

Generation and Maintenance of False Memories in Humans: Exploring the Role of Sleep

A

Thesis Submitted

In Partial Fulfilment of the Requirement

For the Degree of

DOCTOR OF PHILOSOPHY

By

Kedarmal Verma (156141012)

Department of Humanities and Social Sciences

Indian Institute of Technology Guwahati



Department of Humanities and Social Sciences
Indian Institute of Technology Guwahati, Guwahati
India

May 2020

**Indian Institute of Technology Guwahati**

Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

DECLARATION

I hereby declare that the thesis entitles “**Generation and Maintenance of False Memories in Humans: Exploring the Role of Sleep**” is the result of investigation carried out by me at the Sleep and Cognition Laboratory, Department of Humanities and Social Sciences, Indian Institute of Technology Guwahati, under the supervision of **Dr. Naveen Kashyap**. The work has been submitted either in whole or in part to any other university/ institution for a research degree.

IIT Guwahati
May 2020

Kedarmal Verma
(Roll No. 156141012)



Indian Institute of Technology Guwahati
Department of Humanities and Social Sciences
Guwahati 781039
Assam, India

CERTIFICATE

This is to certify that Mr. Kedarmal Verma has prepared the thesis entitled “**Generation and Maintenance of False Memories in Humans: Exploring the Role of Sleep**” for the degree of Doctor of Philosophy at the Indian Institute of Technology Guwahati. The work by carried under my supervision and in strict conformity with the rules laid down for the purpose. It is the result of his investigation and not been submitted either in whole or in part to any other university/institution for a research degree.

IIT Guwahati
May 2020

Dr. Naveen Kashyap
(Associate Professor)
Thesis Supervisor



Dedication

*To the betterment of human society, and those people who were falsely convicted
to punishments...!!*

ACKNOWLEDGMENTS

I express my heartfelt gratitude at the outset to my supervisor **Dr. Naveen Kashyap** Associate Professor in Psychology, Department of Humanities and Social Sciences, IIT Guwahati, for been a tremendous mentor for me. I am extremely thankful and indebted to him for sharing his expertise, sincere and valuable guidance extended to me. His invaluable suggestions and foresightedness helped me in a big way in the completion of this research work for which I really feel privileged. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. Your advice on both research as well as on my career have been priceless.

I am extremely grateful to my colleague and friends **Dr. Suman Dhaka, Ms. Pallavi Ojha, Jaiprakash Kushwaha** for their invaluable contribution to my thesis work. I would like to express our sincere thanks to volunteers and participants of the experiments who devoted their time and knowledge in the implementation of this project.

I express my gratitude to my Doctoral committee members, **Prof. Nachiketa Tripathi, Dr. Sambit Mallik, and Dr. Dilwar Hussain** for providing me all the help and needed directions for the research on the subject.

At last but not the least, I am thankful to my parents for their unwavering patience, understanding, and encouragement, as the present work is much because of their personal sacrifices and support for which I shall ever remain indebted.

IIT Guwahati

May 2020

Kedarmal Verma

(156141012)

ABSTRACT

Human memories are far from accurate as the process of its formation involve variables that can lead to its reconstruction and distortions. This leads to people remembering events and facts that never happened in reality. Generating and maintaining false memories within the laboratory is difficult. The present thesis experiments with semantic and category associates and compares their effectiveness in generating false memories within the laboratory across varied time delays and retrieval mechanisms. Nocturnal sleep has been known to benefit memory stabilization and consolidation. We reason that since neurobiological mechanisms within sleep promote true memory formation, it may also modulate the formation and maintenance of false memories. The data of our study point to some very interesting results that suggest both semantic and category associates are equally effective in generating false memories that are persistent over long delays. Also, retrievals using recognition leads to higher false memories. Similarly, our results evidence that sleep leads to high false memory generation for only category associates which are persistent across time.

Keywords: Critical Lures, Intrusions, Studied Items, False Memory, Semantic Associates, Category Associates, BAS, DRM, Recall, Recognition, Line Drawings, Sleep Deprivation, Sensitivity, Response Bias, Retention Interval

LIST OF PUBLICATIONS

JOURNAL PUBLICATIONS

1. **Verma, K., & Kashyap, N.** (2019). Sleep deprivation enhances false memory on the Deese-Roediger-McDermott (DRM) task. *Psychological Thought, 12(1)*, 120-130. [ISSN: 2193-7281; Research Article]
2. **Mal, K., Abhishekh, H. A., Chawla, M. P., Raju, T. R., & Sathyaprabha, T. N.** (2017). Influence of age and gender on the function of postganglionic sympathetic sudomotor axons. *The National medical journal of India, 30(3)*, 136-138. [PubMed ID: 28936997; Short Research Report]
3. **Verma, K., Dhaka, S., & Kashyap, N.** (2016). Does Nap Differentially Modulate Object Specific Recognition Memory? *Recent Advances in Psychology: An International Journal, 3(2)*, 1-11. [ISSN: 2395-5465; Research Article]

CONFERENCE PUBLICATIONS/PROCEEDINGS

1. **Kedarmal Verma, Pallavi Ojha, & Naveen Kashyap** (2020). **Recognition Memory of Critical Lures Across Sleep for Category Associate task**, at *The 32nd International Congress of Psychology (ICP 2020) on "Psychology in the 21st Century: Open Minds, Societies & World"* at Prague Congress Centre Prague, Czeck Republic.

2. Pallavi Ojha, **Kedarmal Verma**, & Naveen Kashyap (2020). **Assessing the impact of cognitive style on face and scene recognition**, at *The 32nd International Congress of Psychology (ICP 2020) on "Psychology in the 21st Century: Open Minds, Societies & World"* at Prague Congress Centre Prague, Czeck Republic.
3. Pallavi Ojha, **Kedarmal Verma**, & Naveen Kashyap (2020). **ERP study of recognition memory for valence face and scene**, at *The 32nd International Congress of Psychology (ICP 2020) on "Psychology in the 21st Century: Open Minds, Societies & World"* at Prague Congress Centre Prague, Czeck Republic.
4. Pallavi Ojha, **Kedarmal Verma**, & Naveen Kashyap (2019). **How Different Learning Styles Can Affect False Memory**, at *29th Annual Convention of NAO P (India) and International Conference on "Making Psychology Deliverable to the Society"* at Pondicherry University, India.
5. **Kedarmal Verma**, Pallavi Ojha, & Naveen Kashyap (2019). **Sleep Modulates Retrieval of False Memory: Comparing Semantic and Category Associates**, at *29th Annual Convention of NAO P (India) and International Conference on "Making Psychology Deliverable to the Society"* at Pondicherry University, India.
6. **Kedarmal Verma** & Naveen Kashyap (2019). **Role of Sleep using Category Associates in Generation of False Memories**, at *10th IBRO World Congress of Neuroscience (IBRO 2019)* at Daegu, South Korea.

7. **Kedarmal Verma & Naveen Kashyap (2019). Comparing False Memories Induced Through Semantic and Categorical Relations**, at 3rd *National Conference on Recent Advances in Cognition and Health (NCRACH)* at BHU Varanasi, India.
8. **Kedarmal Verma & Naveen Kashyap (2018). Semantic Associates Leads to Higher False Recognition Than Category Associates on False Memory Task**, at 28th *Congress of National Academy of Psychology & International Conference* at University of Delhi, India.
9. **Kedarmal Verma, Suman Dhaka, Jaiprakash Kushwaha, & Naveen Kashyap (2018). Does Sleep Benefit Prospective Intention Realization? Comparing Valence and Neutral Cues**, at 24th *Congress of the European Sleep Research Society (ESRS)*, Basel Switzerland.
10. Lipsa Sahoo, **Kedarmal Verma & Naveen Kashyap (2018). Effect of Emotional Context on Memory Retrieval**, at 5th *Annual Conference of the Association for Cognitive Science*, India at IIT Guwahati, India.
11. **Kedarmal Verma & Naveen Kashyap (2018). Recognition not Recall Improves False Memory Formation in a DRM Task**, at 2nd *National Conference on Recent Advances in Cognition and Health* at BHU, India.

12. **Kedarmal Verma, Naveen Kashyap and Suman Dhaka (2017). Does Stimuli Valence Effect False Memory Recognition in Dees-Roediger-McDermott (DRM) Paradigm?** at 25th *International Conference on Sleep Medicine and Research* at Goa, India.

13. Suman Dhaka, **Kedar Mal** & Naveen Kashyap (2016). **Effect of Transcranial Direct Current Stimulation on Sleep Quality**, at 4th *international conference on Recent Advances in Cognition and Health* at BHU (**Best Paper Award**).

14. Suman Dhaka, Naveen Kashyap and **Kedar Mal** (2016). **Event-Related Alpha and Theta Responses in a Visuo-Spatial Working Memory Task Across Nap**, at 25th *Silver Jubilee Convention, National Academy of Psychology-India*.

15. Dhaka, S., **Kedar, M.** & Kashyap, N. (2015). **Does tDCS differentially modulate object specific encoding across nap**, at Federation of European Neuroscience Societies (FENS) organized conference on *Neurobiology of sleep and Circadian Rhythm*, Copenhagen, Denmark.

16. Suman Dhaka, **Kedar Mal** and Naveen Kashyap (2015). **Does nap deferentially modulate object specific recognition memory**, at 3rd *International Conference on Cognition, Brain and Computation* at IIT Gandhi nagar, Gujarat, India.

CONTENTS

Page Numbers

Declaration	ii
Certificate	iii
Declaration	iv
Acknowledgment	v
Abstract	vi
List of publications	vii - x
Tables of content	xi - xii
Abbreviations	xiii - xiv
List of figures	xv
List of tables	xvi
List of graphs	xvii
<hr/>	
Chapter 01: Introduction and review of literature	01 – 47
Introduction.....	01 – 03
Theoretical Foundation and Review Literature.....	03 – 41
Research Gap in False Memory Literature.....	41 – 43
Rationale of the False Memory Research.....	43 – 45
Research Questions.....	45 – 47
<hr/>	
Chapter 02: Research Aim and General Methodology	48 – 57
Research Objectives.....	48
General Methodology.....	48 – 57
Questionnaires.....	49 – 51
Stimuli.....	52
Task.....	52 – 54
Participants.....	54 – 55
Tools.....	55
General Design.....	56 – 57
<hr/>	
Chapter 03: Stimuli Development	58 – 64
Experiment 01.....	58 – 60
Experiment 02.....	61 – 64

Chapter 04: Behavioral and Sleep Experiments.....	65 – 157
Experiment 01.....	65 – 78
Experiment 02.....	79 – 88
Experiment 03-A.....	89 – 99
Experiment 03-B.....	100 – 116
Experiment 04.....	117 – 157
Introduction.....	117 – 120
Experiment 04-A.....	121 – 139
Experiment 04-B.....	140 – 157
<hr/>	
Chapter 05: General Discussion.....	158 – 167
<hr/>	
References.....	168 – 188
<hr/>	
Appendices.....	189 – 224
Appendix-A.....	189 – 204
Informed Consent.....	190 – 191
General Questionnaire.....	192 – 193
Drug Use Questionnaire (DAST-20)	194 – 195
Memory and Attention Test.....	196
Mood Questionnaire.....	197
The ESS Scale.....	198
PSQI.....	199 – 202
MMSE.....	203 – 204
Appendix-B.....	205 – 207
E-Prime 2.0 Professional.....	206
Polysomnographic Tools and Technique.....	207
Appendix-C.....	208 – 213
Appendix-D.....	214 – 224

ABBREVIATIONS

A'	Sensitivity/Discriminability
ANOVA	Analysis of Variance
ASSM	American Academy of Sleep Medicine
B''	Response Bias
BAS	Backward Associative Strength
BC	Before Christ
CA	Category Associate
CL	Critical Lure
CSA	Childhood Sexual Abuse
DRM	Deese-Rodieger-McDermott
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
ESS	Epworth Sleepiness Scale
FAC	False Alarm Rate to Critical Lures
FAF	False Alarm rate to Foils
fMRI	Functional Magnetic Resonance Imaging
FTT	Fuzzy Trace Theory
H	Hits
HF	High Frequency
LF	Low Frequency
MFQ	Memory Functioning Questionnaire

MMSE	Mini Mental State Examination
NAM	Neighborhood Activation Model
NREM	Non-Rapid Eye Movement
PFC	Pre Frontal Cortex
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
REM	Rapid Eye Movement
SWS	Slow Wave Sleep
WASF	Wake After Sleep Offset
WASO	Wake After Sleep Onset



LIST OF FIGURES

Figure 1.1: Multi-Store Model (Atkinson & Shiffrin, 1968)	Page No. 07
Figure 1.2: Working Memory Model (Baddeley & Hitch, 1974)	Page No. 08
Figure 1.3: Long-Term Memory Division (Tulving, 1972; Roediger, 1990; Schacter, 1987; Sun et al., 2001)	Page No. 10
Figure 1.4: Hypnogram Showing Sleep Stages with Respect to Their Sleep Hours	Page No. 31
Figure 1.5: Sleep Cycle with Different Sleep Stages	Page No. 33
Figure 1.6: Development of Memory during Consolidation Processing (adopted: The Neuroscience of Sleep by Stickgold and Walker, 2009; page no. 231)	Page No. 35
Figure 4.1.7: Experimental Paradigm for Recognition of Words in Semantic Task	Page No. 67
Figure 4.1.8: Experimental Paradigm for Recall of Words in Semantic Task	Page No. 68
Figure 4.2.9: Experimental Paradigm for Recognition of Pictures in category Task	Page No. 81
Figure 4.2.10: Experimental Paradigm for Recall of Pictures in category Task	Page No. 82
Figure 4.3.11: Effectiveness of False Memory Induction Methods Across three retention Intervals in Recall Test	Page No. 91
Figure 4.3.12: Effectiveness of False Memory Induction Methods Across three retention Intervals in Recognition Test	Page No. 102
Figure 4.4.13: Experimental Night Protocol for Category Task	Page No. 125
Figure 4.4.14: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recall Test in Category Task	Page No. 126
Figure 4.4.15: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recognition Test in Category Task	Page No. 127
Figure 4.4.16: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recall Test in Semantic Task	Page No. 143
Figure 4.4.17: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recognition Test in Semantic Task	Page No. 144
Figure 4.4.18: Experimental Night Protocol for Semantic Task	Page No. 146

LIST OF TABLES

Table 1.1: Contribution in Memory Research	Page No. 04
Table 4.2: Mean Scores of Critical Lure Words [Representation: Mean±SD]	Page No. 71
Table 4.3: Mean Scores of Intrusion Words [Representation: Mean±SD]	Page No. 71
Table 4.4: Mean Scores of Studied Words [Representation: Mean±SD]	Page No. 72
Table 4.5: Mean Scores of Critical Lures Pictures and True Target Pictures	Page No. 84
Table 4.6: Mean Scores of Memory Performance in Recall Test Across Task Type	Page No. 95
Table 4.7: Sensitivity (A') and Response Bias (B'') of Critical Lures and True Target Items Across Task Type	Page No. 106
Table 4.8: Mean Scores of Recall and Recognition Memory Across Sleep Nights in Category Associates [Mean (Standard Deviation)]	Page No. 130
Table 4.9: Descriptive Statistics of Polysomnographic Report of Experimental Night for Category Associates [Mean and SD]	Page No. 131
Table 4.10: Mean Scores of Recall and Recognition Memory Across Sleep Nights in Semantic Associates [Mean (Standard Deviation)]	Page No. 149
Table 4.11: Descriptive Statistics of Polysomnographic Report of Experimental Night for Semantic Associates [Mean and SD]	Page No. 150

LIST OF GRAPHS

- Graph 4.3.1:** Mean scores of recall memory, (A) Overall mean scores of CL, Intrusion and Studied items across SA and CA tasks, (B) Mean scores of CLs across retention intervals between DRM and CA task. [$p < 0.05$] **Page No. 96**
- Graph 4.3.2:** Mean scores of recall memory, (C) Mean scores of intrusions across retention intervals between DRM and CA task, and (D) Mean scores of studied items across retention intervals between DRM and CA task. [$p < 0.05$] **Page No. 97**
- Graph 4.3.3:** Mean scores of CLs recognition, (A) Sensitivity of CLs across DRM and CA task, (B) Sensitivity of CLs across retention intervals between DRM and CA Task. **Page No. 107**
- Graph 4.3.4:** Mean Scores of, (C) Response bias of CLs across DRM and CA task, and (D) Response bias of CLs across all retention intervals between DRM and CA task. **Page No. 108**
- Graph 4.3.5:** Mean scores of studied items recognition, (A) Sensitivity of studied items across DRM and CA task, (B) Sensitivity of studied items across retention intervals between DRM and CA Task. **Page No. 109**
- Graph 4.3.6:** Mean Scores of studied items response biases, (C) Response bias of studied items across DRM and CA task, and (D) Response bias of studied items across all retention intervals between DRM and CA task. **Page No. 110**
- Graph 4.4.7.** Number of pictures recalled. (A) true recall of picture items. (B) false recall of critical lure picture items. (C) false recall of intrusion picture items. Comparisons are across sleep and sleep deprivation nights for recall of true target, critical lures and intrusions. (* represents the p-value where, $p < 0.05$; NS = non-significant; Error bars denotes SE) **Page No. 132**
- Graph 4.4.8:** The Recognition Memory was measured by A' (Sensitivity), for (A) Critical lure pictures (False Memory) and (B) True target pictures. (* represents the p-value where, $p < 0.05$ and the error bars denotes the SE). **Page No. 133**
- Graph 4.4.9:** The Memory Response bias calculated by B'' for (C) Critical lure pictures (False memory) and (D) True target pictures. **Page No. 134**
- Graph 4.4.10.** Number of words recalled. (A) False recall of critical lure items. (B) false recall of intrusion words. (C) True recall of studied word items. Comparisons are across sleep and sleep deprivation nights for recall of true target, critical lures and intrusions. (* represents the p-value where, $p < 0.05$; NS = non-significant; Error bars denotes SE) **Page No. 151**
- Graph 4.4.11:** The recognition memory was measured by A', for (A) Critical lure words (False Memory) and (B) True target words. (* represents the p-value where, $p < 0.05$ and the error bars denotes the SE). **Page No. 152**
- Graph 4.4.12:** The memory response bias calculated by B'' for (C) Critical lure words (False memory) and (D) True target words. **Page No. 153**

CHAPTER 01: INTRODUCTION AND LITERATURE REVIEW

“Memory, like Liberty, is a Fragile Thing....” [Elizabeth Loftus]

INTRODUCTION

We all have gone through that feeling where we can swear that we know a person, event or detail but somehow the truth does not add up in reality. The information we claim as true comes to us so naturally that little shred of belief exists on which we can challenge it. Still in reality, our claims are false. The phenomena just described sums up nicely the concept of false memory. Human memory forms an inherent part of the human cognition and plays a major role in most cognitive functions. Our memory defines us and is very intimate to us. Some researchers suggest human memory to be the most systematic study of the soul. Most definitions of memory suggest one of the following meaning – a) a location containing information storage; b) a container of experiences (engram) and c) mental process that acquires stores and retrieves knowledge. A concept closely related to memory is learning which describe the ability of humans to change behavior contingent on experience. Learning leads to memories. Over the years’ memories have been described using metaphors like wax tablets, tape recorder, library, switchboard, lock and key and computer program to name a few. The field of human memory is vast and has a rich history. Below we discuss in brief some historical events in memory research.

Interest in the understanding about human memory started thousands of years ago. In ancient time, Greek philosopher “Plato” wrote about memory that it is “aviary” and compared it to a wax tablet with impressions. Historically memory was compared to empty cabinets, telephone networks and computers. In the 1960s and 1970s, differentiation of memory started and later, memory models

were developed to understand the mechanism and processing of information in the human memory system. It was earlier believed that human memory is susceptible to changes as we get experiences. It is permanent in nature; it will not have affected by any changes or any new mental representations. However, this view of memory was repeatedly challenged with evidences from studies on memory reconstruction. The *false memory syndrome* foundation, formed in 1992 proposed that memory is not permanent rather it can be reconstructing or modified. This ideation of memory has received support from variety of research studies on false memories. Different false memory paradigms were created to prove the reconstructive nature of memory.

