CROSS-MODAL TIME PERCEPTION: DOES IT EMERGE FROM DISTRIBUTED TIMING MECHANISMS OR IS IT CONTROLLED BY A CENTRAL TIMING MECHANISM?

A

Thesis

Submitted in the partial fulfilment of the requirement for the award of degree of

Masters of Arts

In

PSYCHOLOGY

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

THAPAR SCHOOL OF LIBERAL ARTS & SCIENCES
The school of new india

Submitted by:

Sukhman preet

(Roll no- 862102038)

Under the guidance of

Dr. Anuj Shukla

Thapar School of Liberal Arts & Sciences

Thapar Institute of Engineering &Technology, Patiala

CERTIFICATE

This is to certify that the thesis entitled, cross-modal time perception: does it emerge from distributed timing mechanisms or is it controlled by a central timing mechanism? is being submitted in partial fulfillment of requirements for the award of the degree of Master of Arts in Psychology, presented in the Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala. This work is carried out under the supervision of Dr. Anuj Shukla, at Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala and that no part of this thesis has been submitted for the award of any other degree.

(SUKHMAN PREET)

This is to certify that the above statement made by the student concerned is correct and true to the best of my knowledge.

(Dr. ANUJ SHUKLA)

TSLAS

Thapar Institute of Engineering and Technology, Patiala

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this thesis entitled cross-modal time perception: does it emerge from distributed timing mechanisms or is it controlled by a central timing mechanism? is being submitted in partial fulfillment of requirements for the award of the degree of Master of Arts in Psychology, presented in the Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala. This work is carried out under the supervision of Dr. Anuj Shukla, at Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala and refers other researchers' work which are duly listed in the reference section. The matter embodied in this thesis has not formed the basis for awarding any other degree at this or any other university.

Date- May 22, 2023

Place- Patiala

(SUKHMAN PREET)

This is to certify that the above statement by the student concerned is correct and true accurate and the best of my knowledge.

(Dr. Anuj Shukla)

Thapar School of Liberal Arts & Sciences, Patiala

DECLARATION

I, Sukhman preet (862102038), a student of masters in M.A. Psychology (2021-2023), at Thapar School of Liberal Arts & Sciences, Patiala, have completed the Thesis entitled Cross-modal Time Perception: Emerges from distributed timing mechanism or controlled by central timing mechanism.

DATE: 22th May 2023

M.A. Psychology (2021-2023)

Thapar School of Liberal Arts & Sciences,

Patiala, Punjab

ACKNOWLEGMENT

William Saroyan once wrote: “Good people are good because they've come to wisdom through failure." We get very little wisdom from success, you know.”

I would like to extend gratitude to my mentor, Dr. Anuj Shukla, at the Thapar School of Liberal Arts and Social Sciences. I am grateful for his efficient guidance and consistent support throughout the project. His willingness to provide timely feedback and advice was invaluable. He made sure I was on the right track and understood the objectives.

His enthusiasm and dedication to the project was truly inspiring. He was reachable to answer my queries. Despite his busy schedule, he gave me the necessary assistance. I'm thankful for him as my mentor. It was his constant encouragement and constructive criticism. He was a source of motivation and kept me on track throughout the project.

I want to thank everyone who took part in my experiment. Without their help, my project wouldn't be complete.

ABSTRACT

In the context of time perception, our study aimed to determine whether cross-modal time perception emerged from a distributed or centralized timing mechanism? Cross-modal influences on temporal perception refer to the phenomenon where information presented in one sensory modality affects time perception in another sensory modality. We employed a novel paradigm in which information was encoded in one modality and judgments were made in another modality.

The study consisted of two experiments. Experiment 1 focused on Intra-Modal time perception (controlled experiment) tasks with two conditions: *Visual training and testing* (V-V), and *Auditory training and testing* (A-A). Experiment 2 examined Cross-Modal time perception tasks with two conditions: *Auditory training* - *Visual testing* (A-V), and *Visual training* - *Auditory testing* (V-A). Detailed descriptions of both tasks can be found in the methodology section.

For the Intra-Modal time perception task, our hypothesis was based on the modality effect in time perception. We expected to observe an overestimation of time in the auditory training and testing condition compared to the visual training and testing condition. In the cross-modal time perception task, if there is a central timing mechanism, there would be no difference in temporal processing when participants were trained in one modality and tested in another. We calculated the Point of Subjective Equality (PSE) for all four conditions.

The results of Experiment 1 showed a significant mean difference between the PSE for the (V-V) condition and the (A-A) condition. In Experiment 2, we expected to find no mean difference between the PSE for the (A-V) and the PSE for the (VA) conditions. However, the results revealed a significant difference between both conditions. This suggests that participants were unable to transfer training from one modality to another.

Building upon these findings, we further investigated whether cross-modal arousal affects time perception or if the modality effect dominates. To examine the influence of cross-modal arousal on temporal perception, we conducted two experiments using a temporal bisection task. In Experiment 1 (Priming task), (Red or Grey) color was displayed before an auditory stimulus (tone) on computer screen. In Experiment 2 (Simultaneous task), Red or Grey color and auditory stimuli (tone) were presented simultaneously on the computer screen.

The results indicated that when visual information is dissociated from temporal information and presented before auditory stimulus (Experiment 1), it has no effect on the duration judgment process. However, in Experiment 2, arousal influenced temporal processing when presented simultaneously with auditory stimulus. These findings suggest that cross-modal arousal effects may arise from general cognitive mechanisms such as attention and memory. When the arousal was presented along with the duration information, then only it modulates temporal processing, indicating that the arousal indirectly modulates the general cognitive processes such as attention and memory that in turns affects perception of time.

Overall, our study provides insights into the nature of cross-modal time perception and highlights the role of distributed and centralized timing mechanisms, as well as the influence of cross-modal arousal on temporal perception.

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CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION & LITERATURE REVIEW

One of the fundamental characteristics of all living organisms is the experience of time. Throughout evolution, time perception has played a crucial role in survival (Gibbon et al., 1984; Terman et al., 1984; Block et al., 1998; Pouthas, 1999). According to Fraisse (1984), subjective perception of time interval duration is influenced by various factors, including emotional engagement, attention span, memory, age, and personality type. These factors contribute to significant variations in time perception. Students studying time perception are familiar with the study conducted by Goldstone & Lhamon (1974), which revealed that "sounds are regarded longer than lights," indicating that auditory stimuli are subjectively perceived to have longer durations than visually equivalent stimuli. Historical observations by Vierordt in 1868 (as cited in Lejeune & Wearden, 2009) and Guyau (1909) further highlighted differences in the perception of durations between auditory and visual events (1890). Understanding the underlying mechanisms of time perception is of great significance, as these observations provide evidence that events' durations can be perceived differently depending on the sensory modality in which they are presented, prompting further research into the mechanisms of time perception and their susceptibility to different sensory cues.

One of the most influential models of time perception is the internal clock model, proposed by (Treisman in 1963) to explain human timing behavior. The internal clock model suggests the existence of a neurological mechanism that continuously and regularly represents time in the brain (Treisman, 1963). According to this theory, time perception is based on the gradual accumulation of temporal information facilitated by a brain pacemaker that generates pulses at regular intervals, thus shaping the experience of time. The pacemaker-accumulator framework has been linked to an embodied model of time perception by several researchers (Wittmann & van Wassenhove, 2009; Wittmann et al., 2010).

Another model of time perception, known as the attentional gate model, was developed based on Treisman's internal clock model. Introduced by Dan Zakay and Richard A. Block in 1995, the attentional gate model proposes that attentional processes regulating the flow of temporal information into working memory influence time perception. This model suggests that attention modulates the amount of time-related information processed by the brain, thereby impacting subjective time perception. In this model, the perceived duration is determined by the total number of pulses, with more pulses resulting in longer perceived time. Attention and arousal are considered primary mechanisms underlying changes in time perception (Droit-Volet & Meck, 2007; Droit-Volet & Gil, 2009). The attentional gate model suggests two mechanisms: one involving a decrease in pulses when attention is diverted, leading to shorter perceived duration, and the other involving an increase in pulses and longer perceived duration due to higher physiological arousal (Gil & Droit-Volet, 2012; Grecucci et al., 2014; Ogden et al., 2015a; Yoo & Lee, 2015; Mioni et al., 2016). Arousal and bodily signals have been associated with subjective time awareness by several authors, highlighting the significant role of our bodies in time perception (Droit-Volet & Gil, 2009; Gil & Droit-Volet, 2012; Pollatos et al., 2014; Ogden et al., 2015a, b). Numerous studies have explored how people judge time or estimate duration in both auditory and visual contexts. Time estimation experiments can be categorized as over-estimation or under-estimation, production or reproduction, or the rate at which the biological stopwatch ticks. Droit-Volet et al. (2004) discovered that durations indicated using auditory stimuli were overestimated compared to visual stimuli, possibly due to the higher speed of the endogenous clock. As the clock speed increases, overestimation also increases, indicating that the pacemaker and accumulator may stop before auditory inputs accumulate pulses for the predetermined duration. Studies investigating the stimulus effect demonstrated that the pacemaker speed for auditory stimuli is faster than for visual stimuli, leading to the perception of longer durations for auditory stimuli compared to visually equivalent durations (Penney et al., 1998, 2000; Wearden et al., 1998). Wearden et al. (1998) presented audio and visual stimuli lasting between 77 and 1183 milliseconds, consistently finding that auditory stimuli were perceived as longer.

In conclusion, time perception is a complex phenomenon influenced by various factors such as attention, arousal, sensory modality, and physiological processes. The internal clock model and the attentional gate model provide valuable frameworks for understanding the mechanisms underlying time perception. The distinction between auditory and visual stimuli in terms of perceived duration highlights the importance of sensory cues in shaping time perception.

