take no more than 15 minutes. At the end of the experiment, you will be asked a few questions regarding the task and the interface used.

### Are there any risks associated with taking part?

There are no significant risks associated with participation.

### Are there any benefits associated with taking part?

There are no benefits associated with taking part in this study.

### What will happen to the results of this study?

The results of this study may be summarised in published articles, reports and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information can also be used for future research.

## Data protection and confidentiality

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a unique participant number rather than by name. Your data will only be viewed by the researcher/research team i.e. Dr Peggy Series and Ruchira Sakalle. All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (DataShare, ownCloud, or Sharepoint) and all paper records will be stored in a locked filing cabinet in the PI's office. Your consent information will be kept separately from your responses in order to minimise risk.

## What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit `www.ico.org.uk`. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at `dpo@ed.ac.uk`. For general information about how we use your data, go to: `edin.ac/privacy-research`.

## Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Ruchira Sakalle at `R.Sakalle@sms.ed.ac.uk` or `pseries@ed.ac.uk`. If you wish to make a complaint about the study, please contact `inf-ethics@inf.ed.ac.uk`. When you contact us, please provide the study title and detail the nature of your complaint.

## Updated information

If the research project changes in any way, an updated Participant Information Sheet will be made available on `http://web.inf.ed.ac.uk/infweb/research/study-updates`.

## Consent

By proceeding with the study, I agree to all of the following statements:

- I have read and understood the above information.
- I understand that my participation is voluntary, and I can withdraw at any time.
- I consent to my anonymised data being used in academic publications and presentations.
- I allow my data to be used in future ethically approved research.