Human memory is a cognitive process like perception, attention and thinking. A number of variables influence memory performance. One variable that modulates memory performance is sleep. Previous research suggests that sleep intervening, learning and retrieval of information, improves performance. The benefit of sleep is attributed to processes in sleep that lead to better maintenance and storage of information as compared to similar periods of no sleep. Human memories are never exact copies of the event that they represent. Reconstruction of facts and events are primary to human memories, which result partly due to source or reality monitoring failures. As result of reconstruction, memories retrieved are markedly different from memories that were originally encoded and stored leading to the occurrence of false memories. Since sleep is known to modulate true memories (memories that actually took place and are correctly recalled) it makes sense that sleep does have some influence of false memories (memories of items similar to recall items but were not learned). Evidence from recent research literature is divided on the influence of sleep on false memories. Some research studies point to decrease in the retrieval of false memories following intervening sleep between learning and retrieval, while other similar studies report increased false memories. Similarly, research on sleep and false memories have mostly employed the Deese-Rodieger-McDermott (DRM) paradigm to test false memory.

The present thesis attempts to unravel the influence of sleep on false memories. Research suggests that memory stabilization and consolidation is a time consuming process and continues 48 hours post sleep. The present studies also compare the effectiveness false memory induction using semantically associated words over categorically associated line drawings. Additionally, the present thesis also tests for the persistence of false memories across varied intervals of time including immediate, 24 hours and 48 hours of delay.

THEORETICAL FOUNDATION AND REVIEW LITERATURE

History of Memory Research

Philosophical roots

Research on memory started several hundred years ago. In ancient time, Plato (428-347 B.C.) proposed memory be a bridge connecting the idealized abstraction of the mental world to the perceptual world (Viney & King, 2009). Rene Descartes (1596-1650) and Immanuel Kant (1724-1804) developed Plato's idea further along the rationalist viewpoint and Aristotle (384-0322 B.C.) proposed that the basis of inquiry into mind was an inquiring reality. He proposed that memories are associations among experiences. British empiricists like Berkeley, Mill, Hume and Locke furthered Aristotle's idea into associationism. During the industrial revolution, memory research was pushed to the backburner and it saw daylight only with the advent of research of Charles Darwin who had a lot to say about human thinking and memory. Following table summarized contribution in memory research from ancient scholars.

Contributor	Year	Contribution
Aristotle	384-322 B.C.	Use concepts of priming, interferences, and false memory creation to explain mental associations; three laws of association i.e. similarity, contrast, and contiguity
George Berkeley	1685–1753	Further worked on the Aristotle’s work
John Locke	1632–1704	
John Stuart Mill	1806–1873	
David Hume	1711–1776	
Robert Hooke (Hintzman, 2003)	1635–1703	Theory of memory with a surprising number of modern insights
Charles Darwin (February–March 2009 issue of American Psychologist))	1809–1882	Impact on scientific thinking about human memory

Table 1.1: Contribution in Memory Research

Memory Research in Psychology

In mid-nineteenth century, psychology became an independent discipline and many researchers started the systematic study of memory. Herman Ebbinghaus (1850-1909) did one of the classic study of psychology on himself as the subject and the experimenter. The results of his studies explain the concepts of a learning curve, forgetting curve, overlearning and saving. Ebbinghaus published “*Über das Gedächtnis in (1885)*” which covers details of his experiments on memory and their results. Fredrick Bartlett (1886-1969), studied how prior knowledge influenced memory and found that information stored in memory are often incomplete and fragmented. Bartlett suggested that remembering information from memory is a reconstructive process often guided by

“schemas”. William James in (1842 – 1910) was the proponent of the functionalist school of psychology. In memory research, his ideas about short and long-term memory were very close to the present distinction in memory processes. His ideas on memory retrieval failures in terms of a phenomenon like the tip-of-the-tongue were groundbreaking. *Gestalt* school of psychology (1887 - 1967) advocated by Wolfgang Kohler, Max Wertheimer and Kurt Koffka did not believe in reductionism but rather believed in the entirety. Their ideas on memory namely, ‘*the whole is greater than the sum of its parts*’ is reflected in modern views of memory that suggest memory to be built of simpler configurations and have qualities different from the components. Behaviorism that provided greater credibility to psychology as a science had its own views on memory. Processes of memory like encoding, storage, and retrieval operate at the unconscious level fall under the concept of conditioning. Two salient forms of conditioning, classical and operant are forms of memory. In the first case, operators get prepared for contingencies that are present in the environment while in the second case operators work by remembering the consequences of their previous actions. John Watson, Ivan Pavlov, and B.F. Skinner are pioneers of behaviorism. One behaviorist who has contributed to memory research immensely was Edward Tolman (1886-1959) whose work on rats on mazes lead to the idea that rats store memory representations of spatial locations and these memory representations formed what was called the ‘*mental map*’.

Modern research on memory began with the questions like where is memory located in the brain? and whether it was possible to locate an individual’s memory. Carl Lashley (1890-1958) did a series of studies and found that neural representations of the memory are stored as ‘*engram*’. Similarly, Donald Hebb (1949) through a series of studies suggested that memories were encoded in the nervous system through a two-part process. In the first step, neural excitation would reverberate around cell assemblies followed by physical changes in the interconnections among neurons are part of the second step. These same processes are today termed as long-term

potentiation and long-term depression. Finally, in 1950 after second-world war, “cognitive revolution” started which rejected the black box conception of the brain and started studying mental activity. Cognitivist emphasized the role of organism in the S-R paradigm of behaviorist and proposed the S-O-R paradigm for the study of such cognitive phenomenon as thinking, problem solving, decision making, memory and attention.

Before coming to the topic of this thesis, it would be important to mention some hidden issues which affect memory research in the background. According to *Neurological basis*, memory is itself the property of nervous system so it is very important to understand the neurological basis of memory. As in computer science, software is somehow depending on hardware; likewise, human memory also acts as software whose functioning is dependent on the brain that acts as hardware. *Emotion* is another hidden issue on which the memory processing is dependent. Many memory researchers have added emotions into their research (Kensinger, 2009). Another issue that affects memory process is “*multiple memory source*” which explains that memory task does not use single source but instead uses the multiple sources. For instance, fuzzy trace theory (Braineed, Reyna & Mojardin, 1999) explains that events are stored in memory as verbatim or gist which leads to reproduction of either detailed or general information about the event at retrieval.

Memory Models

Multistore model (Atkinson & Shiffrin, 1968): This model of memory was proposed by Atkinson and Shiffrin in 1968, and is popularly known as “Multi-store model”. The model hypothesizes that information from the external environment is first received then processed and finally stored somewhere in the brain. Memory system is divided into three components i.e. *sensory register*, where incoming information first registers and is available for a very brief time, *short-term storage*

where information from sensory stores resides for 20-30 seconds and finally *long-term store* which stores information for a longer time. Information is processed in a linear path (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965).

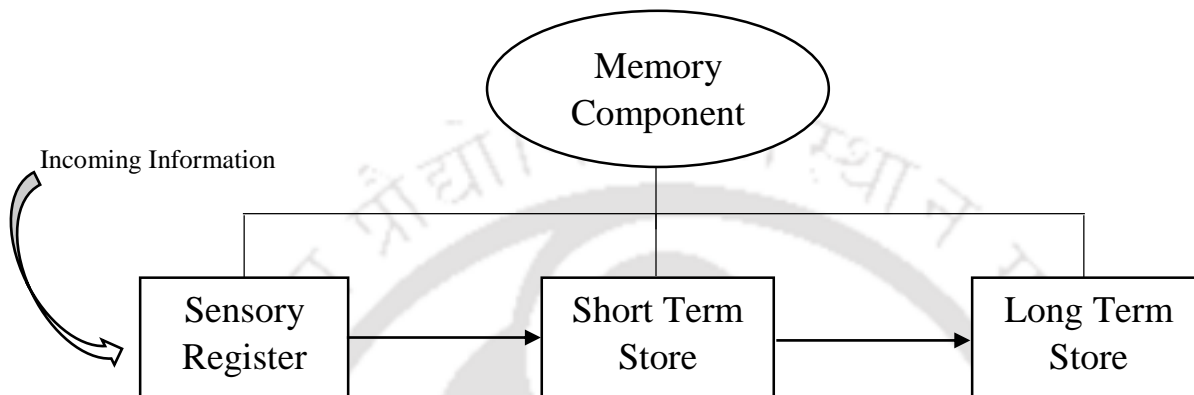


Figure 1.1: Multi-Store Model (Atkinson & Shiffrin, 1968)

Sensory Memory: This memory is initially connected to Perception and described as it is a record of our percepts (Baddeley, 1990). Incoming information initially registers in sensory memory for very brief time and serially propagates to short-term storage to long-term storage.

Short-term memory: It has capacity to hold small amount of information in an active form for short duration. It selects input information from sensory memory (Atkinson & Shiffrin, 1968) and holds it for 20-30 seconds. The capacity of STM is 7 ± 2 chunks of information (Miller, 1956).

Short-Term Memory v/s Working Memory: Multi-store model (Atkinson & Shiffrin, 1968) is a unitary system where no subcomponents are described for each component. It is simple and the information is propagating in a linear manner. Research evidence in connection with the working of the Multi-store model found inconsistencies with the concept of short-term memory as passive store. This led to the introduction a new concept of *working memory* which is the type of short-term memory where information is not stored in single store but is stored under different

subsystems and that information processing in working memory is in active form (Baddeley & Hitch, 1974). According to Baddeley's working memory model, there are three sub-components i.e. *central executive*, *visuo-spatial scratch pad* and *phonological loop* to process different information.

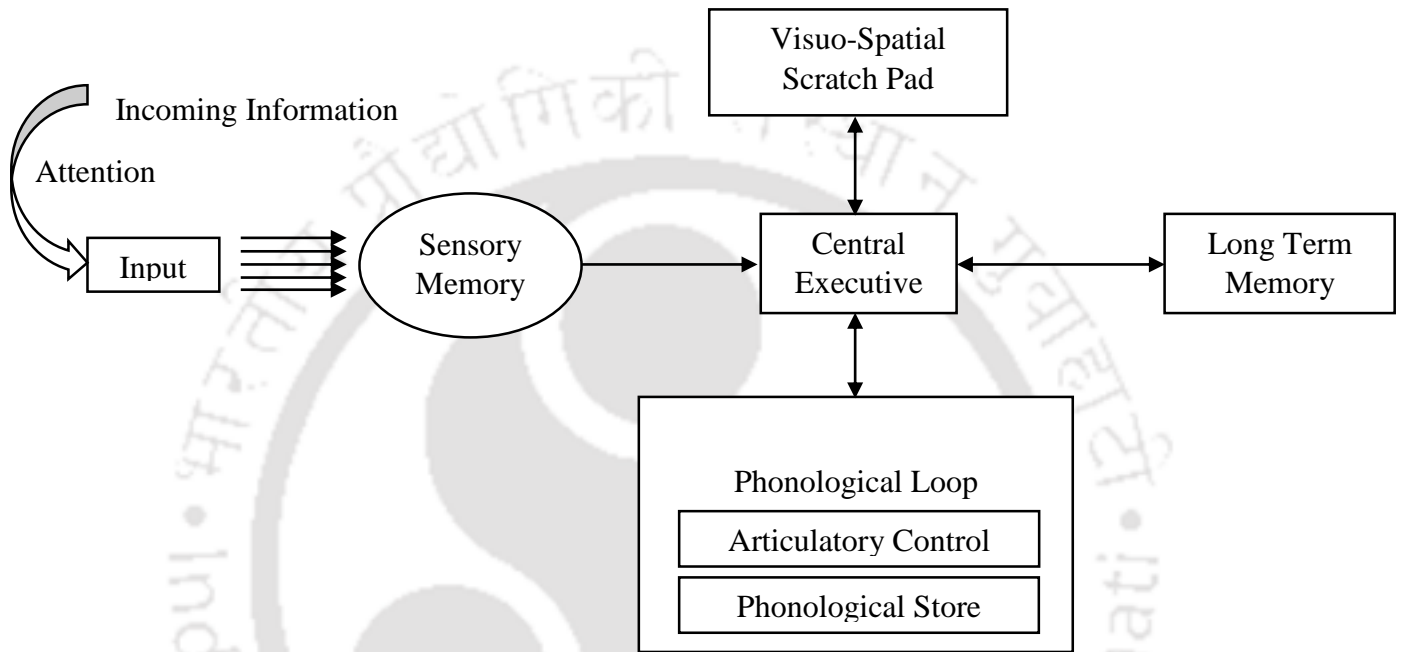


Figure 1.2: Working Memory Model (Baddeley & Hitch, 1974)

Central executive, works as an attentional component rather than memory store and directs the flow of information (Baddeley, 1990), that is central executive does not participate in the storage and retrieval of information instead it allocates resource to cognitive tasks being performed by subsystems under its supervision. Along with the central executive two new subsystems were proposed namely, *phonological loop* which stores and process the verbal materials and *visuospatial sketchpad* that stores and processes the visual materials with their spatial arrangement. Further, a new component added called as an *episodic buffer* (Baddeley, 2000) which interacts with different information and make possible the transfer of information into and from LTM.

Long-Term Memory

In long-term memory, incoming information can be retained for longer duration and its capacity is also unlimited. Akin to Baddeley and Hitch's conceptualization of working memory, cognitive psychologists have sub-divided LTM into different systems which function independently and according to different rules.

Semantic/Episodic distinction: Tulving (1972) subdivided LTM into *episodic memory* which is a memory for specific events and *semantic memory* which is a memory for general knowledge and facts and not bound to particular time and event (Tulving, 1972; Squire et al., 1993). In support of semantic/episodic distinction, Schacter (1996) investigated so many cases of different types of amnesia.

Implicit and Explicit memory: This is another division of LTM done by Roediger (1990) and Schacter (1987). *Explicit memories* are those type of memories which consciously recollected the information and *implicit memories* unconsciously uses the prior knowledge and storage of information.

Declarative v/s Non-Declarative Memory: This division of LTM was established by Sun, Merrill, and Peterson in 2001. *Declarative memories* are basically related to knowledge, facts, information, and ideas, whereas *non-declarative memories (procedural)* deals with that information which are implicitly processed.

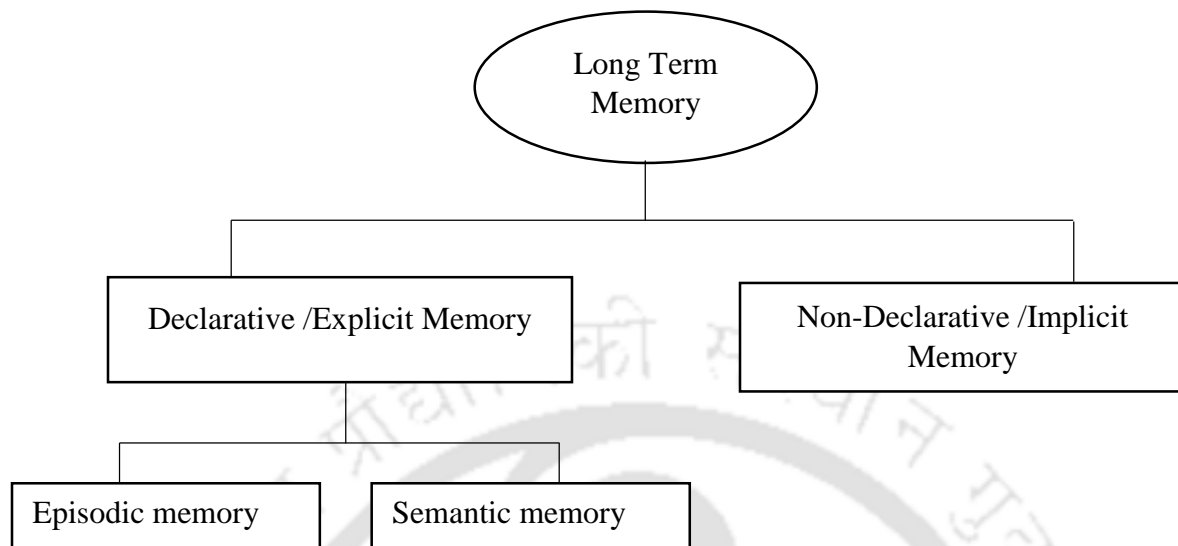


Figure 1.3: Long-Term Memory Division (Tulving, 1972; Roediger, 1990; Schacter, 1987; Sun et al., 2001)

History of False Memory Research

The first reports of false memory syndrome became known in 1992, when a group of families and professionals affiliated with the University of Pennsylvania and John Hopkins University formed the false memory syndrome foundation to document the problems faces by families in which certain individuals have memories of childhood sexual abuse. Following the reports, a massive increase in reports of false memory cases arose within the society. The scientific study of false memory, however, has roots in the work of three famous psychologists including the work of Alfred Binet (1857-1911) on suggestive questioning in the legal arena, Jean Piaget (1896-1980) works in constructive memory in children and Frederic Bartlett (1886-1969) reports on repeated recall of narrative texts in adults. Binet offered four conclusions about false memory reports. *First*, memories of individuals are susceptible to distortion through autosuggestion or misinformation. *Second*, nature and form of leading questions distort memories. *Third*, he suggested the once an

erroneous response is given it is incorporated in memory and *fourth* he reported that small children are more susceptible to memory distortion when tested in groups. Like Binet, Jean Piaget also found that children were more susceptible to false memories. Piaget made two predictions about memory falsification. *First*, he proposed that false memories arise because of mismatch between children's cognitive developmental stage and the stimuli to be remembered. *Second*, he reported the *long-term improvement* effect that suggests forgetting induced deterioration of memories were very low in children. Frederic Bartlett conducted experiments on remembering of texts (*war of the ghost*) across multiple retrievals sessions and concluded that recall of narrative was constructive and took on specific "form" (*gist memory*) from the first attempt and was preserved on delayed tests. He also reported that the productions (both the first and subsequent ones) were more concise and tightly organized than the narrative itself; many details from the narrative were omitted; and many of the reported details were recalled in a distorted manner, including additions of unstated objects and events. In 1974, most prominent cognitive psychologist "Elizabeth Loftus" became a lead false memory researcher after her debuting research project to investigate the effect of language on the development of false memory. Post-1995 a lot of work is being carried out on false memory phenomena.

Reconstructive Nature of Memory

The first reports of false memory syndrome became known in 1992, when a group of families and professionals affiliated with the University of Pennsylvania and John Hopkins University formed the false memory syndrome foundation to document the problems faces by families in which certain individuals have memories of childhood sexual abuse. Following the reports, a massive increase in reports of false memory cases arose within the society. The scientific study of false

memory, however, has roots in the work of three famous psychologists including the work of Alfred Binet (1857-1911) on suggestive questioning in the legal arena, Jean Piaget (1896-1980) works in constructive memory in children and Frederic Bartlett (1886-1969) reports on repeated recall of narrative texts in adults. Binet offered four conclusions about false memory reports. *First*, memories of individuals are susceptible to distortion through autosuggestion or misinformation. *Second*, nature and form of leading questions distort memories. *Third*, he suggested the once an erroneous response is given it is incorporated in memory and *fourth* he reported that small children are more susceptible to memory distortion when tested in groups. Like Binet, Jean Piaget also found that children were more susceptibility to false memories. Piaget made two predictions about memory falsification. *First*, he proposed that false memories arise because of mismatch between children's cognitive developmental stage and the stimuli to be remembered. *Second*, he reported the *long-term improvement* effect that suggests forgetting induced deterioration of memories were very low in children. Frederic Bartlett conducted experiments on remembering of texts (*war of the ghost*) across multiple retrievals sessions and concluded that recall of narrative was constructive and took on specific "form" (*gist memory*) from the first attempt and was preserved on delayed tests. He also reported that the productions (both the first and subsequent ones) were more concise and tightly organized than the narrative itself; many details from the narrative were omitted; and many of the reported details were recalled in a distorted manner, including additions of unstated objects and events. In 1974, most prominent cognitive psychologist "Elizabeth Loftus" became a lead false memory researcher after her debuting research project to investigate the effect of language on the development of false memory. Post-1995 a lot of work is being carried out on false memory phenomena.