The concept of cross-modal time perception is currently in the spotlight within the context of time perception. Research is now being conducted to gain a better understanding of how the human brain is able to process temporal information from different sensory modalities. Multiple studies and research has been conducted on cross-modal time perception using a variety of experimental paradigms and approaches. The primary motivation of the study to determine whether the cross modal time perception emerges from distributed timing mechanism or controlled by the central time mechanism? The distributed timing mechanism assumes that independent timing mechanisms within each sensory modality carry out temporal processing whereas, central timing mechanism proposes that temporal processing is controlled by a central mechanism that integrates information across sensory modalities.

1.2 MOTIVATION OF THE STUDY-1

Researchers can learn more about the underlying cognitive processes involved in cross-modal integration by determining whether timing mechanisms are largely distributed within each sensory modality or are centrally coordinated across modalities. Past literature has focused mainly on within-modality effects but it is still unclear whether there is common or separate time mechanism. In order to study this, we used an unique paradigm in which the encoding of information was done in one modality and the judgment was accomplished in another. Therefore, it contributes to our understanding of how the brain integrates temporal information across different sensory modalities.

Therefore, our area of interest was to investigate whether cross modal time perception emerged from a distributed or centralized timing mechanism? We conducted 2 experiments. Experient-1, Intra Modal time perception (controlled experiment) which had 2 conditions- *Visual training and Visual testing* (V-V), *Auditory training and Auditory testing* (A-A) conditions and Experient-2, Cross Modal time perception also had 2 conditions- *Auditory training and Visual testing* (A-V), Visual *training and Auditory testing* (V-A), (description of both tasks is given in the methodology section). *The Point of Subjective Equality* (PSE) was calculated for all 4 conditions. Results of experiment-1 showed a significant mean difference between both PSE V-V and PSE A-A conditions. While, for experiment-2 we expected to see no difference between A-V condition and V-A conditions, but results showed a significant mean difference between both conditions. If there was a training effect, then in the V-A condition the duration of the auditory testing phase was to be underestimated because training may have been transferred from the visual training phase to the auditory testing phase. In the results, however, there was no training effect, but rather a testing effect.

CHAPTER-2

STUDY-1: DOES CROSS-MODAL TIME PERCEPTION EMERGE FROM DISTRIBUTED OR CONTROL BY A CENTRAL TIMING MECHANISM?

2.1 INTRODUCTION

Time is an integral aspect of our daily lives, permeating every moment and activity we engage in. Whether we find ourselves occupied, relaxed, overwhelmed with emotions, or simply bored, time remains a constant presence. It accompanies us as we move, drive, listen to music, hear the phone ring, engage in conversations, or partake in physical activities. Unlike other senses such as sight, touch, hearing, smell, and taste, there isn't a distinct sensory receptor dedicated solely to the processing of time. However, our brain serves as a remarkable timing mechanism, allowing us to perceive and experience the passage of time. This fundamental ability to comprehend and engage with time is shared among all living organisms. It was a crucial survival mechanism throughout evolution (Gibbon et al. 1984; Terman et al. 1984; Block et al. 1998; Pouthas 1999). The subjective experience or perception of time passing is called time perception. The duration of events experienced by different people and under various conditions can vary greatly. The sayings "time flies when you're having fun" and "a watched pot never boils" are examples of how psychological time is subjective and potentially changeable while physical time seems objective. Its formability is made most clear by the various temporal illusions we experience. A temporal illusion is a distortion in how one perceives time that can be brought on by a variety of factors, such as stress. If the timing and sequential order of events are misperceived, a person may momentarily perceive time slowing down, stopping, or speeding up. In reality, when we say time slows down, we mean our internal clock quickens. This gives the appearance that time in the outside world moves slowly down.

Duration estimation, also known as explicit timing, plays a crucial role in human adaptation to the environment. Extensive research has been conducted on time judgment and duration estimation, particularly in the auditory and visual domains. These studies examine various aspects such as over-estimation and under-estimation, production or reproduction of time, and the functioning of the biological stopwatch. Goldstone & Lhamon (1974) observed that "sounds are regarded longer than lights," indicating that auditory stimuli are subjectively perceived to have longer durations than visual stimuli of equal actual length. This finding aligns with earlier observations made by Vierordt in 1868 (referenced in Lejeune & Wearden, 2009) and Guyau (1909) regarding differences in the perception of durations between sound and visual events. Several factors can influence human ability to estimate the duration of a task. Below, we discuss a few of these factors: a) Sensory modality: The modality through which information is presented, such as auditory or visual, can affect duration estimation. Auditory stimuli may be perceived as lasting longer than visual stimuli. b) Attention: The level of attention devoted to a task can influence duration estimation. When individuals are more engaged and focused, their ability to accurately estimate time may improve. C) Emotional state: Emotional experiences can impact the perception of time. For example, time may appear to pass more slowly during stressful situations and faster during enjoyable or exciting experiences. Understanding the factors that influence duration estimation in humans is essential for comprehending our temporal perception and cognitive processes. By investigating these influences, researchers can shed light on the mechanisms underlying time perception and contribute to a broader understanding of human’s cognition.

2.1.1 Stimulus-based effects

Some of the variables, like sensory modality, intensity, size, complexity, familiarity, and whether an interval is "filled" or "empty," have been known for some time; however, others, like the biasing effects of symbolic magnitude, difference-from-background, emotionality, pitch, speed, and changes in speed, have only recently been discovered. For instance, one recent study discovered that while novel images were left on screen for longer during a production task (implicating a slower internal clock, leading to a shorter subjective duration), novel images were judged to last greater than repeated ones (implicating a faster internal clock, leading to a longer subjective duration). Even more methodological dependence has been reported in recent investigations of emotional arousal effects on the perception of time. This demonstrates that the perception of time is influenced by both the complexity of the stimulus and the emotional arousal of the viewer, highlighting the importance of considering both variables when studying temporal perception. This is due to angry faces being left on the screen for longer.

The clock rate difference is due to an attentional effect on the mode switch and is revealed only when the memories for the short and long anchor durations consist of a mix of contributions from accumulations generated by both the fast auditory and slower visual clock rates. When this occurs auditory signals seem longer than visual signals relative to the composite memory representation.

2.1.2 Auditory versus visual stimulus

Studies on the stimulus effect showed that the pacemaker speed for auditory stimuli was faster than for visual stimuli, i.e., duration is judged to be longer than it actually is and the subjective time appears to be longer for auditory stimuli than for visual stimuli for the same objective time (Penney et al. 1998, 2000; Wearden et al. 1998). In comparison to visual stimuli, Droit-Volet et al. (2004) found that the target duration stated in terms of audio stimuli was overestimated. This might be attributed to the endogenous clock's speed. This is because the endogenous clock is faster for audio than visual stimuli, leading to the perception that audio stimuli are presented for a longer duration than they actually are. This phenomenon is known as the “audio-visual asynchrony effect” (Droit-Volet et al., 2004). The overestimation increases with the clock speed. It may be explained by the switch closing between the pacemaker and the accumulator. This is before auditory stimuli continue to cause pulses to collect for a predetermined amount of time.

The objective of this study is to investigate the phenomenon of cross modal time perception, specifically examining whether it emerges from distributed or central timing mechanisms. The study consists of two experiments: Experiment 1 focuses on Intra Modal time perception, while Experiment 2 examines Cross Modal time perception (both task descriptions are provided in the methodology section). The primary motivation behind this study is to determine whether cross-modal time perception is governed by a central timing mechanism. To address this, a unique paradigm was employed, in which information was encoded in one modality (e.g., auditory) while judgments were made in another modality (e.g., visual). We conducted two experiments and each experiment had 2 conditions. The hypothesis for experiment-1 suggests that due to modality effects on time perception, we anticipate an overestimation of time in the *Auditory*

Training – Auditory Testing (A-A) condition compared to the *Visual Training-Visual Testing* (V-V) condition. As for experiment-2, if a central timing mechanism is at play, we would expect no difference in temporal processing when participants are trained in one modality and tested in another. By conducting these experiments and testing these hypotheses, this study aims to contribute to our understanding of the underlying mechanisms of time perception, particularly in relation to cross-modal processing.

2.2 METHODOLOGY

2.2.1 Experient-1: An intra-modal time perception

2.2.1.1 Apparatus- The stimuli were presented and controlled using Open Sesame stimulus presentation software. It was presented on a 17inch CRT monitor running at 100Hz frame rate.

2.2.1.2 Participants- A total of 23 right-handed participants (12 male) and (11 female) were recruited from the Thapar Institute of Engineering & Technology (TIET), Patiala, India. The participants were aged 18-25 years. No participants reported any history of visual or auditory impairments or problems. The study was approved because all experimental techniques and procedures were carried out in accordance with the applicable rules and regulations of the Thapar Institute of Engineering & Technology (TIET), Patiala, India. Informed consent forms were obtained from all participants.

In order to study the modality effect (intra-modal time perception), two kinds of stimuli were used: a visual stimulus (black square box) 2^{o} visual angel and an auditory stimulus (tone) of 440Hz. Given the modality effect on time perception, we expect an overestimation of time in the *auditory training-auditory testing* (A-A) condition compared to the *visual training - visual* *testing* (V-V) condition. Each participant performed 2 conditions V-V and A-A. Furthermore, for each condition the participant was asked to estimate whether the duration of the stimulus was long or short.

TRAINING		TESTING
AUDITORY	→	**AUDITORY**
VISUAL	→	**VISUAL**

In both conditions, there was a training phase and a testing phase. *Training phase* was further divided into *Observation and Feedback phase*. The participant was instructed to sit in a calm lab with soft lighting. The participants signed an informed consent form in which they were provided with information about the experiment and assured that they could leave at any time. The instructions were given in both verbal and written format. The distance between the participant and the computer monitor was 57 cm.

All doubts regarding the experiment and procedure were cleared before starting the experiment. After collecting consent forms, each participant performed both the conditions V-V and A-A. There was ~10 minutes break between two conditions. The order of the conditions was counterbalanced among participants.

2.2.1.3 In the *Visual training-Visual testing* (V-V) condition, participants were trained and tested in the same modality, which was visual. *Training phase* was divided into 2 parts – *an observation phase* and *a feedback phase.* As part of the observation phase, participants simply had to concentrate on observing a black square box with a short duration (200ms) and a long duration (800ms). In the feedback *phase*, these two durations (short or long) were randomly shown on the screen. Participants then had to correctly answer by pressing the buttons 'S' for Short duration and 'L' for Long duration. This was to indicate whether the displayed duration of a visual stimulus (black box) was short or long. The response was then marked as "correct" or "incorrect". All participants performed 20 trials. The participant was only allowed to proceed to the testing phase after 90% accuracy in the feedback phase. In the Testing phase, the participant was presented with visual stimuli (black square box) and it was flashed in the center of the computer screen. Visual stimuli were presented for varying durations from 200ms to 800ms durations in steps of 100 ms. Participants were asked to press the button "L" on the keyboard if they felt the stimuli duration was closer to the long duration and the button "S" if it was closer to the short duration.(see figure-1). No feedback regarding correct or incorrect was given in the testing phase. All participants performed 70 trails.

2.2.1.4 In the *Auditory training-Auditory testing* (A-A) condition, participants were trained and tested in the same modality, namely auditory. Training phase was divided into 2 parts – *an observation phase* and *a feedback phase*. In *the observation phase*, participants were asked to carefully listen to a tone of short (200ms) and long (800ms) duration. The tone was presented through JBL headphones and the volume of auditory stimulus was adjusted for each participant. *In the feedback phase*, these two durations were randomly played. Participants then had to correctly answer by pressing the buttons 'S' for Short duration and 'L' for Long duration to indicate whether the played duration of an auditory stimulus (a tone) was of short or long anchor duration. The response was then marked as "correct" or "incorrect". All participants performed

20 trials. The participant was only allowed to proceed to the testing phase after 90% accuracy in the feedback phase. In the testing phase, the participant was presented with a tone for varying durations from 200ms to 800ms in steps of 100 ms. Participants were asked to press the button "L" on the keyboard if they felt the stimulus duration was closer to the long duration and the button "S" if it was closer to the short duration. (See figure-2) No feedback regarding correct or incorrect was given in the testing phase. 70 trials were performed by all participants.

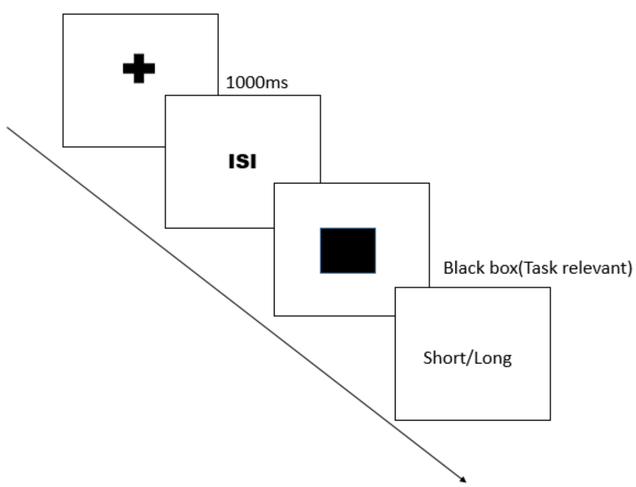

Figure 2.1: Visual Temporal Bisection Task: Task-illustration. The trial began with the fixation cross, followed by a fixed 1000ms inter stimulus interval (ISI). After the ISI, the visual stimulus (black square box) was presented for varying durations from 200ms to 800ms in steps of 100ms.

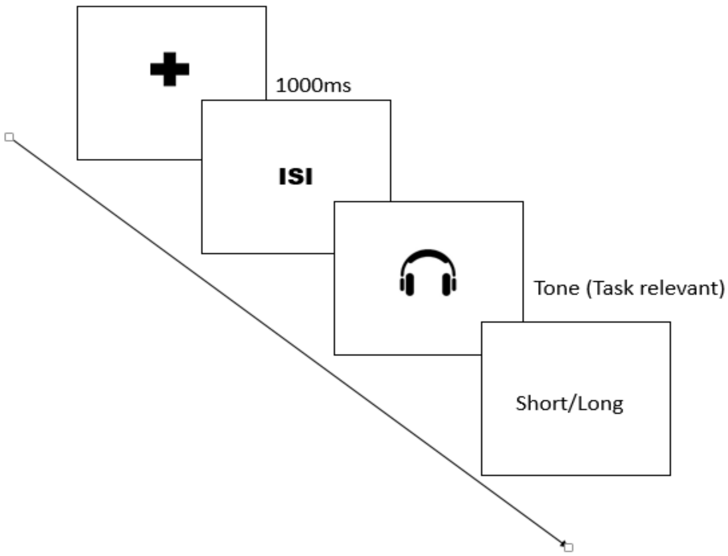

Figure 2.2: Auditory Temporal Bisection Task: Task-illustration. The trial begins with the fixation cross, followed by a fixed 1000ms inter stimulus interval (ISI). After the ISI, the auditory stimulus (a tone) was presented for varying durations from 200ms to 800ms in steps of 100ms. Participants were asked to estimate whether the duration of the auditory stimulus was long or short.

2.2.1.5 RESULTS

The data was recorded in short or long responses. Statistical analysis for the study was carried out using Microsoft Excel and JASP, which is a programming language. Our methodology consisted of estimating the PSE (mean) for each of the conditions using psignify-4, a MATLAB-based toolbox.

Experiment-1 included data from 23 participants. The *point of subjective equality* (PSE) was calculated. PSE is the value of a comparison stimulus that is equally likely to be judged higher or lower than the value of a standard stimulus. A left shift in the psychometric curve results in smaller PSE estimates, whereas a right shift results in larger PSE estimates.

In the Intra Modal time perception, the PSE for V-V (*visual training- visual testing*) condition was 0.602 ± 0.070 seconds (mean ± SD), whereas PSE for A-A *(auditory training- auditory testing)* condition was 0.517 ± 0.047 seconds.

Table-1: Shows Descriptive statistics for PSE visual training-visual testing (V-V) and PSE auditory training-auditory testing (A-A) conditions

	PSE (V-V)	PSE(A-A)
N	23	23
Mean	0.602	0.517
St. Deviation	0.070	0.047

we used paired sample t-test for the analysis of the data and it indicated the significant results with the mean difference (85ms) between the mean value of PSE V-V and PSE A-A conditions that differs significantly from each other [t (22) =5.591 , p = .001, Cohen's d=1.166].

Table-2: shows the paired sample t-test for PSE (*visual training and visual testing*) and PSE (*auditory training and auditory testing*) conditions

Measure-1	Measure-2	t	df	p	Mean Difference	Cohen's d
PSE (V-V)	PSE (A-A)	5.591	22	.001	0.085	1.166

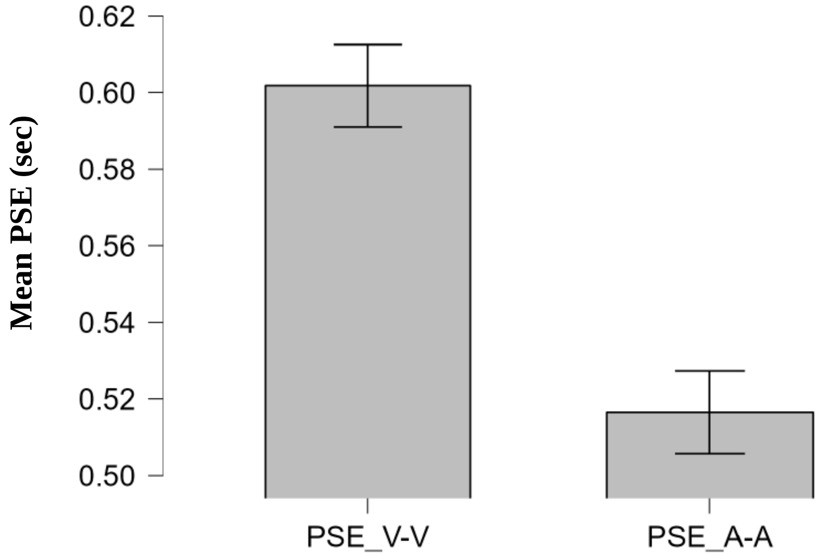

Figure 2.3: Plots of PSE V-V and PSE A-A conditions: Lower PSE is interpreted as an overestimation of duration. Higher PSE is interpreted as an underestimation of duration. Thus the figure indicates, visual training and visual testing (V-V) condition has higher PSE and is interpreted as underestimation of duration, whereas auditory training and auditory testing (A-A) condition has lower PSE and is interpreted as overestimation of duration.

2.3 METHODOLOGY

2.3.1 **Experient-2: The cross-modal time perception**

2.3.1.1 **Participants-** A total of 27 right-handed participants (13 male) and (14 female) were recruited from the Thapar Institute of Engineering & Technology (TIET), Patiala, India. The participants were aged 18-25 years. No participants reported any history of visual or auditory impairments or problems. The study was approved because all experimental techniques and procedures were carried out in accordance with the applicable rules and regulations of the Thapar Institute of Engineering & Technology (TIET), Patiala, India. Informed consent forms were obtained from all participants.