The Recovered / False Memory Debate

In recent years, the most influencing debates in cognitive psychology are the concern with the issues of forgetting, retrieving and creating autobiographical memories. Primarily, the debate started with the understanding of the effect of childhood sexual abuse (CSA) trauma on adult memory. It was observed that few survivors of war and random violence show complete loss of memory for events (Pope et al., 1998) and many have good memory for traumas (Golier, Yehuda & Southwick, 1997). On another side scientist's evidence, criticized that the events studied in laboratory settings were not similar to CSA to validate for generalization (Berlinear & Williams, 1994; Kluft, 1997). One of the most active participant in this debate was Elizabeth Loftus when she has started a review article (Loftus, 1993).

In response, new research paradigm was developed which induced participants to recall their childhood events which had not occurred. This paradigm creates false memories by suggestibility (Loftus & Pickrell, 1995) and narratives (Garry & Wadi, 2005). In 1999, Porter et al. found in their study that 25% of adult participants developed complete false memory while 30% partial false memory for their events (Porter et al., 1999).

Laboratory-based studies on false memory started when McDermott and Roediger developed the famous paradigm known as *DRM paradigm* (Roediger & McDermott, 1995). This DRM paradigm simplifies false memory research under laboratory settings and has been used in dozens of studies evaluating false memory phenomena within the constraints of laboratory (Pezdek & Lam, 2007). An fMRI study showed that different areas of the brain were activated during true and false *word recognition* in false memory experiment designed using the DRM paradigm (Cabeza et al., 2001).

It becomes clear from the discussion above that human memory is malleable in nature and open to shaping. How such shaping of memory occurs, what are the mechanism, how do different stimuli affect false memory, how does neural activity changes with different stimuli for false memory etc. are very exciting questions to unravel.

What is a false memory?

In general, we can define false memory as recollection/remembering of events that did not actually happen/occur in the past. According to literature, the available false memory definition varies as some researcher state it as an error of commission (distortion) (Barlett, 1932; Carmichael, Hogan & Walter, 1932), while others define it as a constructive process of memory (Bransford & Johnson, 1973; Loftus & Palmer, 1974). Groups of researchers have studied false memory in terms of false recognition of words (Anisfeld & Knapp, 1968; Cramer, 1970; Underwood, 1965), and false recall of words (Deese, 1959).

Varieties of false memory

The different types of false memory are actually dependent on the varied experimental paradigms. There are two types of responses through which occurrences of false memory can be identified *intrusion* that occurs during recall test and *false alarms* that occur during recognition test. Experimental paradigms for false memory includes *semantic intrusion* in list recall, *semantic false alarms* in list recognition test, *false memory during inferences*, *suggestibility* of eyewitness memory, *false identification* of criminal suspects, false memory for *schema-consistent events*, false

memory in *reality monitoring*, false memory for *reasoning*, and *autobiographical false memory* (Brainerd & Reyna, 2005).

- 1) *Semantic intrusion in list recall*: In this paradigm, subjects are presented with lists of semantically associated words. The list recall paradigm yields a characteristic false memory effect – the recall of some unstudied words that preserve the meaning of studied words. The false recall of these words is known as *semantic intrusions* in list recall. This procedure is a standard in false memory research.
- 2) *Semantic false alarms in recognition* – In word recognition experiments subjects study words and perform on a “yes” or “no” memory test to judge whether probe words are from learned lists or not. The test probes are either presented (*target*) words or unrepresented (*distractors or lures*) words. Correct judgments of targets form *hits* while incorrect judgments of unrepresented words as targets form *false alarm*. False alarms are the false-memory responses in recognition studies.
- 3) *False memory for semantic inferences* – Bransford and Franks (1971) made subjects study sentences containing a different number of proportions (idea units) and then respond to recognition tests on which some probes were targets and others were unrepresented sentences (meaning preserving distractors and meaning violating distractors) containing the studied propositions. They reported that subjects readily identified meaning violating distractors as new. However, subjects could not distinguish with high confidence between targets and meaning preserving distractors on ‘*old/new recognition test*’ suggesting that false and true memories were highly intertwined.
- 4) *Suggestibility of eyewitness memory* – Loftus (Loftus 1975; Loftus et al., 1978; Loftus & Palmer, 1974) developed a procedure for studying whether suggestive questioning falsifies witness’s memory for crucial details. The central hypothesis behind her proposal is that

inherent constraints of eyewitness's situations may make the resulting memories especially vulnerable to distortions via suggestions. Crimes involve complex events sequences that revolve around a theme with most events being only briefly experienced and attended, it can be predicted that events memories might be excellent while memories for many details be sketchy to non-existent.

- 5) *False identification of criminal suspects* – Eyewitness identification is important to the legal system. Testing of an eyewitness in the laboratory requires exposing the witness to precisely controlled sequences of events followed by later identifications under two test formats: culprit present and culprit absent.
- 6) *False memory for reality monitoring*- These *reality-monitoring failures* are an interesting variety of partly-true-and-partly-false memories. They are true as they are within the compass of one's experience, but are false in the sense that the origin of the events has been misidentified.
- 7) *False memories for reasoning* – This paradigm centers on the possibility that memory falsification can be an outgrowth of reasoning error. Illogical reasoning related outcomes might contribute greatly to the loss of subject's memory for the information on which reasoning was based, distorting memory so that it adheres with the outcomes of the reasoning (Reyna, 1995).
- 8) *Autobiographical false memory* – This paradigm of false memory is the least controlled and most naturalistic and suffers from problems of clean measurements of true and false memory and clear experimental manipulations. Establishment of cause and effect relationships between variables and false memories is very difficult under this paradigm. Subjects under this paradigm live their lives ordinarily with experimenter intervention and report target events in diary. Later at some point in a future test of subject's memories for life events from the diary is tested.

Existence of false memory

It is difficult to maintain control over stimulus during false memory experimentation (Roediger, 1996), and this may be the reason for limited research on memory illusion until the middle of 20th century.

Evidence for false memory presence

A host of research studies proves that false memory exists. Researchers found that false memories could be created and implanted. A classical study done by Loftus and her colleagues (Loftus, Feldman & Dashiell, 1995) reported that eyewitness recognizes false information as true. In this study, they provide set of questionnaire to implant false memory (*misinformation effect*: McCloskey & Zaragoza, 1985) in which misinformation is provided to witness for implanting a false memory. *Suggestibility* is another factor that implants false memory. A famous study was done to investigate the susceptibility of children for false memory. The study used Sam-Stone experiment (Leichtman & Ceci, 1995) and found that age, stereotype, and suggestion are factors influencing the formation of false memory. A lot of paradigms have been developed to implant false memory (Koriat et al., 2000; Loftus, 2003).

False memory generation in laboratory setup: The DRM paradigm

It is possible to create false memory in laboratory settings. Deese (1959) performed the first false memory experiment which was reinvented in the work of Roediger and McDermott in 1995. They made a famous, reliable and better paradigm known as DRM (Roediger & McDermott, 1995). DRM paradigm uses the recall and recognition test for verifying the false memory occurrences.

Generally, false recall and recognition rates are high for non-studied critical lure words (Roediger & Gallo, 2003) and critical lure words recognize with confidence rating known as remember/know judgment scale (Tulving, 1985). A lot of false memory research has been done using DRM paradigm (Gallo, 2006; Roediger & Gallo, 2003). DRM paradigm is presently the most reliable tool to study false memory under laboratory conditions.

Theoretical Basis of False Memory

The present section will explain the theoretical principles behind the workings of false memory phenomenon. This section is divided into two parts. The first part includes “early explanations” based on traditional theories and the second part includes “recent approaches” to the study of false memory. Early explanations use three traditional scientific knowledge i.e. *constructivism*, *schema-theory*, and *source monitoring framework* while the recent approaches are explained through the *opponent-processes theories*.

Early explanation

There are three traditional approaches to explain false memory mechanism. The first of the three traditions *Constructivism* includes studies of false memories for semantic inferences (Bransford and Franks, 1971; Kintisch, 1974) and false memory for ambiguous texts narratives (Bartlett’s, 1932). The approach intended to explain errors in memory for complex narrative materials. The second approach *schema theory* evolved from schema consistent memory (Brewer & Treyens, 1981; Lampinen et al., 2001) and centers on erroneous memories of people, objects, and events that are normally experienced (dining at a restaurant). The third approach, *the source monitoring*

framework emerged from reality monitoring studies (Johnson et al., 1988) and studied partly-true-partly-false memories in which the remembered event was actually experienced (dreams to thoughts). Source monitoring theory suggests that the origins of such experiences are often incorrectly remembered by relying on cues that are generally but not invariably reliable discriminators of real versus mental experiences.

Recent explanation

Modern explanations of the false memory phenomena can be illustrated with the help of *opponent processes theories* that were developed from *dual processes theories* of true memory. Therefore, it is necessary to know the dual process theories of true memory. According to dual-process theory, *recognition* phenomena are a two-part process involving *familiarity* and *recollection*. Work of Atkinson and colleague (Atkinson & Juola, 1973, 1974; Atkinson & Wescourt, 1975; Juola, Fischler, Wood & Atkinson, 1971); Mandler and team (Mandler, 1980; Graf & Mandler, 1984) and Jacoby (1991) explained and developed the theoretical explanation for dual processes of recognition. For *recall*, the dual process explanations are less available but recently dual nature for recall task has appeared (Bellezza, 2003) which includes, *recognition like recall* and *pure recall*.

1. Fuzzy-trace theory

Initially, *fuzzy trace theory* was used to describe reasoning and decision-making mechanism but recently (Brainerd & Reyna, 2001; 2002; Reyna, 1995; Reyna & Brainerd, 1995) it is being used for explaining false memory mechanism. According to this theory, two memory traces are established i.e. *verbatim* and *gist*. Verbatim trace of memory stores the surface detail of stimuli

and gist trace stores the meaning of stimuli. This theory states that false memory depends on *gist trace*. Fuzzy-trace theory uses the *opponent process* where false memory increases during study as the process produces *gist traces* whereas decrement occurs at retrieval through memory editing process which controls recollection.

2. Activation monitoring framework

This is another account of false memory mechanism that was actually developed from source monitoring framework. This theory was developed by Roediger and his colleagues (Roediger et al., 2001) in which two opponent process occur to check the dissociative effect of study variables i.e. during study phase, activation of critical words occurs and source monitoring/memory editing occurs during retrieval time. In brief, during study phase *distinctiveness* of words enhances its retrieval dependent on its item specific aspects and relationship with list words (Hunt & Einstein, 1981). During test time, participants distinguish activation of the actual list presented and internal activation and the mistake of internal activation for critical words results into source monitoring error (false memory generation).

Major Findings in False Memory

Researchers argued that therapeutic practices can create false memories in individuals and published the details of the reality of repressed memories (Loftus, 1993; Lindsay & Read, 1994). Attention towards *false memory* started when a legal case of 1990, bearing long-term repressed memory (20 years) was investigated and the memory report was vetted by a therapist and family members (Loftus, 1993). After this case, media houses started publishing lots of cases bearing

resemblance to false memory (Darnton, 1991; Oldenberg, 1991; Ritter, 1991; Edmiston, 1990), lawyers started consulting court cases with psychologists for their views on the false memory perspective (Lofft v. Lofft, 1989), and a number of people started reporting repressed memories relating incidents (Loftus, Weingardt, & Hoffman, 1993). The authenticity of repressed memories started being debated in academic circles (Bottoms, Shaver, and Goodman, 1991; Ganaway, 1989). These debates outlined some sources that can affect memory authenticity like therapist's suggestions (Ganaway, 1989), and taped interviews (Watters, 1991) and clearly evidence the malleable nature of memory (Harsch & Neisser, 1989). This was the start of false memory research within the scientific world.

False Memory formation: Loftus and Pickrell (1995) conducted a classic experiment that proposed a possible mechanism for false memories. They reported that misrepresentation of post-event information can alter the recollection of individual which enhances false memory formation. They argue that the suggestion of being lost in the mall (Loftus & Pickrell, 1995), hospitalization and other events (Hyman et al., 1995) develop memory traces and these suggestions when gets integrated with other similar knowledge of being lost (other's stories), leads to false memories. They also hypothesized that *schematic reconstructions and source confusion* may also be responsible for false memory formation (Schacter & Curran, 1995).

DRM Paradigm Development: In the year 1995, a famous false memory paradigm known as *DRM Paradigm* was developed by Roediger and McDermott. By the development of this paradigm, it becomes very easy to investigate false memory in laboratory settings and in recent two-decade maximum false memory research was done with DRM paradigm (Pezdek & Lam, 2007). Before developing DRM paradigm, the occurrence of false memory was investigated with sentences (Bransford & Franks, 1971; Brewer, 1977), prose passages (Scullin & Dooling, 1974), slide

sequences (Loftus, Miller, & Burns, 1978) and videotapes (Loftus & Palmer, 1974). In all of these paradigms, the magnitude of false memory effect was depending on the method of testing (McCloskey & Zaragoza, 1985; Payne, Toggia, & Anastasi, 1994).

Roediger and McDermott (1995) repeated Deese's (1959) findings and found that his subjects often accurately recalled the list items after single trial with a few intrusions when they were instructed to guess (Cofer, 1967; Roediger & Payne, 1985). They also employed the remember / know procedure (Tulving, 1985) to explain the phenomenological basis for false recognition of non-presented critical words. They had found that non-presented critical words were more falsely recognized than weakly related words and interestingly the hit rates were almost same (Non-presented words rate=.84 and presented words=.86). Their results showed that false recognition is directly related to the number of related words in the list (Hall & Kozloff, 1973; Hintzman, 1988).

Underwood (1965) explains that false recognition actually starts implicitly during encoding phase when subjects are seeing the associative words. If the subject is not attending the list words attentively then activation implicitly spreads through the associative networks (Anderson & Bower, 1973; Collins & Loftus, 1975) causing false recognition error due to residual activation left within networks. Reality monitoring within associative networks could additionally enhance false memories (Johnson & Raye, 1981). Most theories assume that false memories occur during encoding (Tulving, 1974) but some researchers suggest that repetition at retrieval could also cause false remembering (Ceci, Huffman, Smith & Loftus, 1994; Hyman, Husband & Billings, 1995; Roediger et al., 1993).

Presentation Modality Factor: Smith and Hunt (1998) showed that stimuli presentation modality effects false memory creation under DRM paradigm. They found that in visual presentation, the false memory reduces in comparison to auditory presentation (Smith & Hunt, 1998). Visual

processing can easily discriminate the study items and non-studied critical items as compared to auditory presentation (Hunt & McDaniel, 1993). It was assumed that visual processing is more discriminable than auditory processing as high correlation was reported between items retrieved and their details on visual modality task as compared to auditory task (Johnson, Nolde & De Leonardi, 1996). The presence of modality effect suggests that discrimination processing for studied as well as non-presented item can occur both at encoding and retrieval. It was also found that false remembering is a function of encoding as well as retrieval when modality of presentation was at play on false memory tasks (Percer & Roediger, 2001). Studies reported that false recall was more when items were auditory studied than visually (Percer & Roediger, 2001; Exp. 01) and that a higher false recognition was observed in the auditory study than visual study when the test was visually performed (Percer & Roediger, 2001; Exp. 02 & 03).

Methodological differences: Within presentation modality can be possible difference for varied results on false memories across modalities. Between subject manipulations of presentation modality revealed reduced false memories for pictorial stimuli over word stimuli (Israel & Schacter, 1997) however, the effect was considerable low when modality manipulation was done within-subject (Schacter et al., 1999). In support of these findings, it was argued that between subject manipulations of modality encouraged subjects to use *distinctiveness heuristic* for reducing false recognition. Subjects during the visual presentation were less likely to encode thoughts of critical lure words (implicit associative response) or theme of list items (gist representation) than during auditory study, hence were unable to recognize and recall the critical words during the test.

Retention Interval and Level of Processing: It was seen that different retention intervals (across time) and level of processing (deep or superficial) affects false recall and recognition in DRM paradigm (Thapar & McDermott, 2001). In terms of the level of processing, it was seen that

presentation order of list affects the false recall. When lists were presented in a blocked manner false recall and recognition were more in comparison to the random presentation of lists (Mathar, Henkel, & Johnson, 1997; McDermott, 1996; Toggia et al., 1999). It was observed that across retention (immediate, 2 days, 7 days), false recall of non-presented critical words and studied words decrease with deep level processing (pleasantness rating, vowel counting) but for superficial processing (color identification) (Thapar & McDermott, 2001) false recall was more for studied words. Sensitivity measure (d' value) of false recognition decreased for varied retention intervals and levels of processing however, the absolute measure did not differ much. This effect was explained with two theoretical principles i.e. *source monitoring framework* and *fuzzy-trace theory* which predicts that verbatim details are forgotten across time and relative increase in semantic/gist information (Barclay & Wellman, 1986; Liecht, 1968; Reyna & Kiernan, 1994; Sachs, 1967).

Presentation duration of lists items: The presentation duration of list items also has impact on the formation of false memory. It was seen that shorter presentation duration of semantically as well as phonologically (Watson, Balota & Roediger, 2001; Sommers & Lewis, 1999) related lists words lead to increased false recall (McDermott & Watson, 2001) and false recognition (Seamon, Luo & Gallo, 1998). It was also seen that inter stimulus interval (ISIs) also affect false memory with increased ISIs leading to the decrement of false recall (Toggia & Neuschatz, 1996). There are two basic processes which seem to help in the formation of false memories in DRM paradigm, i.e. *spreading activation* and *monitoring* (Roediger & McDermott, 2000; Balota et al., 1999). During *spreading activation*, one concept is connected to another concept in such a way that activation of one leads to activation of another through connected nodes (Collins & Loftus, 1975). This spreading activation process is automatic and fast processing (Posner & Snyder, 1975) and the level of activation will be greater when the associative link between list words and critical words will be stronger. *Monitoring* process is another mechanism for an explanation of false memory

generation. This process is basically strategic or control process which takes place during encoding and retrieval. During encoding, people separate cues of the environment and thoughts generated by the external environment. During retrieval time, people decide whether the activated concept is related to the previously occurred event (McDermott & Watson, 2001). *Neighborhood Activation Model (NAM)*: Luce & Pisoni, 1998) describes auditory word recognition in which stimulus words are recognized in the context of phonologically similar words. It was seen that false recall can also be induced through phonological modality and false recall pattern is also looks similar to semantic list's pattern (Sommers & Lewis, 1999).

Additional characteristics of stimuli responsible for false memory generation: It was seen in the DRM paradigm (the most influential technique to create a false memory at present time) based researches that, certain features of stimuli that enhance false memory (Roediger, Watson & McDermott, 2001). Some of these stimuli characteristics that influence the mechanism of false memory formation in DRM paradigm is discussed. Deese (1959) identified two factors which affect veridical as well as false recall. The two factors were *associative connections* between words within the study list and *associative connections* between study list words and critical words. It was reported that when stronger associative strength between items of the list will lead to better recall of list items and decrease intrusion (Deese, 1959a). When the association between study list and critical word is stronger, false recall of critical item will be greater (Deese, 1959b). BAS (Backward Associative Strength) is the predictor which can predict the variance in the false recall. High BAS value activates critical items when list items are presented (Deese, 1959b) unconsciously through *spreading activation* (Roediger, Balota & Watson, 2001). A few researchers have started working on factors which effects false memory formation. like *Inter-Item Associative Strength* (they call it as connectivity) and mean BAS value for critical items (McEvoy, Nelson, & Komatsu, 1999). They reported results similar to Deese (1959a; 1959b) that greater

inter-item associative strength of the list leads to more recall of list items and lower false recall of critical items. They also found that high BAS value lists lead to more false recall than low BAS value lists. Interestingly low BAS value list words produce high false recall and false recognition (Gallo & Roediger, 2002) and thus it was argued that BAS is not the only factor for false memory creation but factors also effectively modulate false memories (Roediger, Watson & McDermott, 2001). These factors are; *Critical Item Variables* includes Word length, Raw Frequency, Concreteness and *List Variables* includes, Forward Associative Strength, Backward Associative strength, Inter-item Associative Strength/Connectivity, Veridical recall of the list.