2.3.1.2 **Stimulus and Procedure-** All the stimuli were identical to experiment-1. A temporal bisection task was used. Aim is to study the cross-modal temporal perception. If there is a central timing mechanism, we would expect no difference in temporal processing when participants trained on one modality and tested on another. Each participant performed 2 conditions- *auditory training - visual testing* (A-V), *visual training and auditory testing* (V-A).

TRAINING		TESTING
AUDITORY	→	**VISUAL**
VISUAL	→	**AUDITORY**

All procedure and task remained the same as explained in experiment-1. The only difference was that participants were trained on one modality and tested on another in experiment-2. The subjects had a ~10-minutes break after completing one condition and then a second condition was performed. The order of the conditions was counterbalanced among participants.

2.3.1.3 **In *auditory training-visual testing* (A-V) condition,** the participant was trained in auditory modality and tested on visual modality. As mentioned in experiment-1, the training phase has 2 parts- *observation and feedback phase.* After completion of the observation and feedback phase, the participant was tested in the visual modality to examine how effective the auditory modality training had been. In the observation phase, participants had to carefully listen to an auditory stimulus (a tone) for long (800ms) and short (200ms) durations. After completing the observation phase, there was then a feedback phase, similar to what was explained in experiment-1. The testing phase, the participant was tested on a visual modality. A black square box flashed in the center of the computer screen. During this experiment, stimuli were presented for varying durations from 200ms to 800ms durations in steps of 100 ms. Participants were asked to press the button "L" on the keyboard if they felt the stimuli duration was closer to the long duration and the button "S" if it was closer to the short duration. No feedback regarding correct or incorrect was given in the testing phase. All participants performed 70 trails.

2.3.1.4 **In the *visual training-auditory testing* (V-A) condition,** participants were trained in visual modality and tested in auditory modality. In (V-A) condition, the same procedure was followed as described above in the (V-A). Training was given in visual modality and testing was given in auditory modality in this condition.

2.3.1.5 RESULTS

The data was recorded in short or long responses. Statistical analysis for the study was carried out using Microsoft Excel and JASP, which is a programming language. Our methodology consisted of estimating the PSE (mean) for each of the conditions using psignify-4, a MATLAB-based toolbox. Experiment-2 reported data from 27 participants.

Cross Modal time perception, PSE for A-V condition was 0.595±0.071 seconds (mean ± SD), whereas PSE for V-A condition was 0.529 ± 0.058 seconds.

Table-3: Shows Descriptive statistics for PSE (A-V) *auditory training-visual testing* and PSE *visual training-auditory testing* (V-A) conditions

	PSE (A-V)	PSE(V-A)
N	27	27
Mean	0.595	0.529
St. Deviation	0.071	0.058

We used a paired sample t-test for the analysis of the data and there was a mean difference (67ms) between the A-V and PSE V-A conditions. The PSEs between the two conditions does differ [t(26)= 5.100, p = .001, Cohen's d= 0.982].

Table-4: shows the paired sample t-test for PSE (auditory training and visual testing) and PSE (visual training and auditory testing) conditions

Measure-1	Measure-2	t	df	P	Mean Difference	Cohen's d
PSE (A-V)	PSE (V-A)	5.100	26	.001	0.067	0.982

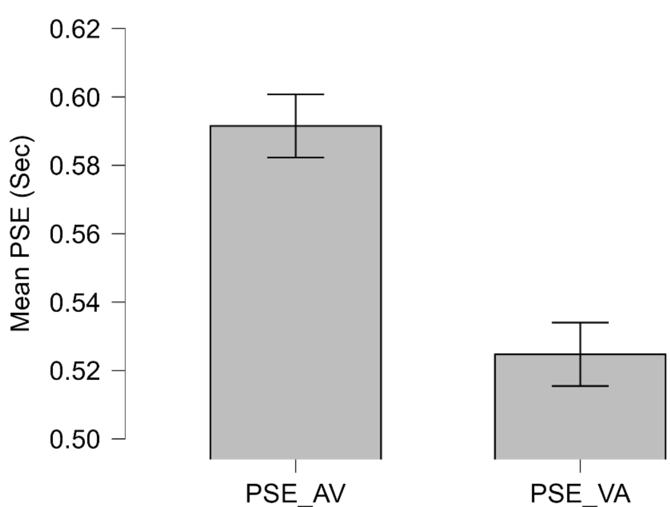

Figure 2.4: Plots of PSE A-V condition and PSE V-A condition: Auditory training and visual testing (A-V) condition has higher PSE and is interpreted as underestimation of duration, whereas Visual training and auditory testing (V-A) condition has lower PSE and is interpreted as overestimation of duration.

2.4 DISCUSSION

The aim of the present research is to study whether cross modal time perception emerges from a distributed or centralized timing mechanism? To study this we conducted two experiments using a temporal bisection task. We hypothesized that given the modality effect in perception of time, we would expect an overestimation of time in the auditory training and auditory testing condition over the visual training and visual testing condition in experiment-1 (an intra-modal time perception task). In experiment-2 (Cross-Modal time perception task), if there was a central timing mechanism, the participants would not experience any change in their temporal processing if they were trained on one mode and then tested on another modality.

Results of experiment-1 showed significant differences between the mean values of PSE *Visual training- Visual testing* (V-V) and PSE *Auditory training- Auditory testing* (A-A). This is supported by the fact that there was a significant difference between the mean values of both the conditions. These results are consistent with previous studies, which suggest internal clock speed is a factor in time perception. Various previous research on the stimulus effect supported the hypothesis and showed that clock speed is the rate at which the inner timing mechanism works. This affects the rate at which events are subjectively perceived. This is one of the reasons that auditory stimuli often cause the internal clock to speed up leading to overestimation and visual stimuli may cause the clock to slow down leading to underestimation of time for the same objective time (Penney et al. 1998, 2000; Wearden et al. 1998). Another study by Droit-Voletet et al. (2004) also found that the target duration was overestimated when provided with an auditory stimulus compared to a visual stimulus. It may be due to the closure of the switch between the pacemaker and the accumulator. The biological stopwatch counts ticks to represent any event or duration, just like a mechanical clock. The resulting response, which varies depending on the pacemaker's speed, is a subjective perception of time (behavioral output). Another study by Penney, Gibbon, & Meck (2000) also confirmed the notion of an accelerated internal clock. It discovered that individuals tend to overestimate interval durations when exposed to auditory stimuli. These differences between auditory and visual information impacts on temporal memory and clock speed and direct attention to modality-specific aspects of time perception.

While experiment-2, we expected to see no difference in mean between the *auditory training-visual testing* (A-V) condition and the *visual training - auditory testing* (V-A) condition. However, results in our study showed a significant mean difference between both conditions. This indicates that temporal processing ability depends on the modality used during testing. Therefore, temporal processing ability appears modality-specific. This implies that there is not a single central timing mechanism, but rather that temporal processing ability is modality-dependent. We expected to see the training effect but there was no training effect in both the conditions of experiment-2, because in the V-A condition there was overestimation of duration and in the A-V condition there was underestimation of duration.

If there was a training effect, then in the V-A condition the duration of the auditory testing phase was expected to be underestimated. This is because training may have been transferred from the visual training phase to the auditory testing phase but there was a testing effect rather than a training effect. This suggests that visual training had no effect on auditory testing duration judgment. Therefore, the hypothesis that training in one modality would affect how the other modality processes duration is rejected.

2.5 SUMMARY

Therefore, to conclude the study the results from experiment-1, showed statistically significant mean difference between *auditory training* - *auditory testing* (A-A) and *visual training -visual testing* (V-V) condition. Whereas, in experiment-2, results showed testing effect rather than a training effect and whether the cross- modal emerges from distributed or controlled by central timing mechanism is still the matter of debate. Further to the previous study whether cross modal time perception emerged from distributed or central timing mechanism? we sought to determine whether cross-modal arousal affects time perception or still the modality effect dominates this. Therefore, Study-2 examines the influence of cross-modal arousal on temporal perception. The results of this study will provide a better understanding of cross-modal arousal influence on temporal processing. In study-2, we conducted 2 experiments using a temporal bisection task. In the visual domain, 'RED' or 'GREY' colors were presented on computer screen and in the auditory domain, we presented an auditory stimulus (tone). In experiment-1, (Red or Grey) colors was displayed before an auditory stimulus (tone). In experiment-2, (Red or Grey) presented on computer screen and the auditory stimulus were presented simultaneously. Results suggest that when visual information is dissociated from temporal information and presented before the duration judgement task, it has no effect on the duration judgement process (experiment-1). In experiment-2, visual information affects temporal processing when presented simultaneously with auditory information. Colors influenced the temporal processing in simultaneous but not in priming task. Findings indicate that cross-modal arousal effects might arise from general cognitive mechanisms like attention and memory.

CHAPTER-3

STUDY-2: DOES CROSS-MODAL AROUSAL HAS INFLUENCE ON TEMPORAL PROCESSING?

3.1 INTRODUCTION

An accurate sense of time and the ability to accurately estimate the duration of temporal intervals are crucial for effective behavioral regulation. The brain has a built-in mechanism for processing time, and the subjective perception of time seems to be based on the accumulation of cerebral units over time, regardless of the specific model used to describe the neural processes involved (Durstewitz, 2004; Matell & Meck, 2004; Karmarkar & Buonomano, 2007). Research on time perception has investigated various aspects, including the existence of an internal clock, as well as the internal and external factors that influence our perception of time. Studies have explored how we perceive the passage of time, the effects of aging on time perception, and how our daily patterns and routines can impact our perception of time. However, our understanding of the effects of cross-modal arousal on time perception is currently limited to uni-modal or one-dimensional studies. Therefore, further research is needed to explore the influence of cross-modal arousal on time perception and enhance our existing knowledge in this area. Arousal plays a crucial role in time perception, particularly in the context of duration judgments. Neiss (1988) argues that arousal is not a singular phenomenon and lacks convincing proof as a separate entity. It has been described as tension (Thayer, 1989), activation (Russell & Barrett, 1999), and motivation (Thayer, 1989). According to Russell & Barrett (1999), arousal is a psychological term that characterizes emotional states influenced by the activity of the sympathetic nervous system, autonomic nervous system, or endocrine system. Arousal is often associated with a sense of high energy and tension and can implicitly affect cognition, judgment, and memory when associated with an emotional response to a subject. In addition to its influence on judgment, arousal also affects cognitive processing, attention, and perception.

Cross-modal arousal refers to the impact of a sensory stimulus on the arousal level of another sensory modality. For example, a tactile stimulus can increase the arousal level of auditory processing, while a sound stimulus can increase the arousal level of visual processing. Research has shown that cross-modal arousal plays a significant role in attention, memory, and decision-making processes. The relationship between arousal and duration judgments can be explained by the pacemaker-accumulator models of time perception, also known as internal-clock models. These models propose that arousal can modify the speed of our internal clock, thereby affecting our perception of time. The internal clock comprises a pacemaker that emits pulses and an accumulator that counts those pulses. The perceived length of an interval is positively associated with the number of pulses accumulated during that interval, such as during the presentation of a visual stimulus. Evidence suggests that arousal can modulate the speed of the pacemaker, with higher arousal leading to a more rapid pacemaker activity and faster perceived temporal intervals. The accumulation of more pulses results in a longer perception of time. Thus, two primary theories, an arousal-based mechanism and an attention-based mechanism, have been proposed to explain changes in the perception of time (Droit-Volet & Meck, 2007; Droit-Volet & Gil, 2009). Various experiments have demonstrated the effects of arousal on time perception by manipulating arousal levels, such as through the presentation of emotionally arousing stimuli like scary characters or facial expressions. For example, Gorn et al. (2012) found that the duration of a red screen was exaggerated compared to a blue screen, indicating that arousal can influence time perception. Similar effects of arousal on time perception have been observed in studies using different stimuli, including facial expressions (Gil & Droit-Volet, 2012), symbolic figures (Schwarz et al., 2013), dance movements (Allingham et al., 2021), and nonmusical sounds like clicks, laughter, and sobs (Mella et al., 2011; Noulhiane et al., 2007; Treisman et al., 1990). In a study by Gil & Droit-Volet (2012), participants verbally judged the duration of neutral, repulsive, and depressing emotional imagery. The results showed that emotional pictures were perceived as lasting longer, with greater overestimation of time as arousal levels increased. Participants tended to overestimate time more when experiencing high emotional arousal (Droit-Volet & Meck, 2007; Gan et al., 2009a; Jia et al., 2015). It is believed that emotional arousal speeds up the pacemaker, leading to the overestimation of time compared to neutral events.

3.1.1 MOTIVATION OF THE STUDY-2

When it comes to time perception, knowledge of arousal effects are limited to only uni-modal and not cross-modal time perception. Therefore, the current motivation of the study-2 is to investigate the influence of cross-modal arousal on temporal time perception. The present study conducted two experiments using a temporal bisection task. In Experiment 1, color (Red or Grey) was displayed on the computer screen before an auditory stimulus (tone). In Experiment 2, the color and auditory stimulus were presented simultaneously. The objective was to examine whether the color can influence participants' ability to judge the duration of the auditory stimulus. By manipulating the presentation of stimuli, the study aimed to explore how cross-modal arousal influenced temporal perception.

3.2 METHODOLOGY

3.2.1 Apparatus- The stimuli were presented and controlled using Open Sesame stimulus presentation software on a 17inch CRT monitor running at 100Hz frame rate.

3.2.2 Participants- A total of 55 right-handed participants (26 male) and (29 female) were recruited from the Thapar Institute of Engineering & Technology (TIET), Patiala, India. The participants were aged 18-25 years. 27 participants performed experiment-1(Priming) and other 28 performed experiment-2(Simultaneous). No participants reported any history of auditory impairments or problems. The study was approved because all experimental techniques and procedures were carried out in accordance with the applicable rules and regulations of the Thapar Institute of Engineering & Technology (TIET), Patiala, India. Informed consent forms were obtained from all participants.

3.2.3 Stimulus - To study the Influence of cross-modal arousal on temporal perception we used two stimuli- visual stimulus (red or grey color) and auditory stimulus (tone) and the frequency of the tone was 440Hz. Given the Arousal effect, if arousal is high in one modality we would expect overestimation of temporal duration in another modality. Participants were asked to estimate whether an auditory stimulus lasted long or short.

3.2.4 Procedure

3.2.4.1 Experiment-1 (Priming)

There was a Training and Testing phase in the task. *Training phase* was further divided into *Observation and Feedback phase*. The participants were instructed to sit in a noise-free lab with soft lighting. During the Feedback phase, they received feedback on their performance in the form of correct or incorrect responses. The participants signed an informed consent form in which they were provided with information about the experiment and assured that they could leave at any time. The instructions were given in both verbal and written format .The distance between the participant and the computer monitor was 57 cm. Prior to starting the experiment, all doubts regarding the experiment were cleared.

The training phase was divided into 2 parts – *an observation phase* and *a feedback phase. In an observation phase,* participants were asked to carefully listen to a tone of short (200ms) and long (800ms) duration. The tone (auditory stimulus) was played through JBL headphones, and the volume of the sound was adjusted for each participant. *In the feedback phase*, these two durations (200ms and 800ms) were randomly played. Participants then had to correctly answer by pressing the buttons 'S' for short duration and 'L' for long duration to indicate whether the played duration of an auditory stimulus (a tone) was of short or long duration. The response was then marked as "correct" or "incorrect". Each participant performed 20 trails (10 for short and 10 for long). The participant was only allowed to proceed to the testing phase after 90% accuracy in the feedback phase. Testing phase was conducted using a priming paradigm, in which 'red' or 'grey' color was presented on the screen followed by temporal information in the auditory domain (tone) for varying durations from 200ms to 800ms in steps of 100 ms. Participants were asked to focus their attention only on the tone being played and instructed to look straight at the computer's screen and then estimate the duration of the tone and press the button "L" on the keyboard if they felt that the auditory stimulus was of long or was closer to the long duration and the button "S" if it was of short or closer to the short duration. Subjects were instructed not to close their eyes while performing the task.

During the testing phase, no feedback was provided about correct or incorrect responses. 140 trails were performed by each participant. (see figure-5).

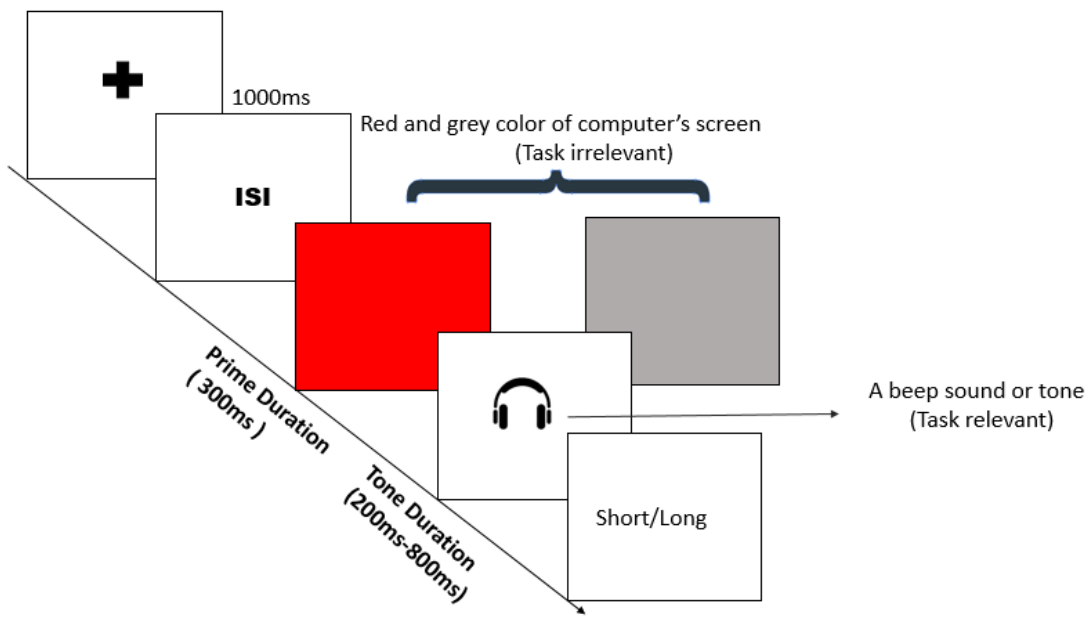

Figure 3.1: Task-illustration. The trail begins with the fixation cross, followed by the inter stimulus interval (ISI) of fixed duration of 1000ms. The color (Red or Grey) was presented on the computer screen after ISI, followed by an auditory stimulus (a tone). Participants were required to estimate whether the auditory stimulus duration was closer to a long or short duration. Red and Grey colors were irrelevant to the task and the participants were only instructed to pay attention to the auditory stimuli (a tone).