Word length, it is the number of letters present in a word. Longer words are more distinctive than shorter. Lengths of critical words are negatively correlated with false recall (Roediger, Watson & McDermott, 2001). *Raw frequency* is number of time a word is printed per million words (Kucera & Francis, 1967). *Concreteness*, it is the rating of critical words on the scale of 1-7, where 1 indicates the *least concreteness* and 7 indicates *most concrete* (Nelson et al., 1999 (published in 2004); Paivio, Yuille, & Madigan, 1968; Toggia & Batting, 1978).

Forward associative strength, is the associate strength between critical word and study word (Nelson et al., 1999 (published in 2004)). *Backward associative strength*, it is the connection between words from study item and critical word (Nelson et al., 1999 (published in 2004)). Mean BAS and false recall, both are positively correlated to each other (Roediger, Watson & McDermott, 2001), mean stronger BAS value leads to a false recall. *Inter-item associative strength/connectivity*, is the connectivity between an item of the list. High mean connectivity score indicates high relationship between items and low mean connectivity score indicates less relationship between items within the list. *Veridical recall of list*, this is the average probability of recall of the studied items. Veridical recall of list items and false recall are negatively correlated (Roediger, Watson & McDermott, 2001). Among these lists of variables only two variables i.e.

Mean BAS value of list items (positively correlated with false recall) and veridical recall items (negatively correlated with false recall) were found significant in influencing false memories. In comparison for false recognition, three factors have been reported significant i.e. word length (negative correlation with small value i.e. $r = -.27$), BAS and veridical recognition (Roediger, Watson & McDermott, 2001). Higher mean BAS value of study list items leads to high false recall (positive correlation) and high veridical list item recall leads to lower false recall (negative correlation).

Category Associates and False Memory: False memory research found that *converging associates* (Roediger & McDermott, 1995) affects the false recall and false recognition by using *continuous recognition paradigm* and *recall/recognition DRM paradigm* respectively. There is another factor known as *categorical associates* which effectes false memory creation (Hintzman, 1988). In the categorical associative procedure of false memory creation, few exemplars per category are presented to subjects randomly and at the time of recognition test subjects have to distinguish studied exemplar and related nonstudied exemplars (Hintzman, 1988), he found that greater exposure of categorical items leads to more false recognition of related nonstudied exemplars. For example, *reading material* is category for *booklet, pamphlet, comic book, broacher* (possible exemplars) etc. False memory for category associates was investigated on children (Brainerd, Reyna & Kneer, 1995b) and it was found that false recognition in younger children was higher than older children over a retention interval of 1-week (Brainerd & Reyna, 1996). Black and white (Strack & Bless, 1994) and colored (Koutstaal & Schacter, 1997) Pictures were also used as stimuli for false memory effect for the category associate. Theoretical explanation of false memory creation for category associates is also supported by Underwood's activation hypothesis (*implicit activation response hypothesis*) which states that during study phase subject is faced with the set of exemplar of the same category which additionally activates non-studied category items

according to their associative strength. Finally, at retrieval activated category leads to activation of non-studied exemplars as false memory. The category items activation might be conscious or unconscious in nature.

Procedure for Category Associates Paradigm: The manipulation of stimuli in category associates are based on *Batting and Montague's Category Norms (1969)*. Category exemplars are presented in blocks during the study phase. The arrangement of exemplars in the category list is according to the frequency of citation in the Batting and Montague norms. During study phase, in category associative procedure, high frequency and low-frequency exemplars are removed from category list and used as critical lure items. During the test phase, this high frequency and low-frequency exemplar items are recognized. Previous researchers did not use the ordered category exemplars (Hintzman, 1988; Strack & Bless, 1994).

History of Sleep Research

Sleep has been a subject matter of research from the time of Greek philosophers to the present day science. Sleep is a natural phenomenon which is not only related with human being but also all the living organisms. The evolutionary timeline for sleep research is from 800 B.C. to till date (<http://healthysleep.med.harvard.edu/interactive/timeline>). Different perspectives and definitions regarding sleep and sleep mechanism were provided by different philosophers in their contemporary periods, viz. Hippocrates (400 B.C.), Aristotle (350 B.C.), Rene Descartes (1619), etc.

In 1834, Rober MacNish published the article “The Philosophy of Sleep” which suggests that, sleep is the intermediate state between wakefulness and death. In 19th century, the relation between eye movement and sleep was first described by Wilhelm Griesing (1868). In 1875, before 50 years

of first EEG development (Hans Berger in 1925), Richard Caton (1875) detect the electrical activity on surface of brain.

The 20th century was devoted for development of tools and basic techniques of sleep research including the discovery of neuronal cells by Cajal (1900) and the first *sleep pill* (known as *Barbital*) to treat insomnia and anxiety. An interesting turn comes in sleep research when the first EEG was developed by German Psychiatrist Hans Berger (1924) to obtain the world's first electrical brain activity of human being. The following year Nathaniel Kleitman setup the world's first sleep laboratory in university of Chicago and became the "father of modern sleep research". Further in 1935, the concept of *biological clock* was introduced by German biologist Erwin Bunning. The year 1937 have great importance in sleep research as in this year, Alfred Loomis, E. Newton Harvey, and Garret Hobart identified the five different stages of sleep i.e. Alpha, low voltage, spindles, spindles plus random, and random using EEG and in the year 1953, REM sleep was discovered by Eugene Aserinsky (student of Dr. Nathaniel Kleitman) and coined the term REM. In subsequent year 1954, the cyclic nature of sleep was established by William C. Dement (another student of Dr. Nathaniel Kleitman). Year from 1960 to 1989, different types of sleep related concept were developed viz. bed-wetting, sleep apnea, genetic links, different sleep disorders etc.

In year 1968, Allan Rechtschaffen and Anthony Kales developed the scoring criteria for sleep stages, they called them "*A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects*" that was modified in 2007 by the American Association of Sleep Research. Epworth Sleepiness Scale (ESS) was developed by Murray Johns in 1991. This is a diagnostic tool for diagnosing sleep disorders and is subjective in nature for the assessment of daytime sleepiness.

Neuronal group theory of sleep by James Kmeger and Feruncobal in 1993, and brain energy metabolism theory was given by Craig Heller and benington in 1995. From 2000 to 2010 recently, new insights into sleep research has been done including, hPer2 gene identification (2001), Melanopsin pigment involvement in circadian system (2001), Restless legs syndrome (RLS, 2003) and iron deficiency relationship, synaptic homeostatic hypothesis (2003), circadian behavioral neural pathway (2003) identification.

The most important active finding in sleep research was identified by Robert Stickgold, Matthew Walker and colleagues. They had found the relationship of sleep and memory. Further in 2007, reclassification of sleep stages was done by *American Academy of Sleep Medicine (ASSM)*, they classified the NREM into three categories viz. N1, N2, and N3. Previously NREM was divided into four stages.

Diekelmann et al. (2008) conducted a study on sleep and false memory in which they investigated whether sleep is responsible for memory performance on false memory tasks (DRM task). With progressing research, a number of variables affecting false memory are being analyzed across sleep. Till date however, the role of sleep in formation of false memory is still unclear

Definitions and Descriptions of Sleep

Polysomnography (PSG), can be defined as “this is the study of sleep” and it is a diagnostic tool used in sleep medicine. The output of polysomnography is known as “*polysomnogram*”. Polysomnography involves recording of brain signals originate during sleeping brain. Under clinical settings it records the brain activity (EEG), eye movement (EOG), muscle activity (EMG), leg movements, heart rate (ECG), blood hemoglobin concentration (Spo2) during sleep. Following

are some important components of a sleep report, viz. *sleep architecture*, *total sleep recording time*, *sleep latency*, *total sleep time*, *sleep efficiency*, *WASO*, *WASF*, and *REM latency* etc.

- 1) *Sleep Architecture*: Sleep architecture is the graphical representation of sleep pattern. It includes all the sleep stages in cyclic manner. This graphical representation is known as “hypnogram”. Hypnogram is graphical representation that plots sleep stage against their respective time duration (See image).

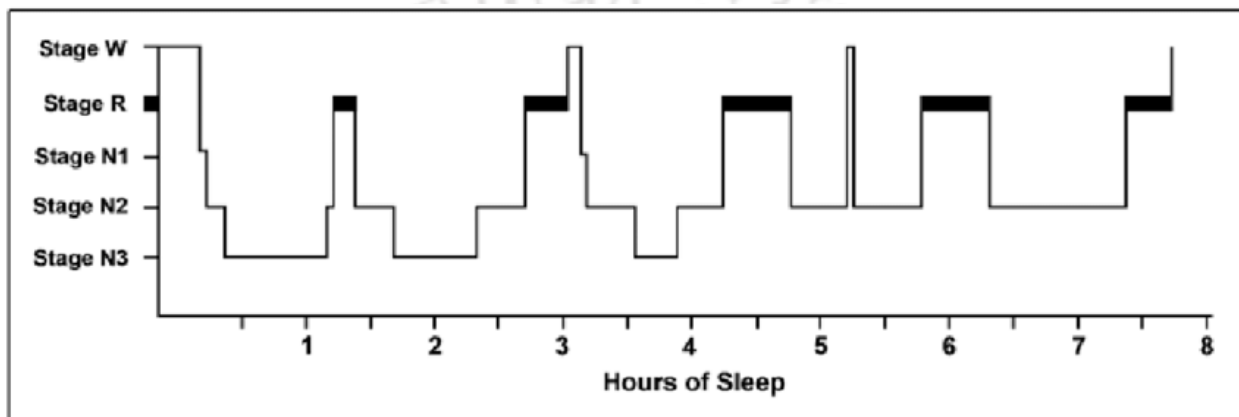


Figure 1.4: Hypnogram Showing Sleep Stages with Respect to Their Sleep Hours

- 2) *Total Sleep Recording Time*: This is the total bed time. It starts when the recording device is ‘ON’ and ends when the device is switched off.
- 3) *Sleep Latency*: This is another parameter of sleep report. This is the time duration from which the light gets off (light out) and participant starts to sleep. It is measured in minutes.
- 4) *Total Sleep Time*: This is the total amount of sleep scored during total recording time. This is actually the sleep onset to sleep offset time. It includes all the sleep stages viz. N1, N2, N3, and REM. Low sleep time indicates that participant get insufficient sleep. Less sleep time is might be due to medications, sleep disorder, and longer sleep time might be due to prior sleep deprivation, effect of medications etc.

- 5) *Sleep Efficiency*: This is the percentage of total sleep time. It is calculated by adding N1, N2, N3, and REM and then divided by total bed time and then multiply by 100.

$$\text{Sleep Efficiency (SE)} = [(N1+N2+N3+REM)/\text{Total Bed Time}] \times 100$$

- 6) *WASO (Wake After Sleep Onset)*: This is the total wakefulness time after sleep onset. It is related to sleep fragmentation.
- 7) *WASF (Wake After Sleep Offset)*: It refer to the wakefulness after sleep offset when the recording device is switched off. This parameter is useful in diagnosing the sleep disorders in sleep medicine.
- 8) *REM Latency*: This is the time, starts from sleep onset to commencement of first REM sleep. It is also used in diagnosing the sleep problems. It is very sensitive to medications, sleep deprivation and circadian rhythm problems.

Following are the sleep stages, including N1, N2, N3, and REM in detail. N1, N2, and N3 collectively known as NREM (Non Rapid Eye Movement) sleep stages.

- 1) *N1 Stage*: This sleep stage is the transition stage from wakefulness to enter into sleep. The high percentage of N1 stage is due to frequent arousal which are due to sleep related problems, environmental disturbances etc. N1 stage is consist of 5% of total sleep time.
- 2) *N2 Stage*: This is second sleep stage consists of 50% of total sleep time. It comes after N1 stage. Low percentage of N2 stage is might be due to sleep fragmentation, high REM sleep, high N3 stage, and sleep arousals etc. and high amount of N2 stage is related to medications and sleep related disorders.

- 3) *N3 Stage*: This is deep sleep stage. It is also known as *Slow Wave Sleep (SWS)* and total occurrence is 20% of total sleep time. It is more in first half of night time and starts reducing in second half of night.
- 4) *REM Stage*: This is *rapid eye movement* sleep stage which occupies 25% of total sleep time. REM stage occurs in every 90 to 120 minutes of each sleep cycle.



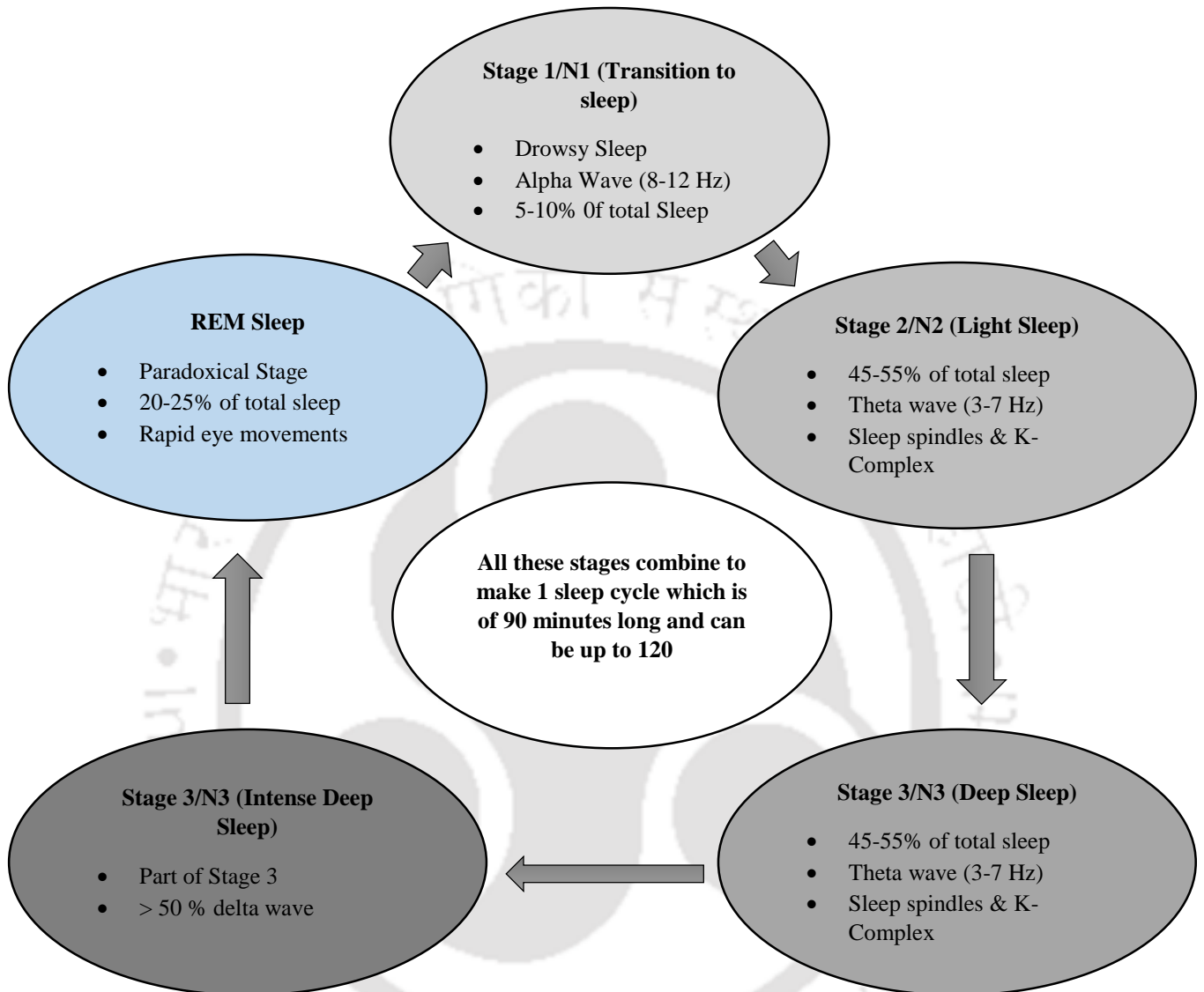


Figure 1.5: Sleep Cycle with Different Sleep Stages

Sleep-Dependent Memory Processing

Research in sleep poses some very interesting questions like why animals especially human beings sleep, what happens in brain during sleep and how does sleep is beneficial for our psychological as well as physiological well-being. Sleep is known to impact a number of cognitive processes like

memory, attention decision making to name a few. For the purpose of the present thesis we will focus our attention to the relationship between sleep and memory. The history of this relationship dates back to 1924 when Jetkin and Dallenbch performed a systematic research on sleep and memory and found that, memory retention after night sleep is better than similar time spent waking (Walker, 2009; Elsevier Inc.). After discovery of the fact that sleep progresses in stages consisting of NREM and REM sleep, researchers starts to investigate how specific sleep stages actively participated in processing the memory. The following section explains the mechanism of sleep dependent memory processing.

Sleep is not a homogeneous state. It is distinctive in broadly two stages *viz.* NREM and REM where NREM consists of three sub stages i.e. N1, N2, and N3. Sleep stages vary in cyclic manner with each cycle lasting for approximately 90 minutes. Sleep promotes the physiological and neurochemical mechanism that induce memory and plasticity in addition to performing several routine tasks like cellular regeneration and other offline maintenance tasks necessary for metabolic functioning.

Nocturnal sleep can be broken down into separate stages, likewise the human memory system is also classified into different memory system. Human memory is divided broadly into two *viz.* declarative memories and non-declarative memory. Declarative memory is explicitly and consciously processed. This memory system is based on facts and further sub classified into *episodic memory* (memory for previous episode/events) and *semantic memory* (memory of general knowledge, not associated with events). Declarative memory is associated with medial temporal lobe, especially with hippocampus while non-declarative memory system is implicit and procedurally processed memory system. Non-declarative memory is sub-divided into *habits*, *procedural skills*, *conditioning*, and *priming*. Human memory system is categorized into different

systems which is very convenient and easy to understand but interestingly it is very rarely that these separate memories operates individually in real life, instead these are operating mutually.

Memory Consolidation: Memory development takes place as time progresses with some unique stages. Initially, the incoming information gets encoded in sensory register and then information representation occurs in the brain. Following information encoding, the next step of the represented information undergoes the *consolidation* which is classically defined as, “*the process in which memory gets resistant to interference from external/internal disturbances*” i.e. memory get stable. This is processed through the passage of time but recently, the concept of consolidation has been modified to include along with *stabilization* the *enhancement* of information. (See Figure below).

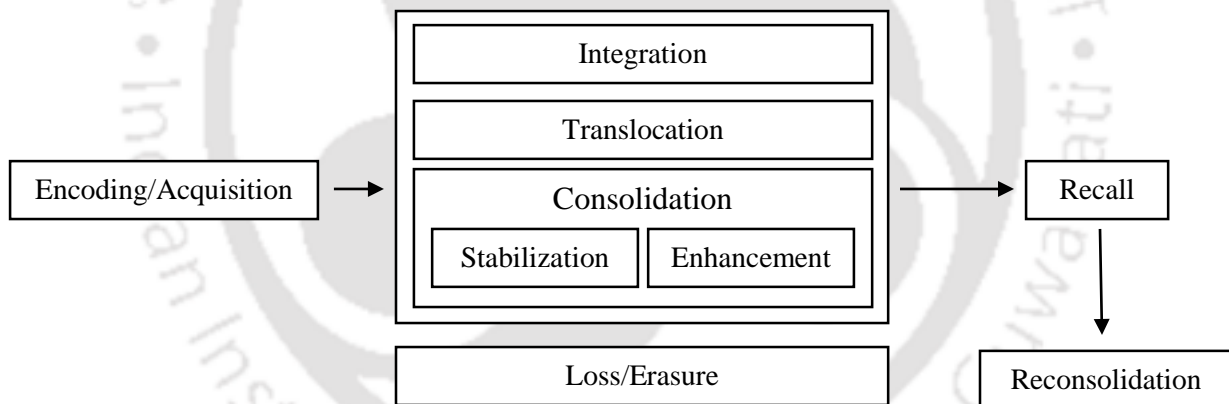


Figure 1.6: Development of Memory during Consolidation Processing (adopted: The Neuroscience of Sleep by Stickgold and Walker, 2009; page no. 231)

The *stabilization* of encoded information is a time intensive processes involving primarily enhancement. During sleep, previously lost memories are restored or additional learning might occur, so through this perspective, the *enhancement* phase of memory consolidation process causes the active restoration of memory. Thus, the consolidation process is occurring in specific state like wake or in sleep or in specific sleep stages. Along with these consolidation process, additional

memory processing also takes place. In *integration process*, the recent encoded information is integrated with already existed information (memory association process). In *translocation process*, the anatomical reorganization of memory representations occurs. Reactivation and reconsolidation process occur with the help of *recall*. The *erasure* processing happens with those memories which encoded outside of awareness.