3.2.4.2 Experiment-2 (Simultaneously)

The instructions remained the same as in Experiment-1 and the same procedure was followed. This experiment also had a training phase that was divided into 2 parts – *an observation phase* and *a feedback phase*. In *the observation phase*, participants were asked to carefully listen to a tone (auditory stimulus) of short (200ms) and long duration (800ms). The tone was played through JBL headphones and auditory stimuli volume was adjusted according to each participant's comfort. *In the feedback phase*, these two durations (200ms and 800ms) were randomly played. Participants then had to correctly answer by pressing the buttons ‘S’ for short duration and ‘L’ for Long duration to indicate whether the played duration of an auditory stimulus (a tone) was of short or long duration. The response was then marked as "correct" or "incorrect". A total of 20 trails were completed by each participant (10 for short anchors and 10 for long anchors). The participant was only allowed to proceed to the testing phase after 90% accuracy in the feedback phase. In testing phase, ‘Red’ or ‘Grey’ color of computer screen and an auditory stimulus (tone) with varying durations from 200ms to 800ms in steps of 100 ms was presented simultaneously. Participants were asked to focus their attention only on the tone being played and then estimate the duration of the tone and press the button “L” on the keyboard if they felt that the auditory stimulus was of long or was closer to the long duration and the button “S” if it was of short or closer to the short duration. (see figure-6) Subjects were also instructed to look straight at the computer’s screen and were instructed to not to close their eyes while performing the task. During the testing phase, no feedback was provided regarding correct or incorrect responses. 140 trials were performed by each participant.

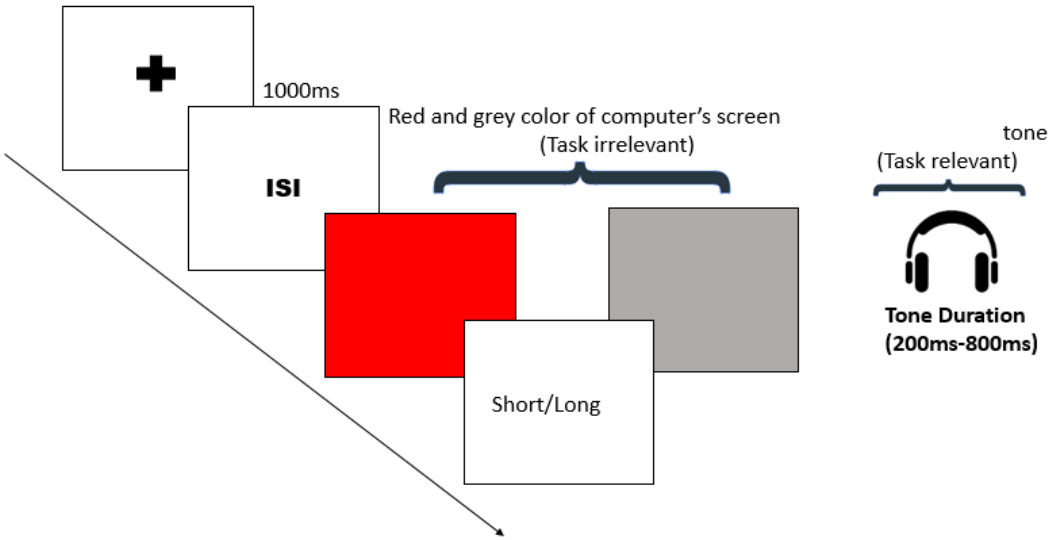

Figure 3.2: Task-illustration. The trail begins with the fixation cross, followed by the inter stimulus interval (ISI) of fixed duration of 1000ms. After ISI, 'Red' or 'Grey' color in visual domain and auditory stimulus (tone) in an auditory domain for varying duration from 200ms to 800ms. Participants were required to estimate whether the auditory stimulus duration was closer to a long or short duration. Red and Grey colors were irrelevant to the task and the participants were only instructed to pay attention to the auditory stimulus (a tone).

3.2.5 **Sam scale rating**

Nonverbal self-assessment manikin (SAM) scales was used to measure the emotional responses to the grey and red stimulus. Nine horizontally aligned pictograms of each emotion were used to represent the emotional characteristics of valence and arousal. For the valence dimension, the scale moves from a smiling, happy figure to a frowning, unhappy figure from left to right. It varies from a thrilled, wide-eyed figure to a relaxed, sleepy figure for the arousal dimension. Numbered labels ranging from "1" to "9" were used to display the scales. "1" stands for "calm" on the arousal scale, and "9" means "arouse." The numbers "1" and "9" on the valence scale, which represent "pleasant" and "unpleasant," respectively. Participants rated their emotional state on both scales by selecting a number between 1 and 9. The arousal and valence of the red and grey stimuli were evaluated. To determine if the red stimulus induced more arousal than the grey stimulus, the SAM ratings were used. First, they performed the experiment and after that they rated the SAM scale.

3.3 RESULTS

The data was recorded in short or long responses. The statistical analysis was done using Microsoft Excel and JSP. We used psignifit-4, a MATLAB-based toolbox, and estimated the PSE (mean) for both the colors “RED” and “GREY”. The *point of subjective equality* (PSE) was calculated. PSE is the value of a comparison stimulus that is equally likely to be judged higher or lower than the value of a standard stimulus.

To examine the Influence of Cross-Modal Arousal on Temporal Perception we used temporal bisection tasks. It was hypothesized that given the Arousal effect, if arousal is high in one modality, we would expect overestimation of the temporal duration in another modality. To test this hypothesis, we conducted 2 experiments- Experiment-1: Auditory duration judgment task (Priming) and Experiment-2: Auditory duration judgment task (Simultaneously). In experiment-1, Color (Red or Grey) was presented before an auditory stimulus (tone) on the computer screen. Whereas in experiment 2, the computer screen color (Red or Grey) and the auditory stimuli were presented simultaneously. A total of 55 subjects participated in the current study. 27 subjects participated in experiment-1 and the other 28 participated in experiment-2.

We performed repeated measures ANOVA, wherein Color was a within-subject repeating factor, and task was a between-group factor. The results revealed that there was a significant difference in experiment-2 (simultaneous task) when color of computer screen either 'red' or 'grey' presented simultaneous with an auditory stimulus as compared to experiment-1(priming task) in which color of computer screen either 'red' or 'grey' followed by an auditory stimulus.

For Auditory duration judgment task (Priming) PSE for Grey was 0.527 ± 0.040 seconds (mean ± SD) and for Red was 0.531± 0.029 seconds, whereas for (Simultaneously) task PSE for Grey was 0.552 ± 0.050 seconds (mean ± SD) and for Red was 0.529 ± 0.059 seconds.

Table-5 shows descriptive statistics

Color	Group	N	Mean	SD	SE	Coefficient of Variation
Gray	Priming	27	0.527	0.040	0.008	0.077
	simultaneous	28	0.552	0.050	0.009	0.091
Red	Priming	27	0.531	0.029	0.006	0.055
	simultaneous	28	0.529	0.059	0.011	0.112

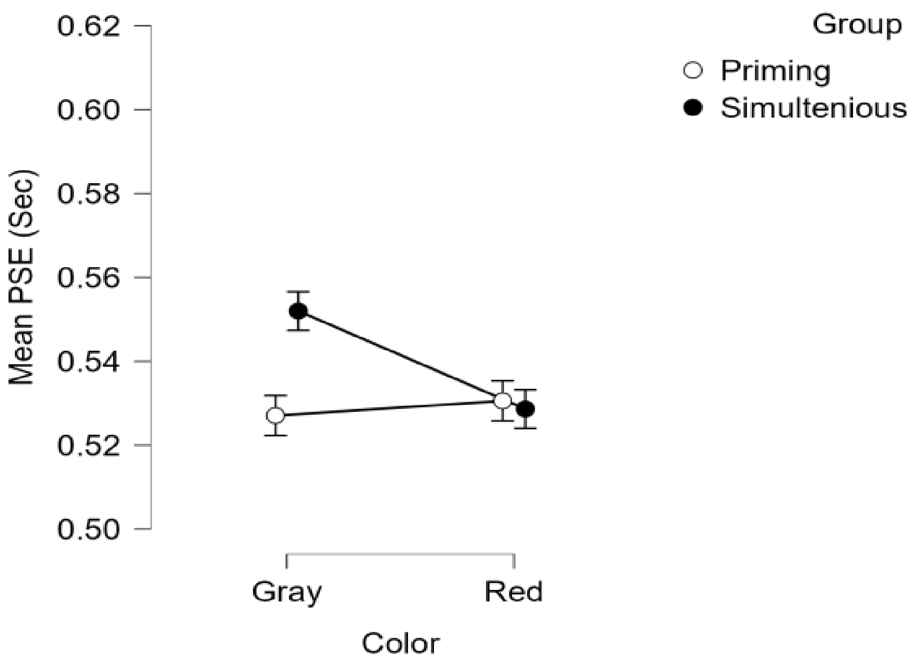

Figure 3.3: A Mean PSE for the different conditions are plotted to show the interaction effect.

Repeated Measures ANOVA was performed .There was a significant main effect of color

[F (1, 53) = 4.481, p = 0.039, η_p^2 =0.078]. There was a significant interaction effect of color*group

[F (1, 53) = 8.194 , p = 0.006 , η_p^2 =0.134].