Sleep and False Memory

Sleep is a vital for living beings. Sleep is important for the human memory and it can modulate cognitive function effectively. The effect of sleep on memory enhancement has been witnessed across many years of research (Ebbonghus, 1985; Jenkin & Dallenbach, 1924; Payne et al., 2008), but recently the association between sleep and false memory questions whether sleep enhances only true memories or it modulates false memories too. The effect of sleep on true episodic memory has been established in a number of research studies (Rasch, Biichel, Gias, & Born, 2007; Diekelman & Born, 2010). Research point that a complete night of sleep with all its stages occurring in sequential manner is responsible for consolidation of newly acquired information (Buzsaki, 1998; Smith, 2001; Stickgold, 2005) by controlling, reactivating and redistribution of information from the hippocampus to neocortex (Diekelmann & Born, 2010). There is lot of literature available for sleep and memory consolidation but the relationship between sleep and false memory is yet to be established for confidence.

In number of studies have tried to establish the relationship between sleep and false memory using the DRM paradigm. These studies reported that no clear differences between sleep and sleep deprivation on the generation of false memories (Diekelmann, Born & Wagner, 2010). False memory generation within sleep is the consequence of reorganization of information during both

consolidation and retrieval (Payne et al., 2009) following sleep or its deprivation (Schacter et al., 2001; Diekelmann et al., 2008).

Diekelman, Landdolt, Lahi, Born, and Wagner (2008) conducted a study where they reported that sleep exert influence on false memory performance on the DRM task. They compared recognition memory performance across sleep group, sleep deprivation group and daytime wake group and found that, sleep deprivation participants showed more false recognition as compared to full night sleep participants. These findings indicate that sleep deprived brain impairs the prefrontal cortex (PFC) activity which is important for source monitoring and results into false recognition (Curran, Schacter, Johnson, & spinks, 2001).

Fenn, Gallo, Margoliash, Roediger, and Nusbaum (2009) found that 12 hours filled sleep does not benefit the false memory, instead false recognition reduced in both aurally (Exp 01) and visually (Exp 02) presented stimuli. It was compared with 12 hours' period filled with daytime wake. They argued that, sleep might have benefited consolidation of verbatim details which enhances the source-monitoring processes, and this may be the reason for lower false memory rates. The same interpretation was explained by activation/monitoring theory for false memory formation (Roediger, Balota & Watson, 2001; Roediger & McDermott, 1995, 2000), which suggests that studied learning words triggers the spreading activation of semantically related words in semantic network which results into activation of unrepresented critical lure words. Fenn and colleagues supports the idea that, sleep increases the source monitoring ability which results into decreased false memory performance, but Dikelman and colleagues (2008) did not found similar results for memory performance as they also compared sleep group with waking group on recognition test.

Sleep and false recognition has been tested in a number of research papers, however Payne et al. (2009) tested the relationship between sleep and false recall. This study is considered as the first one for false recall and sleep (mentioned in Delgado & Payne, 2017). They found that, sleep helps

in increased false recall of critical lure words in comparison with day time wake group participants. They also found that correct recall of studied words is enhanced after full night sleep. In supports of their findings, Payne et al. (2009), argued that in DRM paradigm, when true and false memory is recalled the gist traces are utilized (Reyna & Brainerd, 1998), and sleep might be beneficial for DRM (gist-heavy semantic task) paradigm which results into increased true and false recall for memory. Along with full night sleep research, Payne et al. (2009) also conducted research comparing 90 minutes of day time nap versus 90 minutes' wakefulness on false recall. They found that, after 90 minutes of nap, false recall increases. Further in 2010, Diekelman, Born and Wagner replicated Payne et al. (2009) and found results similar to them. Diekelman, Born and Wagner (2010) found increased false recall after full night sleep in comparison with wake group, however these results did not hold for true recall. One interesting reported by Diekelman, Born and Wagner's (2010) was increased false recall for low performers. McKeon, Pace-Schott, and Spencer (2012) found that false recall rates reported by subjects were lower than Payne et al. (2009) false recall rates. These findings provide the supportive evidence to the idea that sleep modulates false recall. It was found that nocturnal sleep enhances both false recall (Payne et al., 2009; Diekelman, Born & Wagner, 2010; McKeon, Pace-Schott, and Spencer, 2012) and false recognition (Diekelman et al., 2008; Fenn, Gallo, Margoliash, Roediger & Nusbaum, 2009; Curran, Schacter, Johnson & Spinks, 2001), from behavioral experiments but no clear electrophysiological evidence for provided for such results.

The human sleep process is cyclic in nature. It starts with stage 01 to stage 02 and further stage 03 and finally REM sleep. Stage 01 to stage 04 collectively called as NREM sleep. REM is rapid eye movement sleep and NREM is non-rapid eye movement sleep. Research on sleep and false memory suggest that gist based false memory formation is thought to occur during NREM stage 3 sleep also known as slow wave sleep (Lo, Sim & Chee, 2014; Payne et al., 2009; Delgado & Payne,

2017). Payne et al. (2009) found negative correlation between studied words recall and SWS duration and SWS percentage. This was the supportive evidence that SWS is beneficial for declarative memory (Gias & Born, 2004). It was already observed that research in sleep and memory performance used the episodic (context specific) memory task but for the DRM task, the memory performance was relying mostly on gist/semantic (context independent) processing. These findings are supported by previous literature where positive correlation between true and false memory performances was reported (Kim & Cabeza, 2007; Payne et al., 2009).

Payne et al. (2009) did not found any correlation between false recall and SWS, as due to low DRM list words they faced the statistical power issue. Delgado & Payne (2017) doubled (from 8 to 16 word lists) the DRM word list to resolve the power issue and found that false memory is negatively correlated with SWS which suggest that SWS might be the detrimental factor for semantic/gist processing. Effect of nap on false memory was also studied for their predictive role by Payne et al. (2009) and this was the only nap study which supports the active role of sleep in formation of false memory.

Recently in 2017, Delgado and Payne investigated the role of sleep in false memory formation across both recall and recognition test. The presentation of stimuli during encoding phase was aural in male voice. They found that inducing sleep immediately after learning results into increased true and reduced false memories even after delayed retention (24 and 48 hrs.). They also found that SWS was negatively correlated with false memory on DRM task in low performers. Some researchers argued that sleep passively played a role in memory consolidation (Wixted, 2004) but Delgado and Payne's (2017) reported that the sleep actively participates in formation of the true as well as in false memories.

Recently it was also found that false memory and distorted memories are linked to sleep deprivation and that sleep-deprived increases susceptibility to suggestive influences (Frenda et al.,

.2014). It was also reported that sleep deprivation leads to false confessions (*This is a narrative statement from an innocent for a crime /when an innocent person confesses guilt /This is an admission of guilt for a crime for which the confessor is not responsible*; adopted from Wikipedia). They found that sleep deprivation impairs the ability of complex decision making which leads to false confessions (Frenda et al., 2016). In contrary to false memory formation due to sleep, it was found that sleep reduces the formation of false memory (Fenn et al., 2009; Lo, Sim & Chee, 2014) as sleep consolidates information which is supported by recollection (Drosopoulos et al., 2005). In older adults, the reduction of false memory after sleep is related to duration of Slow wave sleep (SWS) (Lo, Sim & Chee, 2014).

RESEARCH GAP IN FALSE MEMORY LITERATURE

Recently, a lot of research is dedicated to investigating the false memory mechanism. Due to high paced research on false memory in recent years a number of contradictory have resulted which has created evident gaps in known literature of false memory. The following are some variables that need to be investigated in some detail for better understanding false memories.

1. **Words Presentation Rate:** Some researchers found that slow presentation rates of words lead to reduced false memory (Gallo & Roediger, 2002; Toggia & Neuschatz, 1996). It was argued that slow presentation rate provides deep processing of list items that can easily discriminated at retrieval (Israel & Schacter, 1997). Further, when less time (fast rate) is provided to subjects to encode list items they learn items with help of their gist representation which leads to increase in false memory (Rhodes & Anastasi, 2000; Toggia, Neuschatz & Goodwin, 1999).
2. **Stimuli Presentation Modality:** Smith and Hunt (1998) found that visual presentation of items leads to less false memory than auditory presentation. They argue that visual presentation

(activate both orthographic and phonological codes) are more discriminable than auditory presentation (activates only phonological code). One clear opposite patterns were reported by Maylor and Mo (1999) where it was found that visual representation leads to more false recognitions than auditory representation. They argue that in auditory presentation there are more perceptual details and distinct memories than visual presentation, so subjects are better able to use reality monitoring to reduce false recognition in auditory than visual presentation. One interesting methodological conflict between the reported studies was the use of between-subject (Smith & Hunt, 1998) and within-subject design (Maylor & Mo, 1999) which could have resulted in differential results of the studies.

- 3. Retention Interval and Level of Processing:** There are few studies on retention interval effects on false recall and false recognition. Some contradictory findings are available for these factors. Few researchers found that there is no effect of retention interval and level of processing on false recall and false recognition (Read, 1996; Tussing & Greene, 1997). They found that deep processing and superficial processing does not show any significant differences for false recognition. Similarly, Read (1996) also did not found any differences in false recall for both levels of processing. A few researchers found that false recall is greater in semantically processed (deep level of processing) than superficially processed (shallow level processing) list items (Rhodes & Anastasi, 2000; Toggia et al., 1999). In 2001, Thapar & McDermott, found that false recall and false recognition are affected by both levels of processing and retention interval. They reported higher level of false recall and false recognition in semantically processed lists than superficially processed.
- 4. In Activation/Monitoring Theory:** The activation/monitoring theory explains that in DRM paradigm presentation of list items during study phase activates the semantic/lexical system leading to the creation of implicit associative responses (Underwood, 1965). This activation

induces those items which are not presented in study list but are associated with presented list items (Anderson & Pirolli, 1984; Collins & Loftus, 1975; Meyer & Schvaneveldt, 1971). But the debatable issue is that, whether the activation of critical items in DRM paradigm is conscious or unconscious? Some researcher assumed it as a conscious process (McDermott, 1997) and some assumed it as unconscious (Seamon, Luo & Gallo, 1998). So it is assumed that activation of critical items in DRM paradigm is processed by “both” consciously or unconsciously.

5. **Sleep Modulates False Memory:** sleep has been found to influence false memories. Research suggests that both sleep and its deprivation benefit false memory on recall tasks (Diekelmann, Born & Wagner, 2010). False memory generation during sleep is the consequence of reorganization of information during memory consolidation process (Payne et al., 2009) while it is attributed to the retrieval process following sleep deprivation (Schacter et al., 2001; Diekelmann et al., 2008). A contrary result suggests that sleep reduces the formation of false memory (Fenn et al., 2009; Lo, Sim & Chee, 2014) as sleep can consolidate information which is supported by recollection (Drosopoulos et al., 2005). In older adults the reduction of false memory after sleep is related to duration of Slow wave sleep (SWS) (Lo, Sim & Chee, 2014).

RATIONALE OF THE FALSE MEMORY RESEARCH

David Diamond, a professor of molecular physiology at South Florida University commented “Memory is a machine, and it is not flawless”, so this is not a surprising that people can falsely remember events that did not happen. One of the pioneer false memory researchers, *Loftus Elizabeth* in their TED talk speech suggested that, “Memory, like liberty, is a fragile thing...”.

False memory is remembrance of those events/information which has never happened in past but people falsely remember them as real. This is due to reconstructive and malleable nature of human memory system. We know that humans have false memory for many things; it may be of personal preferences and choices for events or things. So the question arises whether these false memories have any impact on our behavior. It was seen that people are very susceptible to suggestions which helps in creating false memory for the particular event. It was also found that false memories are the cause of wrongful convictions as they lead to false identification of suspect, false recollections of information providing misleading information during interrogations, court trials etc. Also, false memory has a disturbing effect on human lives in terms of false suggestions to individuals which leads to false acceptance of events that did not happen, false allegations, false beliefs for a crime like sexual abuse etc.

These above-mentioned reasons are motivating researchers to do more research to unravel the false memory phenomenon, investigate factors affecting false memory, test reliability of paradigms used in laboratory setting under real-life settings etc. The *first* implication of false memory research is more concerned with the testing hypothesis that brings forward the theoretical debate, instead of focusing on empirical phenomena. *Secondly*, less literature is available on false memory in comparison to true memories so neuropsychological investigation of false memories will develop literature and can distinguish true and false memory. Research on true memory was already done very well and efficiently but malleable nature of memory was less understandable so recently lot of research is trying to understand the false memory mechanism, how different variable is affecting false memory formation, how clinical population related with false memory, how legal and judiciary system understand false convictions and develop legal policies etc.

In the present thesis, we plan to investigate the role played by sleep on false memory. Since false memories are formed in much the same way as true memories it will be interesting to study the

mechanism of consolidation and stabilization of false memory across retrieval intervals filled with sleep and sleep deprivation. Additionally, we plan on comparing two well-developed methods of inducing false memory in the present thesis. We plan on comparing the category associate (using simple line drawings) and the semantic associate (words) methodologies of false memory induction and test the efficiencies of these methods under retrieval intervals filled with sleep. The reason for choosing these methodologies for comparison is that they are very rugged and the most used methodologies for false memory formation under laboratory conditions.

RESEARCH QUESTIONS

Review of the research literature on false memory formation has made us formulate the below mentioned research question that will help in understanding in more detail the false memory phenomena.

1. Whether the multiple methodologies of inducing false memory can be compared on their relative effectiveness of false memory formation?

Rationale: Research literature on false memory suggest at least seven methodologies for inducing false memory in humans. Out of these seven methodologies, only three have been actively studied. In the present thesis, we aimed at comparing two widely used methods of inducing false memory in terms of their effectiveness in inducing false memories. We compare the Deese-Rodierger-McDermott (DRM) paradigm that uses words lists for inducing false memory with the category associate method that uses line drawing for false memory induction. The DRM is a semantic task while the category associate is a visual task and both of them form different mental representations. Hence comparing them will provide a better understanding of the false memory formation process.

2. Whether performance on false memory tasks vary with the strategy of retrieval used for accessing false memories?

Rationale: The strategy for retrieval of memories plays an important role in the accessibility of memories. Recognition and recall uses different processing mechanisms for accessing and retrieving memories and thus the content and specificity of memories reproduced also varies. In the present study, we wanted to test whether the effects of using varied retrieval mechanisms significantly affect performance on false memory task

3. Whether retention interval (between encoding and retrieval) on false memory tests interact with the performance on false memory tasks?

Rationale: An important factor that modulates performance on memory studies is the retrieval interval between learning and retrieval. This happens as activities during the retrieval effect can lead to active interference in the consolidation of memories leading to performance difference at retrieval. In addition, the process of consolidation of memories is time dependent with the first eight hours responsible for maximum forgetting. Research studies suggest that it is only after 48 hours have passed after learning that memories traces are transferred from the hippocampal to neocortical sites for storage and consolidation processes terminate. In the present study, we wished to test the effects of retention interval on the performance of false memory tasks.

4. Whether the deprivation of sleep has any role to play in the formation of false memory?

Rationale: The last research question tested whether retention interval between learning and retrieval modulates false memory performance. A number of studies report intervening activities following learning during the retention interval effects retrieval. The deprivation of sleep offers an

interesting opportunity to test how post-learning brain processes modulate performance of memory tasks at retrieval. The deprivation of sleep is known to provide an excellent biological medium that hinders the stabilization and consolidation of memory traces acquired at learning. In the present study, we were interested in testing whether brain processes during stabilization and consolidation has any role to play in the performance on false memory tasks.



CHAPTER 02: RESEARCH AIMS AND GENERAL METHODOLOGY

RESEARCH OBJECTIVES

The previous chapter reviewed human memory system and the existence of false memories. The review outlined some interesting questions that the present thesis will address.

1) False memory generation

- a) Whether inducing false memories using line drawing and words can be compared in terms of their relative effectiveness in generating false memories
- b) Whether performance on false memory tasks vary with the strategy of retrieval used for assessing false memories
- c) Whether retention interval (time between encoding and retrieval) modulate performance on false memory task

2) Role of sleep in false memory

- a) Whether sleep has a specific role to play in the generation of false memories
- b) Whether sleep or its deprivation differentially affects the generation of false memories induced using line drawings (category associates) and words (semantic associates)

GENERAL METHODOLOGY

In this section, we briefly outline the various tools and equipment we have used in the present thesis. Additionally, we also define how the tool / equipment was used in the present thesis. This section aims to minimize unnecessary repetitions and redundancies caused by repeated reference to common tools and equipment included in the thesis

QUESTIONNAIRES

(1). Mini-Mental State Examination (MMSE): The mini-mental state examination (MMSE) is the most commonly used instrument for screening cognitive function. It was developed by Folstein, et al. (1975). MMSE consists of eleven items questionnaire that tests five area of cognitive functions (orientation, registration, attention and calculation, recall and language). The maximum achievable score on this test is 30. A score less than 23 is indicates cognitive impairment. MMSE administration takes only 5-10 minutes and is extensively used in both clinical and research settings.

In the present thesis: the MMSE is used to screen subjects with mild to major cognitive impairments. It is thus an important exclusive criterion for participant's recruitment. The mean score for MMSE is 27 ± 1.27 which is greater than 23 which indicate that participants are normal i.e. participant don't have any cognitive impairments [N = 72].

(2). Mood Questionnaire: This is developed in-house and measures mood of the participants on five-point scale. Volunteers taking this test have to report their present feelings on sub-scales of sleep, activity, tension, tiredness, boredom, motivation, and concentration.

In present thesis: Mood questionnaire is used to scan for abnormal mood changes across participants in the various experiments. The mean score for Mood questionnaire calculated to be 17.47 ± 1.34 which is greater than 15, indicates no mood discrepancy for all the participants (N=72).

(3). *Memory and Attention Test:* In memory test, participants were asked to write the name of occupations in one minute. In attention test, participants have to write words that start with the alphabet “A” in one-minute. They were advised not to write names of people and compounded words.

In present thesis: the memory and attention test is a quick check of the memory and attention functioning of the volunteers during retrieval. The mean score of memory test found to be 9.23 ± 1.34 which is more than 5. For attention test mean score is 11.67 ± 1.05 which is greater than 5. These memory and attention scores indicate that there is no decrement in both for all participants (N=72).

(4). *Drug Questionnaire:* DAST-20 is used to assess the information about participants’ potential involvement with drugs excluding alcohol and tobacco during the past 12 months. The DAST-20 is scored by summing the number of responses that indicate the drug used problems. “No” response to questions 4 to 5 indicate problem. For all other questions, a “Yes” response indicates drug use problems.

In the present thesis: the DAST-20 is used to screen participant’s involvement with drugs and is an important part of exclusion criteria. The average score obtained across participants was less than 5 indicating no drug use problems among all participants (N=72).

(5). Pittsburgh Sleep Quality Index (PSQI): The Pittsburgh Sleep Quality Index (PSQI) was developed in 1988 by Buysse et al. (1989). It is very effective instrument used to measure the quality and pattern of sleep in adults. It differentiates “poor” from “good” sleep quality by measuring seven components of sleep, i.e. subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and day time dysfunctions over the last month. Questions on PSQI are related to individuals’ usual sleep habits during the past month only. Answers should include the most accurate reply for the majority of days and nights during the last month. The items from the PSQI are summed to create a total score which represents overall sleep quality. A total score of “5” or greater is indication of poor sleep quality. PSQI is standardized sleep questionnaire for clinicians and researchers as well to use with ease.

In present thesis: PSQI is used to monitor sleep quality of volunteers and thus forms an important component of exclusion criteria for subjects across experimental nights. The average PSQI score across participants came equal to 6.33 ± 2.18 , which indicates that the sleep quality of subjects is very normal (N=30).

(6). Epworth Sleep Scale: ESS was developed in 1990 by Dr. Murray Johns to assess the daytime sleepiness. This is self-administered sleep questionnaire. This questionnaire has 8 questions, and respondents are asked to fill each questions with 4-point rating scale (0-3), with chances of dozing while they are engaged in 8 different daytime activities. This questionnaire approximately takes 2-3 minutes to fill. Higher values indicate the excessive daytime sleepiness and lower values indicates normal sleepiness.

In the present thesis: ESS was used as exclusion criteria component. Average ESS scores obtained by subjects across experimental nights was 11.06 ± 3.49 which indicates very low propensity towards daytime sleepiness (N=30).

STIMULI

- 1) **Words:** Semantically associated words were used as stimuli in the DRM (Deese-Rodieger-McDermott) task list which were used for the induction of false memory. These word stimuli were extracted from databases of semantically related words that were used previously for completing the DRM task (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959a, 1959b). Words used for forming the DRM list were arranged in descending order of their backward associate strength. Similarly, word length and complexity were also kept within range to maintain homogeneity among DRM lists [See **Appendix C**].
- 2) **Simple Line drawings:** Categorically associated line drawings of objects belonging to a common category were used as stimuli in CA (Category Associated) task for the induction of false memory. These categorically associated pictures were extracted from the previously developed database (Battig & Montague, 1969). Each picture was associated with their main categorical characteristics and arranged in descending order according to their frequency of occurrence. Further, these pictorial stimuli were standardized for their *name agreement*, *familiarity*, and *visual complexity* values [See **Appendix D**].

TASKS

Research literature on false memory suggest at least seven methodologies for inducing false memory in humans. Out of these seven methodologies, only three have been actively studied. In the present thesis, we aimed at comparing two widely used methods of inducing false memory in terms of their effectiveness in inducing false memories. We compare the Deese-Rodieger-

McDermott (DRM) paradigm that uses words lists for inducing false memory with the category associate method that uses simple line drawing for false memory induction. The DRM is a semantic task while the category associate is a visual task and both of them form different mental representations.

1. Deese-Roediger-McDermott Paradigm: In DRM task, semantically associated words were used as the stimuli. In this task, semantically associated list words are presented sequentially in descending order of their BAS (backward associative strength) values. For example, *stream, flow, bridge, lake, boat, tide, swim, run, fish, and water* are semantically associated list words for the critical lure word *river* (word with highest BAS value). In *DRM paradigm*, total ten lists with ten words in each list were presented to the subjects with instruction to attend each word and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/word with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during the study phase as well as during the test phase. The experiment was designed in e-Prime Software Version 2.0.10.353. [See **Appendix C** for words list items]

2. Category Associate Paradigm: In category associate method, we used simple line drawings as stimuli. In this task, category examples were presented in order of their frequency of availability according to Battig and Montague norms. For example, *shirt, raincoat, socks, pant, shoe, skirt, sweater, gloves, belt, scarf, vest, and bermuda* are category exemplars of *cloths* category. In present study, total ten category lists with ten exemplar pictures (related to category) in each category list were presented to the subjects with instruction to attend each picture and be prepared for a later retrieval test. Total 100 (10 list x 10 items in each list) line

drawing picture were presented during encoding phase. The lists were presented at the rate of 3000 milliseconds/picture with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during the study phase, but at the time of the test phase, intra-list items were randomly presented. The experiment was designed in e-Prime Software Version 2.0.10.353. [See **Appendix D** for pictures list items].

PARTICIPANTS

Total 136 undergraduate students (all male) of age range from 17 to 25 (Mean \pm SD: 19.07 \pm 1.17) from Indian Institute of technology Guwahati volunteered for the experiments in the exchange of partial credit (for daytime experiments) towards a course requirement or equivalent monetary (for sleep experiments) benefit. All the samples for each experiment are randomly selected and recruited for experimentation Each participant was tested individually in sessions that lasted approximately 40 minutes for behavioral experiments and eight hours for night experiments. All the participants completed the following set of questionnaires, i.e. a personal data form including questions about their age, gender, eyesight etc. along with informed consent form, mood questionnaire, mini-mental state examination (Folstein et al.,1975), memory and attention test, drug questionnaire (DAST-20), memory functioning questionnaire, Pittsburgh sleep quality index (Buysse et al., 1989), and Epworth sleep scale.

Inclusion criteria: Average academic performance, normal scores on behavioral questionnaires, Adaptation of sleep laboratory conditions, young adults, corrected to normal vision and no known history of any psychological, psychiatric and physical abnormalities in the last six months prior to experimentation.

Exclusion criteria: Mild to moderate neurological/psychiatric conditions, abnormal sleep/wake cycles, mild to moderate addictions in any form.

TOOLS

1. **10 channel sleep polysomnography Nihon-Khoden:** Sleep polysomnography with the help of Nihon-Khoden machine was used to track the sleep cycles across experimental nights. During experimental nights, sleep electrodes (surface cup electrodes) were put on the participant's scalp with the help of conducting paste according to 10-20 montage system. Sleep stages recorded or obtained by applying A₁, A₂ (ear lobed electrodes) as reference, C₃, C₄, O₁, O₂ (Scale electrodes) as main sleep electrodes, EOG-L, EOG-R (eye movement electrodes), EMG-L, EMG-R (chin electrodes), and F_z (ground electrode).
2. **ACTi watch:** This is the device to use to track the daily physiological activity and sleep/wake patterns of participants before the nights' experiments. This is very small, comfortable, and waterproof wrist watch. This device is scientifically proved to access the daily activity and sleep/wake patterns.
3. **E-Prime ver 2.0.10.353:** E-Prime is a presentation software used in behavioral sciences to present the psychological task. In this study, it was used to present the DRM and CA both task according to study design.

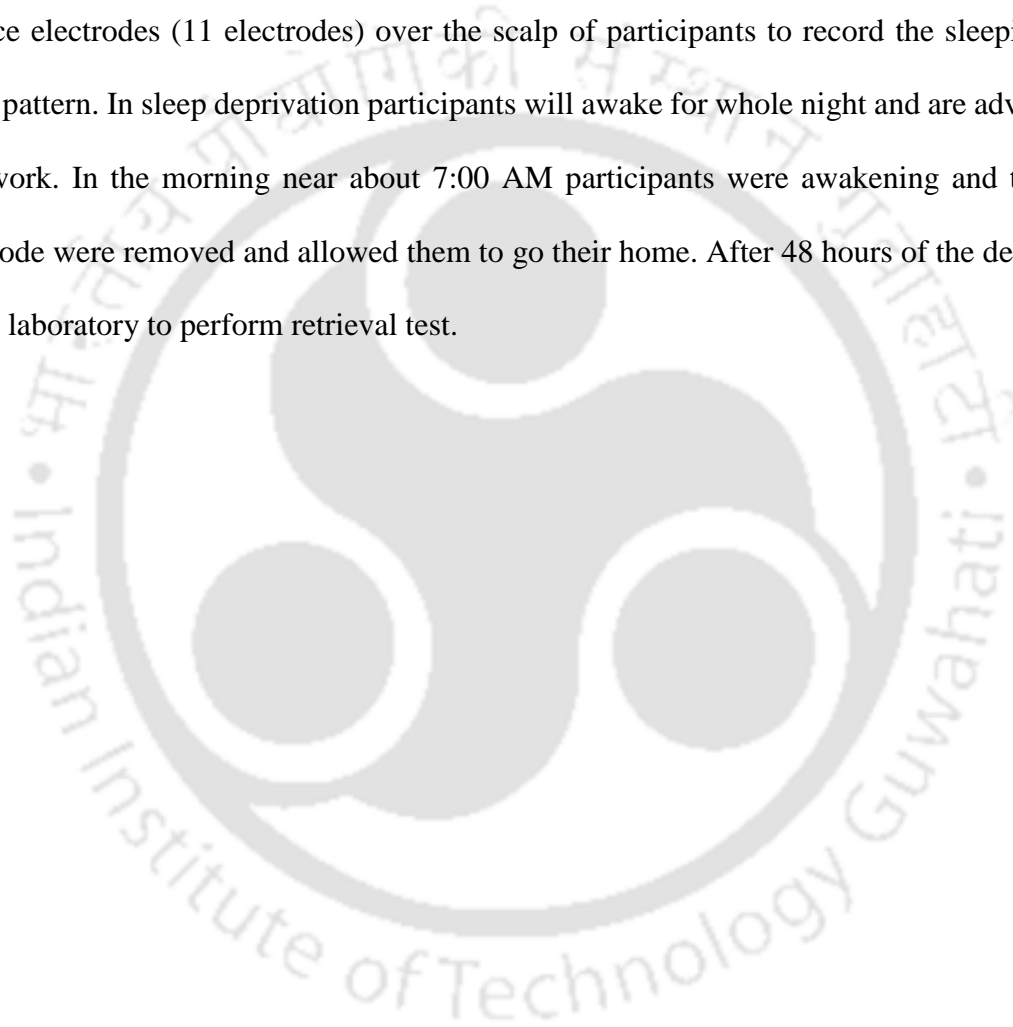
GENERAL DESIGN

1. **Behavioral Experiments:** In the present thesis, the behavioral experiments were conducted with two false memory induction methods. False memory induction methods included in this study were, semantic associate task, and category associated task. Semantic associated (DRM) task is concerned with semantically associated words, whereas category associated (CA) task concerns categorically associated simple line drawings. Semantically associated words list and categorically associated pictures were extracted from previous available data base, and all stimuli were normalized. Word stimuli were normalized on their BAS (backward associative strength), word lengths, whereas pictures were normalized on the basis on their familiarity and visual complexity scales. False recognition and false recall of presented stimuli along with the Correct recognition and recall were the behavioral measurements. Critical lures and intrusions are the actual measurements of false memory.

Along with the behavioral measures of both false memory task, behavioral measures of participant's mental state were also conducted and calculated to verify their normal mental state. For this purpose, general questionnaire, drug questionnaire (DAST), memory functioning questionnaire, mood questionnaires, MMSE were administered. For evaluation of good sleep quality, we use Pittsburgh sleep quality index (PSQI), and Epworth sleep scale (ESS).

2. **Sleep Experiments:** In this present thesis, sleep recording was carried out to monitor the sleep architecture of volunteers sleeping in the sleep laboratory. The measures used for sleep architecture assessment were total sleep time, sleep efficacy, sleep latency, and stage wise sleep time. Subjects on experimental sleep nights came at laboratory at 9:00 PM. Prior to the

sleep nights' participants were advised not to take daytime nap or stimulants (coffee/tea and alcohol, and smoking) 24 hour before and after the experimental nights. After arriving at the laboratory, participants have to fill the behavioral questionnaires. Following the behavioral questionnaires, the participants perform the false memory task. Now, after completion of task, participants either went for sleep or sleep deprivation condition. In sleep condition, we put surface electrodes (11 electrodes) over the scalp of participants to record the sleeping brain wave pattern. In sleep deprivation participants will awake for whole night and are advise to do any work. In the morning near about 7:00 AM participants were awakening and the sleep electrode were removed and allowed them to go their home. After 48 hours of the delay came to the laboratory to perform retrieval test.



CHAPTER 03: STIMULI DEVELOPMENT

EXPERIMENT 01: Development of word stimuli for recall and recognition groups

OBJECTIVE 01: To test whether intra-item BAS values of group A (recognition) and group B (recall) and inter-item BAS values of both group are different or same/comparable.

OBJECTIVE 02: To test whether the intra-item word lengths of group A (recognition) and group B (recall) and inter-item word lengths of group A and group B are same or different.

HYPOTHESIS:

- a) There will be insignificant differences in the BAS values in within group and between groups words.
- b) Word lengths within and between groups are also comparable.
- c) The interaction between groups for BAS value as well as word lengths all are comparable.

VARIABLES:

Independent variables: Words

Dependent variables: BAS value, Word length

DESIGN:

The analysis for stimuli selection is based on 2 groups [Group A (Recognition) vs. Group B (Recall)] x 2 Stimuli factor [Word Length and BAS value]. One-way ANOVA is used to analyze

for BAS value and word length of individual groups. Interaction between group A (recognition) and group B (recall) was analyzed to make both group controlled.

METHODOLOGY:

Material

Two group were made where each group consists of total 10 lists with 10 words (semantically associated) included for study phase. The semantically associated words are extracted from previously developed false memory literature (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959a, 1959b) and served as word stimuli. All words were with the particular backward associative strength and listed in decreasing BAS value. Another factors i.e. word length was also included to control the stimuli effect.

Statistical Analysis

For each group A and group B, there is separate word lists. Each list words were analyzed independently with one-way ANOVA with BAS value and word length. Interaction effect also analyzed between group word list.

RESULTS:

Within group A (Recognition), the word length of list items (Mean = 5.04; SD = 1.27) is comparable [$F_{(9,90)} = 1.86$; $p = 0.067$], and BAS values are also (Mena = 0.157; SD = 0.183) comparable [$F_{(9,90)} = 0.627$; $p = 0.772$]. Similarly, within group B (Recall), the word length of list

items (Mean = 5.06; SD = 1.17) is comparable [$F_{(9,90)} = 0.976$; $p = 0.465$], and BAS values are also (Mean = 0.152; SD = 0.184) comparable [$F_{(9,90)} = 0.745$; $p = 0.667$].

Word length of group A (Recognition) list words and group B (Recall) list words are significantly different [$F_{(1,9)} = 2653.50$; $p = 0.00$]. Similarly, the BAS values between group A (Recognition) list words and group B (Recall) list words are also significant differ [$F_{(1,9)} = 7.86$; $p = 0.021$].

CONCLUSION:

We have found that word length of all the list words in each list of each group are comparable, they are not differing with each other. Similarly, in regards to BAS values also all the words in each list in each group are similar to each other. But, between group A and group B, all the words of all lists are significant different to each other in both in word length as well as BAS values.

Note: Words list database is presented in **Appendix C**

EXPERIMENT 02: Development of Line drawings database as stimuli for recall and recognition groups, and their standardization on the basis of Picture-Word Agreement

OBJECTIVE 01: Development of simple line drawings

Line drawings of each group were made by using *Adobe illustrator 2017* Photoshop software. Total 240 simple line drawings were developed wherein 120 line drawings used in the recognition group and remaining 120 used for recall group. Each picture was a black-and-white outline on the white background. Each picture has a dimension of 597 x 843 pixels with 72 dpi (high) resolution.

OBJECTIVE 02: To check whether each line drawing and their characteristics are significantly comparable

METHODOLOGY:

Participants

Total of 34 undergraduate participants (all male) of age range from 18 to 25 years (Mean±SD: 20.05±1.17) has participated in this Picture-word agreement task. All the participants opted for the introductory psychology course. Their age group was 18-25 years. All the participants were good in English language but they were not native English speakers.

Material

Two group were made where each group consists of a total 12 category lists with 10 line drawings (Category associated) included for the study phase, so the total of 120 pictures in each group.

These categorically associated pictures were extracted from the previously developed database (Battig & Montague, 1969) and served as picture stimuli. Each picture was associated with their main categorical characteristics and arranged in descending order according to their frequency of occurrence.

Procedure

All the pictures were projected sequentially on the large white screen using the Sony slide projector. At the start of the task, participants have described the purpose of the task and instructed to perform task very carefully and attentively. Each picture slide was presented for 5000 milliseconds. They were instructed to write the name of each picture in the English language, and if they remembered the picture's name in their native language then they can write the picture name in that language also. All the participants gave their responses to the paper sheet by writing the appropriate name of each picture. For the participation, all the participants were credited with course credit as they were part of the introductory psychology course. Three measurements parameters were taken for each picture i.e. *name agreement*, *familiarity*, and *visual complexity*.

Name Agreement

All the participant at the time of task performance instructed to attend all the picture very carefully and attentively. In this name agreement section, participants were instructed to write the name of the picture which had comes first in their mind. If, they were unable to recognize the object when instructed to respond DKO (*Don't Know Object*). If they know the object but don't know the name then they instructed to respond DKN (*Don't Know Name*), and finally, if they know the object but unable to retrieve the name then instructed to respond TOT (*Tip-of-The-Tongue*).

Familiarity

In this parameter, participants were instructed to judge their opinion on the familiarity of each picture. In this response, they have to rate their response according to how they are familiar with the picture in their real experience, not in the way of drawing. By the definition of familiarity, it is "the degree to which you have come in contact with the picture of how you think about the picture." For the response to be taken, a 5-point rating Likert scale was used, where, 1 indicates *very unfamiliar* and 5 indicates *very familiarly*.

Visual Complexity

This parameter is included to rate the visual complexity of picture drawings. Here, the definition of complexity is, "the amount of details of line in the picture." Participants were instructed to rate their response on 5-point rating Likert scale where they have to respond from 1 (indicating the *very simple*) to 5 (indicating *very complex*). They also instructed that their rating should be on the basis of drawing itself rather than the real picture of the environment.

Statistical Analysis

For each group A (Recognition) and group B (Recall), frequency and percent agreement analysis was done for each picture for picture name agreement. For familiarity and visual complexity, the mean and SD were calculated. Independent t-test was conducted to calculate the descriptive statistics.

RESULTS:

Independent t-test was conducted to compare familiarity and visual complexity of simple line drawings across recall and recognition groups.

- 1) *Familiarity*: There was not a significant difference in the score of recall ($M = 4.10$, $SD = 0.46$) and recognition ($M = 4.12$; $SD = 0.42$) conditions; $t_{(32)} = -0.144$, $p = 0.887$ (2-tailed).
- 2) *Visual Complexity*: There was not a significant difference in the scores of recall ($M = 1.88$, $SD = 0.63$) and recognition ($M = 2.12$, $SD = 0.68$) condition; $t_{(32)} = -1.098$, $p = 0.281$ (2-tailed).

CONCLUSION:

These results suggested that the familiarity of presented line drawings across in recall and recognition groups are not different, i.e. all the line drawings are similar in their familiarity scale. Similarly, the visual complexity also not different, i.e. all the line drawings of both recall and recognition groups are simple on the visual complexity scale.

Note: Picture lists database is presented in **Appendix D**

CHAPTER 04: BEHAVIORAL AND SLEEP EXPERIMENTS

EXPERIMENT 01: Semantic Task and False Memory

OBJECTIVE 01: The present study aimed at testing the role of retrieval strategy and retention interval on semantically induced false memory performance

HYPOTHESIS:

H₁: Performance on semantically induced false memory (critical lures) will increase in recognition in comparison to recall retrieval strategies

H₂: Retention interval between learning and retrieval will positively modulate the performance on semantically induced false memory

VARIABLES:

Independent variables: Retrieval strategy (Recall and Recognition)
Retention intervals (immediate, 24 Hours, and 48 Hours)

Dependent variables: Recall and recognition scores of critical lure words, intrusion words and studied (true target) words.

DESIGN:

This experiment uses a [2 Retrieval strategies (Recall, Recognition) x 3 Retention intervals (Immediate, 24 Hours, 48 Hours)] mixed factorial design with repetition on second factor. Number

of critical lure words, intrusion words, true target words serve as dependent variable and are used for calculating the false memory performance.