Table-6 Shows Repeated Measures ANOVA

Within Subject Effects

Cases	Sum of Squares	df	Mean Square	F	p	η_p^2
Color	0.003	1	0.003	4.481	0.039	0.078
Color*Group	0.005	1	0.005	8.194	0.006	0.134
Residuals	0.032	53	$6.048x10^{-4}$			

Between Subject Effect

Cases	Sum of Squares	df	Mean Square	F	p	η_p^2
Group	0.004	1	0.004	0.989	0.324	0.018
Residuals	0.195	53	0.004			

The simple main effect analysis suggests that duration of the tone (an auditory stimulus) was overestimated when the color of computer screen ‘red’ or ‘grey’ was presented simultaneously with auditory stimulus i.e in simultaneous task [F(1, 53) = 12.857, p = .001] whereas, the arousal effect on temporal perception was not seen in experiment-1(priming).

Table-7 Shows Simple Main Effects-Color

Level of Group	Sum of Squares	df	Mean Square	F	P
Priming	$1.652x10^{-4}$	1	$1.652x10^{-4}$	0.268	0.609
Simultaneous	0.008	1	0.008	12.857	0.001

Table-8 shows descriptive statistics for Arousal and Valence

	Arousal (Red)	Arousal (Grey)	Valence (Red)	Valence (Grey)
N	55	55	55	55
Mean	6.655	3.127	4.455	6.455
SD	1.635	1.689	2.115	2.089

Results showed descriptive statistics for arousal and valence scores on SAM scale for all 4 conditions. The arousal for red was 6.65 ± 1.635 and for grey 3.127±1.689. The value for red was 4.455±2.115 and for grey was 6.455±2.089.

Results showed that red was a more arousing color than grey with a mean difference of 3.527±0.345 (SE). Paired sample t-test showed significant results on arousal, [t (54) = 10.221, p<.001, Cohen's d=1.378].

Table-9 shows Paired sample t-test on Arousal.

Measure-1	Measure-2	t	df	p	Mean Difference	SE Difference	Cohen's d
Arousal (Red)	Arousal (Grey)	10.221	54	.001	3.527	0.345	1.378

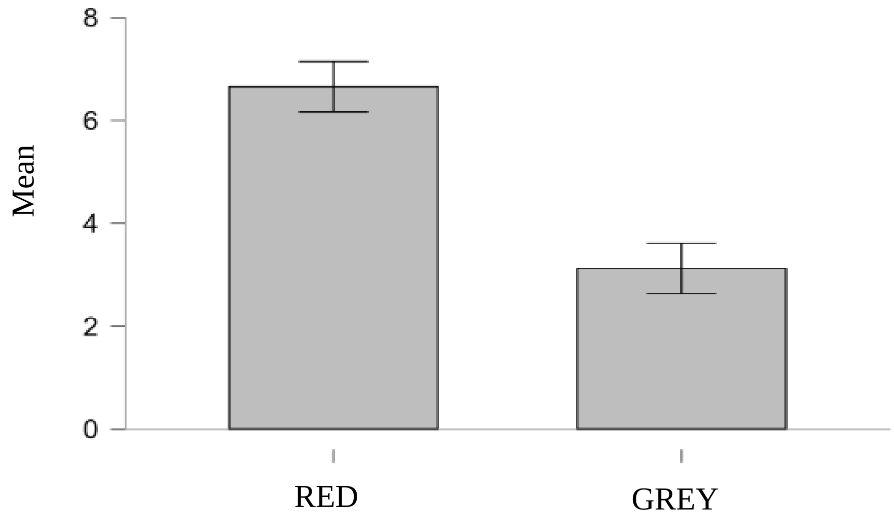

Figure 3.4: Bar Plot of Arousal (RED and GREY): Shows red was more arousing than grey color.

Paired sample t-test showed significant results on valence as well [t(4.435), p = .001, Cohen's d=0.598].

Table-10 shows paired sample t-test on Valence.

Measure-1	Measure-2	t	df	P	Mean Difference	SE Difference	Cohen's d
Valence (Red)	Valence (Grey)	4.425	54	.001	2.000	0.451	0.598

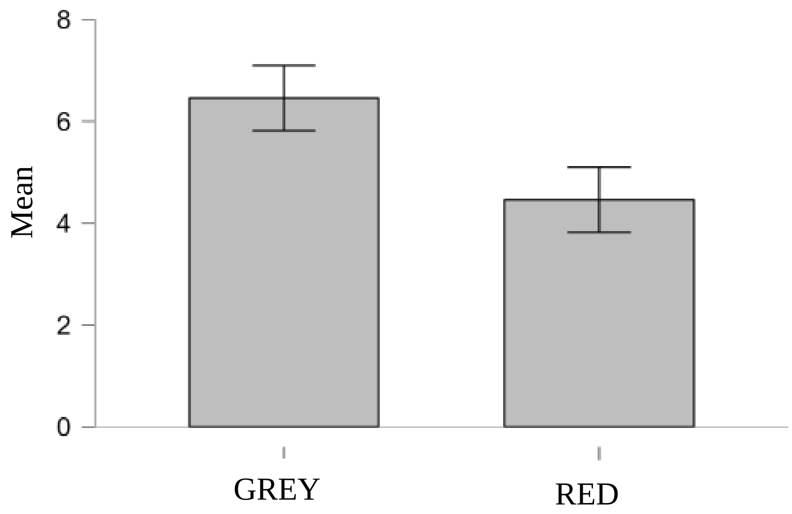

Figure 3.5: Bar Plot of Valence (RED and GREY): Shows grey was more pleasant than red color.

3.4 DISCUSSION

The primary objective was to determine whether there was any arousal effect or whether the modality effect still dominated the temporal duration. It was hypothesized that given the Arousal effect, if arousal is high in one modality, we would expect overestimation of the temporal duration in another modality. Therefore, we conducted 2 experiments using a temporal bisection task. Experiment-1: (Priming task) and Experiment-2 (Simultaneously).

Results showed in experiment-1 (priming), there was no significant effect of arousal on temporal perception when the 'Red' or 'Grey' color was presented on the computer screen before an auditory stimulus (tone). However, in experiment 2 (simultaneous) when red or grey color was presented along with an auditory stimulus (tone) showed a significant influence of arousal (colors) on temporal duration. Various studies have shown that arousal can influence judgement, thoughts, and memories as long as it is implicitly assigned to or associated with an emotional response towards the subject of the judgement, thought, or memory.

Therefore, one of the possibilities for the influence of ‘red’ or ‘grey’ color on temporal perception when presented simultaneously could be related to attention and memory because the association of the colors with the auditory stimulus allowed the participants to focus on the task, and their use of their memories of the colors to form judgments. Due to the fact that red is seen as being extremely arousing and that high arousing stimuli are linked to greater levels of attention, numerous studies have demonstrated this association. Arousal stimulates the attentional processes. Attention may concentrate solely on stimuli that are important to arousal during times of high arousal, while ignoring those that are less arousing. According to Greene, Bell, and Boyer, warm colors like yellow, red, and orange compared to cool colors like brown and grey, have a higher effect on attention. According to various authors, arousal affects attention by speeding up the brain's internal clock (Angrilli et al., 1997; Noulhiane, Mella, Samson, Ragot, & Pouthas, 2007). This phenomenon is known as the arousal-biased competition theory. It suggests that when the brain is aroused, it processes information more quickly and pays more attention to emotionally salient information. This is why warm colors like yellow, red, and orange may be more likely to capture attention than cooler colors like brown and grey. As ‘red’ is a high arousing stimuli, it directly increases the rate of pulse emission by the pacemaker, thus leading to overestimation of temporal processing. This increase in arousal can lead to a quicker cognitive response and the ability to process more information more quickly. Additionally, the colors can elicit a certain emotion that can further enhance the attention-grabbing effect. For example, a red-colored object can create a feeling of urgency, alerting the brain to pay more attention and process the information faster. Such effects of arousal on time perception were observed in a number of studies that varied the level of arousal. This is because when we are in a state of arousal, our sympathetic nervous system activates, resulting in an increase in heart rate and respiration. This heightened state of alertness increases the speed of neural processing, which in turn leads to quicker cognitive responses. For example, by presenting scary characters, or by presenting different kinds of facial expressions.

Another factor is memory. Memory and retention are greatly influenced by arousal. Cahill and McGaugh's (1995) investigation of the relationship between arousal and memory is one of the most well-known. Participants in this study were shown a sequence of neutral and emotionally stimulating images, and their recall of the images was examined. The findings suggest that participants recall emotionally arousing images better than the neutral ones. The amygdala, a brain region involved in emotional processing, was also shown to be more active during the encoding of emotionally arousing images. This shows that the amygdala is a significant factor in enhancing memory retention for highly arousing events.

Last but not least, two different paired sample t-tests for arousal and valence were used to analyze the rating scale data. Results for arousal and valence were statistically significant for both. Red was considered to be arousing than grey for arousal, whereas grey was perceived to be a more pleasant color than red for valence. So, it's possible that this is a contributing element as well. The findings of the t-tests show that the assessments of red and grey for arousal and valence differ significantly. This implies that colors may have an impact on people's perceptions, and could therefore be a contributing factor to the overall outcome.

3.5 SUMMARY

The objective of the current study was to examine whether the color can influence participants' ability to judge the duration of the auditory stimulus. To explore how cross-modal arousal influenced time perception we conducted 2 experiments using a temporal bisection task. Results of experiment 2 showed the effects of arousal on temporal processing were observed when the color "RED" or "GREY" was simultaneously presented with an auditory stimulus (tone). The duration of the tone was modulated by the colors of the computer screen. Therefore, we propose that the impact of colors on temporal perception might be related to attention and memory.