METHODOLOGY:

Participants

Twenty healthy participants (all males) of age group between 18 to 25 (19.27 ± 1.27) years volunteered for the memory experiment. Volunteers were undergraduate students of IIT Guwahati who were compensated with partial course credit for the participation. All participants were free from serious medical conditions or drug dependence.

Material

DRM task was used to induce false memory for pre-selected word lists. Two groups of subjects participated in the experiment. Subjects from one group only performed on recall tests while subjects of second group performed only on recognition tests. The subjects were assigned to the groups randomly. Subjects in each group studied 10 lists with 10 words in each lists. The words used were semantically associates and were extracted from previously developed false memory word corpus (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959a, 1959b). Words were presented using e-prime presentation software on the center of computer screen with each word written in font size of 14 Time New Roman fonts. Words on each list were arranged in descending order of their backward association strength (BAS) values. In order to maintain constancy, the within lists factors i.e. word length and, BAS value were made constant across all lists.

Procedure

This experiment included two groups (recall, and recognition). Subjects in each group were made to study the given lists of words and later perform on the retrieval tests assigned for that group. At the beginning of the experiment, each participant filled battery of behavioral questionnaires that included Mood questionnaire, MMSE, Memory and Attention test, Memory Functioning Questionnaire. Total 10 lists with 10 words in each list were presented to the subjects with instruction to attend each word and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds *per* word with an inter-stimulus interval of 2000 milliseconds. List items were sequentially presented during study phase as well as during test phase. The experiment was designed in e-Prime Software Version 2.0.10.353.

At *recognition phase*, participants provided the *old/new* judgment for each presented word. Responses generation on the recognition test was self-paced by participants. Each recognition list contained three old words (from learning list), three new words (unrelated words as distractor) and one critical lure word. A distractor task was introduced between studied and recognition phases to prevent a repetition of lists. The whole experiment runs for approximately 40 minutes.

At *recall phase*, participants were free to recall the list words. All the responses were taken on plain white paper. Distractor task was also introduced between study phase and recall phase to prevent repetition of list words.

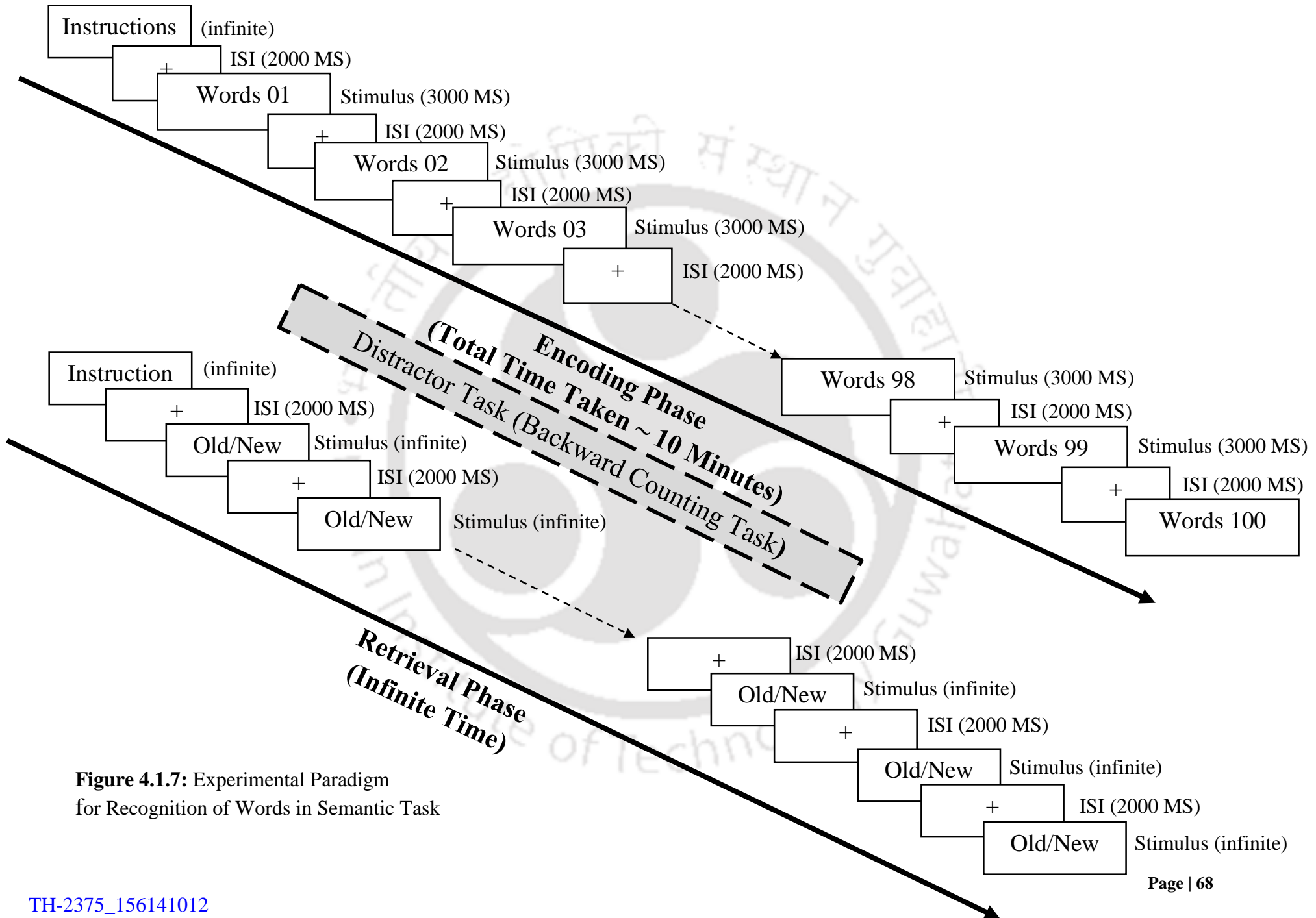


Figure 4.1.7: Experimental Paradigm for Recognition of Words in Semantic Task

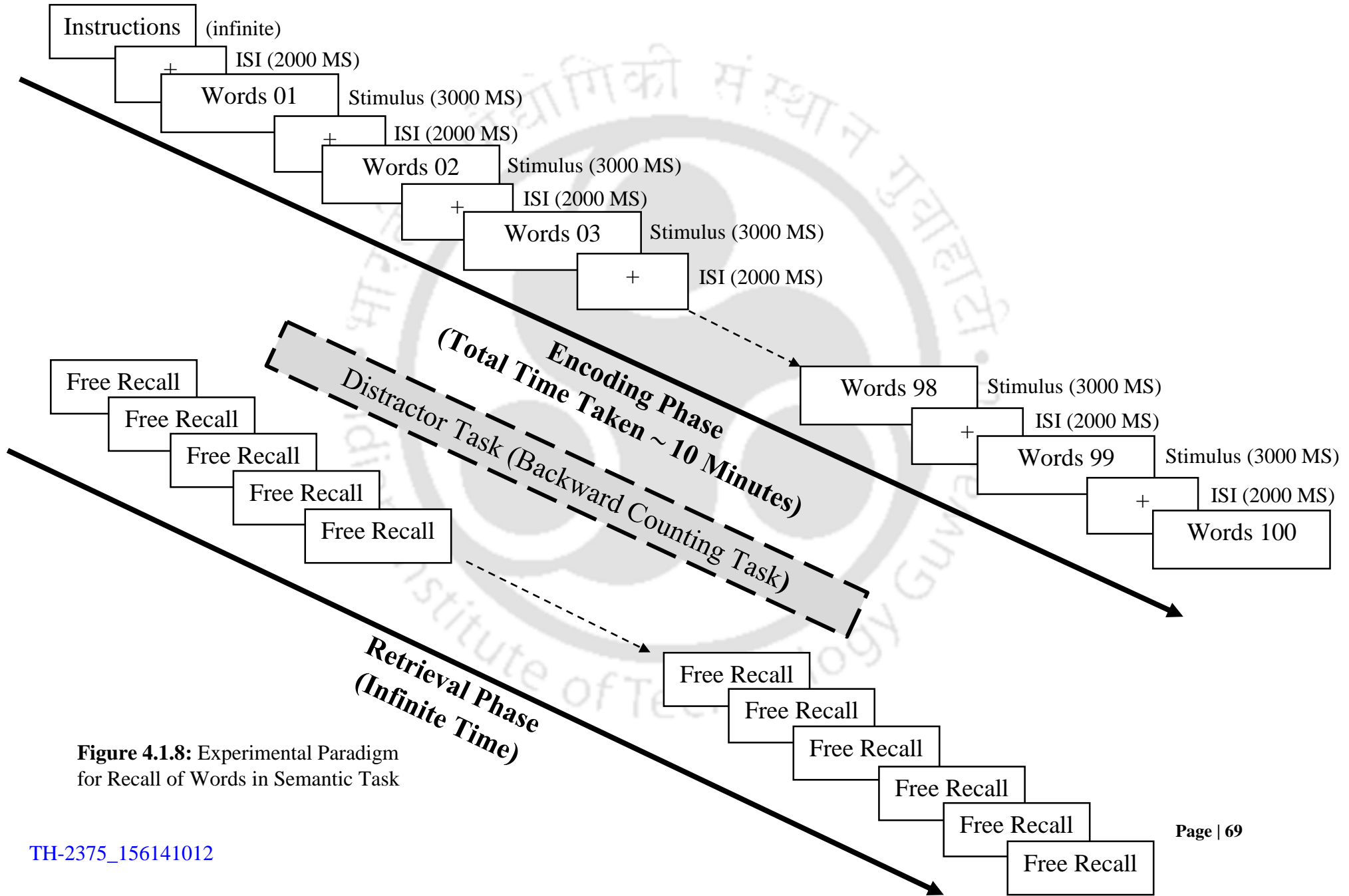


Figure 4.1.8: Experimental Paradigm for Recall of Words in Semantic Task

Data analysis

The results are presented as mean correct responses of studied words, intrusion words and critical lure words (CL). Intrusion words and CL words are actual measurement of false memory in DRM paradigm. Two-way analysis of variance (ANOVA) was used to measure the differences between retrieval strategies (recall v/s recognition) and repeated measure ANOVA within subject was used to analyze the differences between retention interval across both recall and recognition for studied words, intrusion words and critical lure words. Bonferroni post hoc analysis were used to examine the interaction levels within subject.

RESULTS:

Mixed ANOVA 2 [Retrieval strategies (Recall, Recognition) x 3 Retention intervals (Immediate, 24 Hours, and 48 Hours)] with repetition on second factor was used to analyze the critical lure and intrusion data.

Critical Lure: Our results found that *critical lure* words were better remembered in recognition than recall retrieval strategy [$F_{(1, 18)} = 39.88, p < 0.05, \eta^2 = 0.689$]. We did not find significant differences between critical lure retrievals across different retention intervals [$F_{(1, 18)} = 1.531, p > 0.05, \eta^2 = 0.078$]. Similarly, the interaction between retrieval strategies and retention intervals were also non-significant. The mean values of the measures are presented in **Table 4.2**.

Intrusion: ANOVA results suggest significant main effect of retrieval strategy for intrusion words [$F_{(1,18)} = 42.526, p < 0.05, \eta^2 = 0.703$]. Additionally, the ANOVA also reported significant main effect of retention interval [$F_{(1,18)} = 23.63, p < 0.05, \eta^2 = 0.568$]. The interaction between retrieval strategy and retention interval turned to be significant [$F_{(1, 18)} = 41.27, p < 0.05, \eta^2 = 0.696$].

Bonferroni post hoc analysis for interaction reveals only during recognition there were significant differences in the number of intrusion words retrieved across the immediate, 24, and 48-hour retention interval. The mean values are presented in **Table 4.3**.

True Target Words: Remembrance for true target words (studied words) was found non-significant between both recall and recognition retrieval strategy [(F_(1,18) = 1.134, p > 0.05, η^2 = 0.059)], but across retention interval [(F_(1,18) = 12.61, p < 0.05, η^2 = 0.412)] and the interaction between test type and retention interval were found significant [(F_(1, 18) = 16.91, p < 0.05, η^2 = 0.484)]. For studied words, only in recall group there was significant differences found between immediate and 24 hours and 48 hours' retention interval. No difference was found between 24 hours and 48 hours' retention interval. The mean values are presented in **Table 4.4**.

Table 4.2: Mean Scores of Critical Lure Words [Representation: Mean±SD]

Test Type	Retention Interval		
	Immediate	24 Hours	48 Hours
Recall	1.40 ± 1.17	1.80 ± 1.03	1.90 ± .99
Recognition	5.80 ± 2.78	6.4 ± 2.11	6.4 ± 2.01

Table 4.3: Mean Scores of Intrusion Words [Representation: Mean±SD]

Test Type	Retention Interval		
	Immediate	24 Hours	48 Hours
Recall	3.40 ± 2.06	2.50 ± 2.27	4.10 ± 3.17
Recognition	4.80 ± 3.76	11.30 ± 3.02	12.90 ± 2.60

Table 4.4: Mean Scores of Studied Words [Representation: Mean \pm SD]

Test Type	Retention Interval		
	Immediate	24 Hours	48 Hours
Recall	23.50 \pm 6.55	19.40 \pm 5.75	19.30 \pm 5.57
Recognition	22.60 \pm 3.80	22.90 \pm 3.14	23.30 \pm 2.75

CONCLUSION:

This study found that critical lure words identification is more in recognition than recall, i.e. false memory words (critical lures) are recognized or retrieved more in recognition than recall. The results suggest that participants are able to identify more critical lure words (false memory identifier) in recognition than recall in semantic task (DRM paradigm), and intrusion words are also identified more in recognition than recall. Studied words are almost identified in similar amount in both recall and recognition test in DRM paradigm of false memory formation. Across retention interval, critical lure words were not differing in amount, they were almost similar in both recall and recognition that shows the persistency of false memory. The interaction between test type (recall v/s recognition) and retention interval (immediate, 24 hours, 48 hours) was not significant i.e., no effect of retention interval across recall and recognition tests was observed. Across immediate, 24 hours and 48 hours' retention, same amount of critical lure words (false memory identifier) were identified in both recall as well as recognition retrieval strategies. However, across retention intervals, intrusion words and studied words (true target) both are significantly differing. Interaction between retention intervals (immediate, 24 hours, 48 hours) and test type (recall, recognition) are also found significant in both intrusion and studied words. Bonferroni post hoc analysis suggests that critical lure words identification (false memory identifier) was not affected by retention intervals (immediate, 24 hours, 48 hours) across both recall and recognition strategies. But, intrusion and studied words affected by retention interval. Retention interval (between immediate and 24 hours and between immediate and 48 hours) were significant only in recognition test for intrusion words, whereas retention interval (between immediate and 24 hours and between immediate and 48 hours) were significant only in recall for studied words.

DISCUSSION:

The first major observation that can be made from the results of the present experiment is that across retrieval intervals (recall vs. recognition) the critical lure words (false memory identifier) are better remembered during recognition than recall. This finding is very close to Roediger and McDermott (1995) finding where they found that false recognition was more than recall (recognition=0.84 and recall=0.65) when tested on subjects with 12 lists containing semantic associates. Underwood (1965) proposed that false recognition responses are generated during encoding when participants are seeing words like *water, tide, boat etc.* that has strong semantic association with the category name word *river*. Later at recognition, participants falsely recognize *river* as an old word (studied word) because of implicit associative responses. Another possible explanation might be like that participants are not aware of implicit activation but activation spreads through associative network (Anderson & Bower, 1973; Collins & Loftus, 1975) and false recognition occurs. In the present study, the recall score of critical lure words are very similar with that of Monds et al. (2017) recall scores. That false recognition is directly related to the number of related words in the word list has been established through research (Hall & Kozlovf, 1973; Hintzman, 1988; Shiffrin, Huber & Marirelli, 1995). The possible explanation for more critical word identification in recognition than recall (more false recognition than recall in present study) might be dependent on retrieval times and can be explained through the two-process theory. According to two-stage theory, during retrieval, participants take decision during recognition only whereas recall relies on recollection of information as well as decision process. Putting it differently, recall process involves search of studied items and then a decision process to retrieve the information, whereas recognition involves only decision process. As recognition involves only one process which might be responsible for memory error or failure (Watkins & Gardiner, 1979)

this leads to false memory. Also during recognition, participants were getting retrieval cues that might be responsible for false memory formation, whereas during recall no cues are present.

Another interesting observation of the present study is that across retention intervals of immediate, 24 hours and 48 hours the critical lure words did not show any significant changes between recall and recognition tests (see **Table 01**). Results similar to the present study were found by Toglia *et al.* (1999) where six word lists were tested across three retention interval (immediate, 1 week, 3 week). The present study was based on 10 list words with 10 words in each list that was tested across three retention intervals (immediate, 24 hours, 48 hours) and reported that false recall and false recognition score across all retention interval were same. The present study evaluated the effects of short retention intervals between learning and retrievals on false memory formation (McDermott, 1996; Payne et al., 1996; Reyna & Kiernan, 1994; 1995; Roediger & McDermott, 1995). The result of the present study supports the “persistence of the false memory effect” (Toglia et al., 1999). We had found this effect by manipulating retention interval between learning and retrieval across both retrieval types (recall vs. recognition). Similar studies were done with recall alone (McDermott, 1996; Payne et al., 1990; Roediger & McDermott, 1995; Schacter, Verfaellie & Pradere, 1996) and the results of such studies supports the persistency effect of retention interval on false memory/illusory memory. Brainerd, Reyna and Brandse (1995) also observed the stable rates of false recall and recognition over the retention intervals. This stability effect can be understood by the *Fuzzy Trace Theory* (FTT) that states that repetition over retention intervals enhances the *gist memories* that lead to the illusory recollection and this strengthening of gist traces and in the process making participants very confident to their memory decision based on gist (Toglia et al., 1999). Mather, Henkel & Johnson (1997) argued that there is condition in which salient semantic information can take precedence over other qualitative information that ordinarily might lead to more reliable source attribution, the net result is a powerful confusion with reality,

as participants often say they actually remember non-presented words as shown by Roediger & McDermott (1995). FTT (*Fuzzy Trace Theory*) also predicted that at the time of memory test, semantically related item, cue's gist trace of studied items. On repeated testing across retention intervals the gist traces remain highly accessible which supports the *hypermnestic effect* for critical intrusion (Payne et al., 1996). It was also found that gist representations are more durable and dominant than verbatim traces (Keenan & Kintsch, 1974; Reyna, 1996). So it would be expected that gist-consistent intrusions occurs with high frequency for semantic processing than non-semantic.

The endurance or persistence effect in this study was observed in critical lure words for both recall and recognition but, this effect was surprisingly following different pattern for *intrusion words* and *studied words*. Persistency was maintained in recall test but on recognition test. The false recognition of intrusion words increases from immediate to 24 hours of retention time and then became almost same from 24 hours to 48 hours' delay. We believe that this might be happening because during recognition test, participants used the cues to discriminate the studied items from intrusion words (very weakly related) which lead to implicit activation (Anderson & Bower, 1973; Collins & Loftus, 1975) and false identification of intrusion words happens. And also, the false recognition of intrusion words across retention intervals after 24-48 hours can be explained with the help of fuzzy trace theory. According to fuzzy trace theory, the gist of encoded information/items would be strengthening over time and the verbatim details would be weakened. For *studied words*, recognition of studied words was constant across retention interval (i.e. studied words scores did not change) but in recall, the score of studied words decreases from immediate to 24 hours of retention time and then became same. It has been found that as time progresses the verbatim detail of information get lost (Keenan & Kintsch, 1974; Reyna & Brainerd, 1995) and remaining recollection almost depends on gist traces of encoded information.

Spreading activation theory (Collins & Loftus, 1975) and *schema theory* (Alba & Hasher, 1983) are very compatible with result of the present study. Spreading activation works at the time of information encoding. At the time of encoding, the presented lists of words in DRM paradigm can creates the activation of high semantically associated words that spreads through semantic system and creates implicit activation responses (Underwood, 1965). This activation may create the concept/item/words that was not present during study phase but has some semantic relations with studied items (Anderson & Pirolli, 1984; Collins & Loftus, 1975). According to *schema theory*, participants already have a schema that actually represents generic knowledge about things, which they see or learn, and then automatically make some stories related to already available schema, which on latter influences the new information.