CHAPTER-4

4.1 GENERAL DISCUSSION

One of the fundamental characteristics that every living creature shares is their ability to experience time. Fraisse (1984) argues that a variety of factors, including emotional commitment, attention span, memory, age, and personality type, influence how subjectively people judge the duration of time intervals. Our memories and experiences with time serve as the foundation for how we perceive time. For instance, if we have had the experience more than once, it might be simpler for us to estimate how long it will last. Our focus and attention can also affect how we perceive the passage of time. In the context of time perception, various cross-modal studies have been conducted. Therefore, in the current thesis we conducted 2 studies. In Study-1, we were interested to know whether cross-modal time perception is distributed or controlled by a central timing mechanism? To study these 2 experiments were conducted. Results from experiment-1 showed The PSE *visual training - visual testing* (V-V) and the PSE *auditory training - auditory testing* (A-A) condition's mean values differed significantly. This outcome validates findings from prior studies that internal clock speed influences how events are perceived. The concept was further strengthened by a number of previous investigations on the stimulus effect, which also demonstrated that the inner timing system operates at a clock speed. The speed at which events are viewed subjectively is impacted by the same. This is one of the reasons why, for the same objective time, auditory stimuli frequently cause the internal clock to speed up, resulting in overestimation, whereas visual stimuli may cause the clock to slow down, resulting in underestimation (Penney et al. 1998, 2000; Wearden et al. 1998). Whereas results in experiment 2, showed the testing effect rather than a training effect. Our finding implies that there is not a single central timing mechanism, but rather that temporal processing ability is modality dependent. If there was a training effect, it was anticipated that the auditory testing phase would be underestimated in the V-A condition. This is because training may have been transferred from the visual training phase to the auditory testing phase but there was a testing effect rather than a training effect. The rising question here is that if there is no training effect, then how the participants were able to perform the task in the testing phase? Is this shows that cross-modal time perception is modality-dependent? or controlled by central timing mechanism is still a matter of debate. In addition to the previous study, study-2 examined the influence of cross-modal arousal on temporal perception. Arousal plays a crucial role in various psychological processes, such as attention, perception, memory, and decision making. Therefore, to study this we conducted 2 experiments using a temporal bisection task. Experiment-1: Auditory duration judgment (Priming) and Experiment-2 (Simultaneously)**.** Results showed in experiment-1 (priming), there was no significant effect of arousal on temporal perception when the 'Red' or 'Grey' color was presented on the computer screen before an auditory stimulus (tone). However, in experiment 2 (simultaneous) when red or grey color was presented along with an auditory stimulus (tone) showed a significant influence of arousal (colors) on temporal duration. This suggests that the influence of the color on temporal perception is related to attention and memory because the association of the colors with the auditory stimulus allowed the participants to focus on the task, and their memories of the colors were used to make their judgments. As the color red is perceived as highly arousing and various research has shown that high arousing stimuli are associated with higher levels of attention. Arousal activates attentional processes. Particularly during periods of high arousal, attention may focus on arousal-relevant things only, rejecting less arousing information. Another factor is memory. Memory and retention are greatly influenced by arousal. Cahill and McGaugh's (1995) investigation of the relationship between arousal and memory is one of the most well-known. Lastly, two different paired sample t-tests for arousal and valence were used to analyze the rating scale data. Results showed that grey was viewed as a more pleasant color than red) for valence, whereas red was more arousing than grey color. So, it's possible that this is a contributing element as well. One of the limitations of the thesis is that it examined cross-modal time perception via only two specific sensory modalities i.e. auditory & visual but not examined other modalities.

CHAPTER-5

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APPENDICES

APPENDIX A: CONSENT FORM FOR STUDY-1

CONSENT FORM

The purpose of this experiment: Research on time perception for the thesis

The overall experiment would be in 3 phases- Training, feedback and testing. In testing phase, you would be presented with an auditory stimulus (tone) and visual stimulus (black box) separately in two different tasks. You need to estimate the duration of the played tone or black box in terms of short or long.

Subject Demographic details

Name-

Date of birth-

Contact number-

I,………, give my consent for the participation in this……………………experiment conducted by………………..

I understand that:

- My data will be used for the research
- My participation is voluntary.
- My information will be kept confidential.

  I have read the information above and I give my consent for my participation in this study.

  Signed: Date

APPENDIX B: CONSENT FORM FOR STUDY-2

THAPAR SCHOOL OF LIBERAL ARTS & SCIENCES
The school of new india

CONSENT FORM

The purpose of this experiment: Research on time perception for the thesis

The overall experiment would be in 3 phases- Training, feedback and testing. In testing phase, you would be presented with an auditory stimulus (tone) and you need to estimate the duration of the played tone in terms of short or long anchor duration.

Subject Demographic details

Name-

Date of birth-

Contact number-

I,………, give my consent for the participation in this……………………experiment conducted by………………..

I understand that:

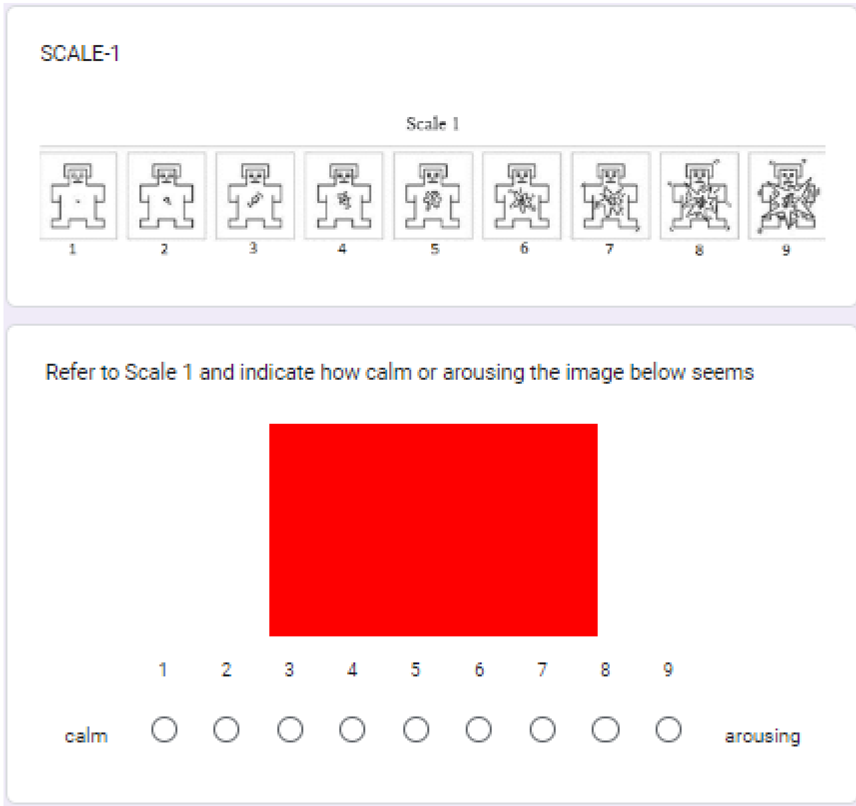
- My data will be used for the research
- My participation is voluntary.
- My information will be kept confidential.

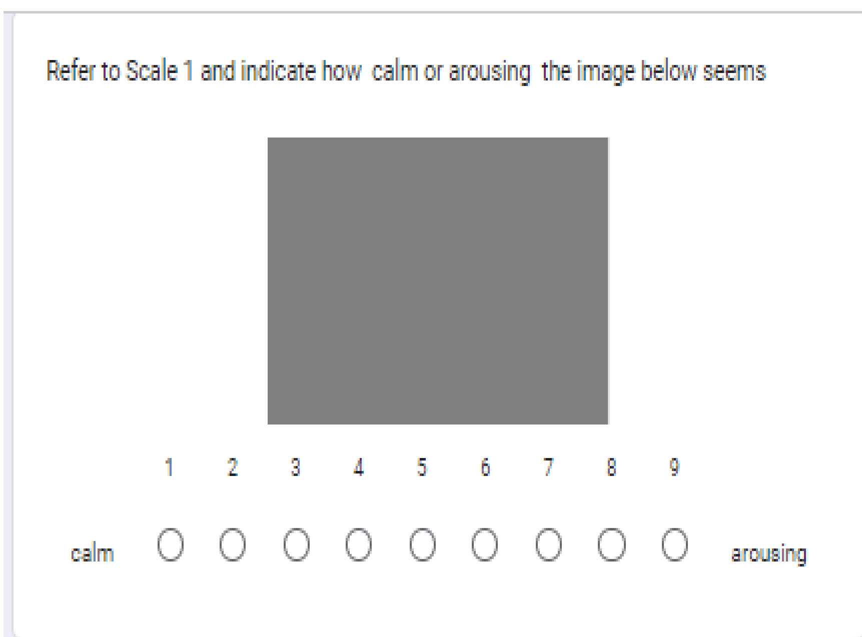
I have read the information above and I give my consent for my participation in this study.

Signed: Date

APPENDIX C: SAM RATING SCALE

SCALE-1

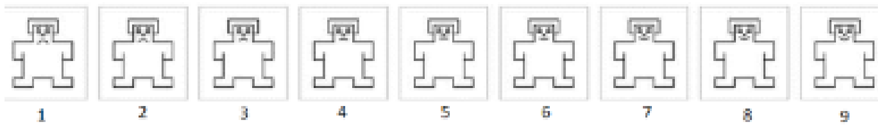




SCALE-2

SCALE-2

Scale 2



Refer to scale 2 and indicate how pleasant or unpleasant the image below seems

	1	2	3	4	5	6	7	8	9	
Unpleasant	○	○	○	○	○	○	○	○	○	Pleasant

Refer to scale 2 and indicate how pleasant or unpleasant the image below seems *

	1	2	3	4	5	6	7	8	9	
Unpleasant	○	○	○	○	○	○	○	○	○	Pleasant