Along with the spreading activation and schema theory, *Fuzzy Trace Theory* (Reyna & Brainerd, 1995) and the *source monitoring theory* (Johnson, Hashtroudi & Lindsay, 1993; Johnson & Raye, 1981) proposed that perceptual details of list items fade across time and participants relies on gist traces (FTT) and internally generated inferences and externally perceived experiences differ in their qualitative characteristics (source monitoring theory), so these difference leads to source confusion and induce false memory.

Overall conclusion of the present study is that recognition leads to more false memory than recall and across retention intervals there is persistency of false memory in both recall and recognition for critical lure words but for intrusion words and studied words the pattern surprisingly different.

EXPERIMENT 02: Category Associates and False Memory

OBJECTIVE 01: The present study aimed at testing the effect of retrieval strategy and retention interval on false memory induced through category associate method

HYPOTHESIS:

H₁: Performance on the category associated induced false memory (critical lures) will increase in recognition in comparison to recall retrieval strategy

H₂: Retention interval between learning and retrieval will modulate the performance on the category associated induced false memory task

VARIABLES:

Independent variables: Retrieval strategy (Recall and Recognition)

Retention intervals (immediate, 24 h, and 48 h)

Dependent variables: Scores of critical lure pictures, and studied (true target) pictures.

DESIGN:

This experiment uses a 2 [(Retrieval strategies: Recall, Recognition) x 3 [(Retention intervals: Immediate, 24 Hours, 48 Hours)] mixed factorial design with repetition on the second factor. Mean scores of critical lures pictures, and true target pictures served as dependent variable. Critical lure pictures are used for calculating the false memory performance.

METHODOLOGY:

Participants

Twenty-eight healthy participants (all males) age [18-25 (19.78 ± 1.34) years] volunteered for the memory experiment. Undergraduate students of institute volunteered for the experiment in return for partial course credit compensation. All participants were free from serious medical and psychiatric conditions or drug dependence.

Material

Category associate paradigm was used to induce false memory using pre-selected pictures (simple line drawings) lists. Two group of subjects participated in the experiment. Subjects from one group performed on recall test while subjects of the second group performed on recognition test. The subjects were assigned to the groups randomly. Subjects in each group studied 10 lists with 10 line drawings in each list. The line drawings were exemplars of various categories and thus all list items were categorically associated. The exemplars used for each category were extracted from previously developed category database (Battig & Montague, 1969). Line drawing were presented using e-prime Version 2 on the center of the computer screen in sequentially order. Line drawing pictures in each list were arranged in descending order of their frequency of availability (Seamon et al., 2000).

Procedure

This experiment included two groups (recall, recognition). Subjects in each group were made to study the given lists of line drawings and later perform on the retrieval tests assigned for that group.

At the beginning of the experiment, each participant filled battery of behavioral questionnaires that included mood questionnaire, MMSE, memory and attention test and memory functioning questionnaire. Total 10 lists with 10 exemplar pictures (related to category) in each list were presented to the subjects with instruction to attend each picture and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/picture with an inter-stimulus interval of 2000 milliseconds. List items were sequentially presented during the study phase, but at the time of the retest, intra-list items were randomly presented. The experiment was designed in e-Prime Software Ver 2.0

At *recognition*, participants provided the old/new judgment for each presented picture. Response generation on the recognition test was self-paced by participants. Each recognition list contained three studied (old) pictures (from learning list), three new pictures (unrelated pictures as distractors) and two critical lure pictures (one high-frequency picture, and one low-frequency picture). A distractor task was introduced between study phase and recognition test to prevent a repetition of lists. The whole experiment runs for approximately 40 minutes.

At *recall phase*, participants were free to recall the list pictures. In the recall of pictures, participants have to recall the name of the pictures. All the responses were taken on plain white paper. Distractor task was also introduced between the study and recall to prevent the repetition of list items.

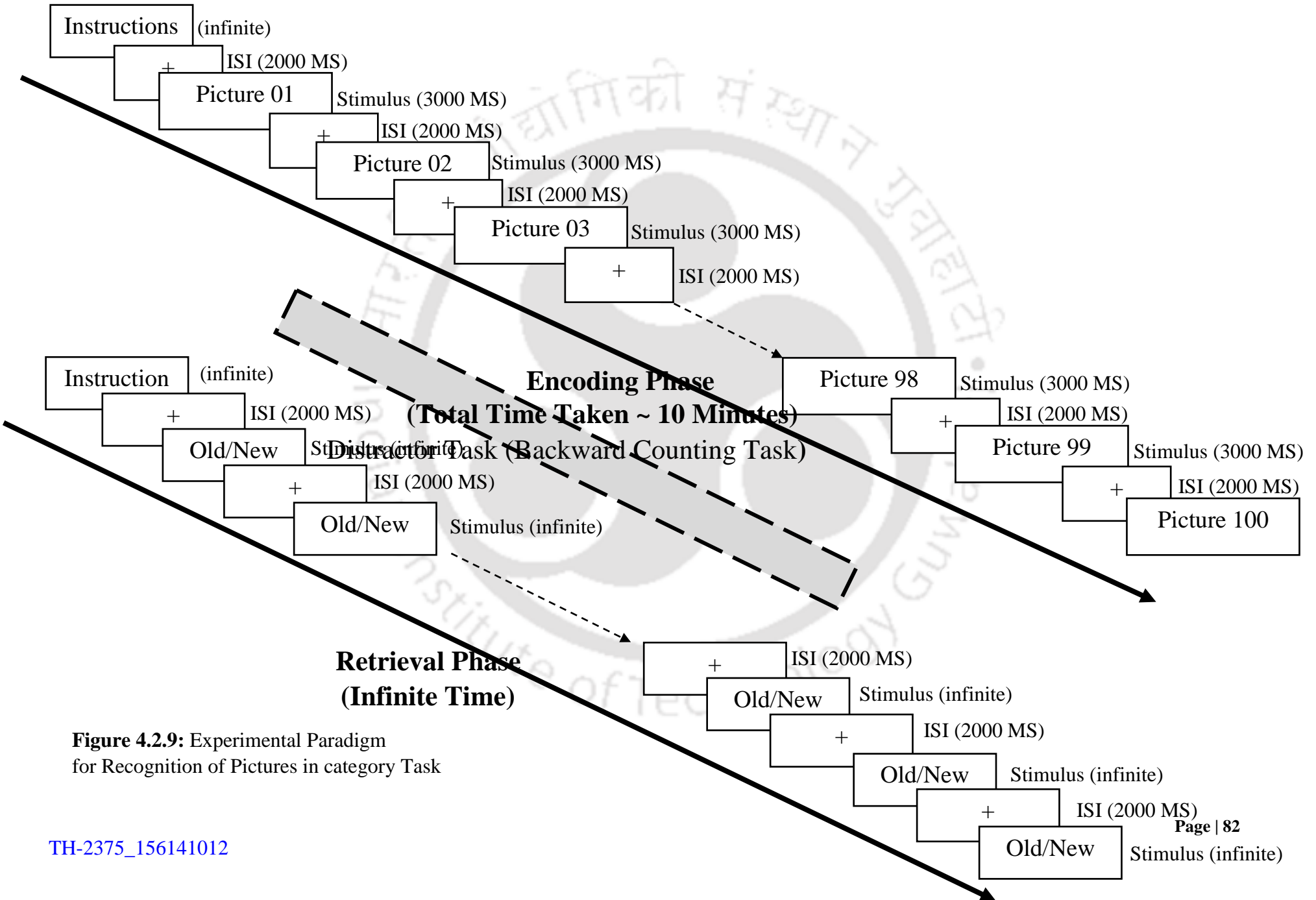


Figure 4.2.9: Experimental Paradigm for Recognition of Pictures in category Task

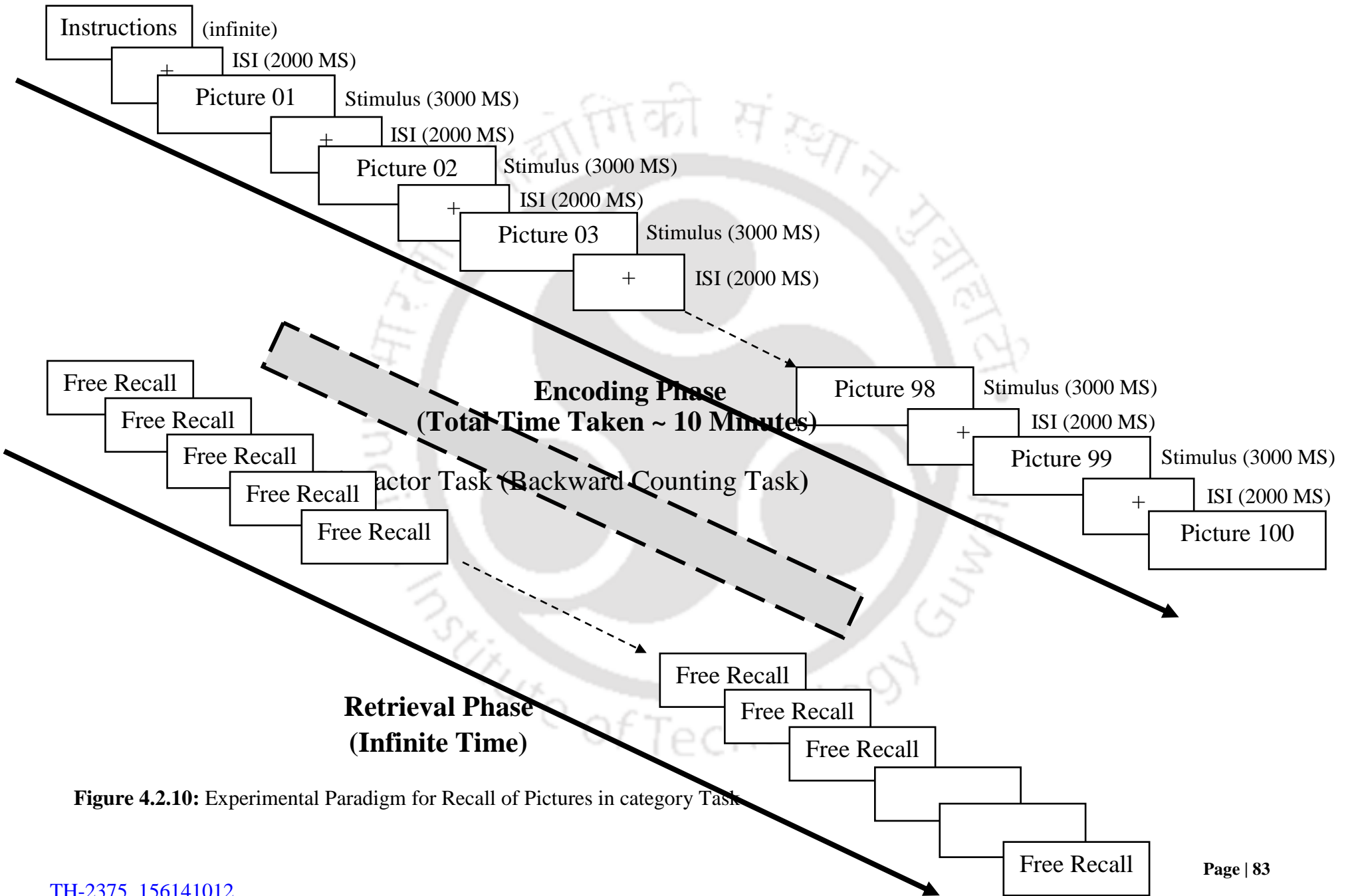


Figure 4.2.10: Experimental Paradigm for Recall of Pictures in category Task

Data analysis

The results are presented as mean correct responses of studied pictures, and critical lure pictures (CL). Critical lure pictures are the actual measurements of false memory in the category associated false memory task. Mixed ANOVA, 2 [Retrieval strategies (Recall, Recognition); Between subject] x 3 [Retention intervals (Immediate, 24 Hours, and 48 Hours); Within-subject] with repetition on the second factor was used to analyze the data.

RESULTS:

Critical Lure: The main effect of test type (recall vs recognition) and retention interval (immediate, 24h and 48h) for retrieval of critical lures were non-significant [$F_{(1, 26)} = 2.122, p > 0.05, \eta^2=0.075$]. However, a significant interaction was reported between retrieval strategies and retention intervals [$F_{(2, 52)} = 4.471, p < 0.05, \eta^2=0.147$] (see **Table 4.5**).

Bonferroni post-hoc analysis reveals that, the number of critical lures retrieved significantly varied on recognition test carried out immediately after learning and 24h after learning. One interesting finding was also revealed by post-hoc analysis that, while retrieval using recall lead to the same number of critical lures reproduced between an immediate and delayed (24h) retrieval intervals, there was significant increase in the number of critical lures being reproduced between immediate and delayed (24h) retrieval interval on recognition.

True Targets: The main effect of test type on true target picture was found significant [$F_{(1,26)} = 4.390, p < 0.05, \eta^2=0.144$]. Main effect of retention interval [$F_{(2,52)} = 8.303, p < 0.05, \eta^2=0.242$] and interaction between test type and retention interval were also found to be significant [$F_{(2,52)} = 5.694, p < 0.05, \eta^2=0.180$] (See **Table 4.5**). Bonferroni post-hoc analysis reveals that, only in

recognition there are significant differences exist between immediate and 24 hours of delay, but in recall there are no differences found.

Table 4.5: Mean Scores of Critical Lures Pictures and True Target Pictures

Dependent Measure	Test Type					
	Recall Rate			Recognition Rate		
	Immediate	24 Hours	48 Hours	Immediate	24 Hours	48 Hours
Critical Lures	2.57 ± 1.39	2.42 ± 1.34	2.64 ± 1.49	2.07 ± 2.16	3.85 ± 1.99	4.00 ± 2.07
True Targets	36.28 ± 9.98	30.92 ± 8.80	29.28 ± 9.44	27.35 ± 3.49	27.40 ± 3.30	26.57 ± 4.20

CONCLUSION:

This experiment has found that critical lures in category associates does not influenced by the both recall and recognition retrieval strategies i.e. critical lures pictures are almost equally remembered in both recall and recognition. But, after 24 hours of retention interval recall and recognition affect the retrieval of critical lure pictures where recognition leads to more critical lures than recall. Across retention intervals, recall test shows the persistency/persistency effect of false memory in category associates. But, in recognition test it was found that from immediate to 24 hours of retention interval the false recognition of critical lure pictures increases and then became constant from 24 hours to 48 hours of retention interval. In recognition of true target pictures, recall leads to more hits then recognition. Across retention intervals, the true targets were decreased as time progress in recall test but it was constant in the recognition test.

DISCUSSION:

In this study, false memory is induced by category associate method through pictures that are simple line drawings. Participants are required to retrieve the study list items are retrieval using either recall or recognition retrieval strategy after three different retention intervals following list learning. This study reported that on immediate retrieval, recall and recognition did not differ on the number of false memory identifiers (critical lures). However, following a 24h retention interval the number of false memory identifiers (critical lures) increased for recognition. These results based on retention intervals reported here are consistent with the *fuzzy trace theory* (Reyna & Brainerd, 1995) which says that as time passes, the perceptual details of items decline and the

participants start to rely increasingly on the gist details of items. Previous studies performed with different delayed retention intervals of [Toglia et al. (1999)] 1 and 3 weeks reported consistent false recall on both the retrievals. The present study differs from Toglia et al. (1999) on the number of list used (10 vs 6 list) and the retention interval for testing (immediate, 24h, 48h vs 1 and 3 week). Thapar and McDermott (2001) has done the experiment on false recall and recognition across retention intervals of immediate, 2 days, and 7 days. They found that false recall and recognition both decline as the time progress.

The present study reported that the number of false memory identifier (critical lures) increased on recognition trials when tested after 24h of retention interval ($p < 0.014$). This finding draws support from the *strength theory* (McDougall, 1904; Postman, 1963) and *generate-recognize theory* (Hollingworth, 1913; James, 1890). Strength theory states that recognition is better in retrieving items than recall i.e. recall requires more information on items stored in memory. According to generate-recognize view, the recall is two stage process in which the item to be retrieved is at first recollected from memory followed by their familiarity assessment whereas in recognition there is only familiarity assessment of items. In the present study, false recognition is more than false recall after 24 hours of delay, which can be supported with generate-recognize view as during recognition, only familiarity decision are required due to which in the presence of additional available cues critical lures are processed as list items. These additional cues and the fact that the critical lures have very high semantic association with the list items leads to errors in source monitoring as a result of which critical lures are falsely remembered as list item (Johnson & Raye, 1981; Johnson, Hashroudi, & Lindsay, 1993).

It was observed that in the visual modality, during studying of pictorial items the maximum perceptual details are encoded (Norman & Schacter, 1997) which will during retrieval time increases the discriminability between “old” and “new” items (Dewhurst & Conway, 1994). So

we can say that in picture recognition condition, the participant's decision was based on the perceptual details of items. The possible explanation for the formation of false memory in category associates is implicit activation theory (Underwood, 1965) and fuzzy-trace theory (Brainerd & Reyna, 1998). According to the implicit activation hypothesis for false memory formation in category associates, series of exemplars of the same category are presented during the study phase leads to activation of non-studied exemplars. This activation is because of the associative strength of non-studied and studied exemplars. The fuzzy-trace theory hypothesized that memory is stored in the brain in two ways, i.e. one form has the surface features of encoded items known as *verbatim* details, whereas another form is known as *gist trace* that has the semantic information of encoded items. The main list items are stored in the *verbatim trace*, whereas the non-studied theme items stored as *gist trace*.

EXPERIMENT 03-A: Comparing the category associate and semantic associate methods of inducing false memory across recall retrieval strategy

OBJECTIVE 01: This experiment is aimed at comparing the effectiveness semantic associate (words) and category associate (line drawings) of false memory induction methods across varied retention intervals for recall retrievals

HYPOTHESIS:

H_{3A-1}: Semantic associates will lead to higher false memory generation than category associates.

H_{3A-2}: Retention interval between learning and retrieval will modulate false memory generation on *category associate and semantic associate* task

VARIABLES:

Independent variables: Retention intervals (immediate, 24 Hours, 48 Hours)

False memory paradigm (line drawings (CA), words (SA))

Dependent variables: Recall scores of critical lures of pictures and words; intrusion pictures and words; and studied (true target) pictures and words.

DESIGN:

The experiment uses, 2 [Methodology: Category Associate, DRM paradigm] x 3 [Retention intervals; (Immediate, 24 Hours, 48 Hours)] mixed factorial ANOVA design. Number of critical

lures, intrusions, true targets serve as the dependent variable and are used for calculating false memory performance.

METHODOLOGY:

Participants

Total eleven healthy participants (age: mean \pm sd = 19.20 \pm 1.15 years; all males) volunteered for the memory experiment. Volunteers were undergraduate students of IIT Guwahati who were compensated with partial course credit for the participation. All participants were free from serious medical and psychiatric conditions or drug dependence.

Material

Category Associate task: Simple line drawings served as stimuli. Participants studied 10 lists with 10 exemplars of a category in each list. The line drawing used for each category list were extracted from previously developed picture database (Battig & Montague, 1969). Line drawing were presented using e-prime (stimuli presentation software) on the center of the computer screen in sequential order. Line drawing in each list were arranged in descending order of their frequency of availability (Seamon et al., 2000).

Semantic associate task: DRM paradigm was used to induce false memory for pre-selected word lists. Participants studied 10 lists with 10 words in each list. The words used were semantically associates and were extracted from previously developed false memory word database (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959).

Words were presented using e-prime software on the center of the computer screen with each word

written in size 14 Time New Roman font. Words on each list were arranged in descending order of backward association strength (BAS). In order to maintain constancy, the within lists factors i.e. word length and, BAS value were made constant across all lists.



Experimental Model of Effectiveness of False Memory Induction Methods:

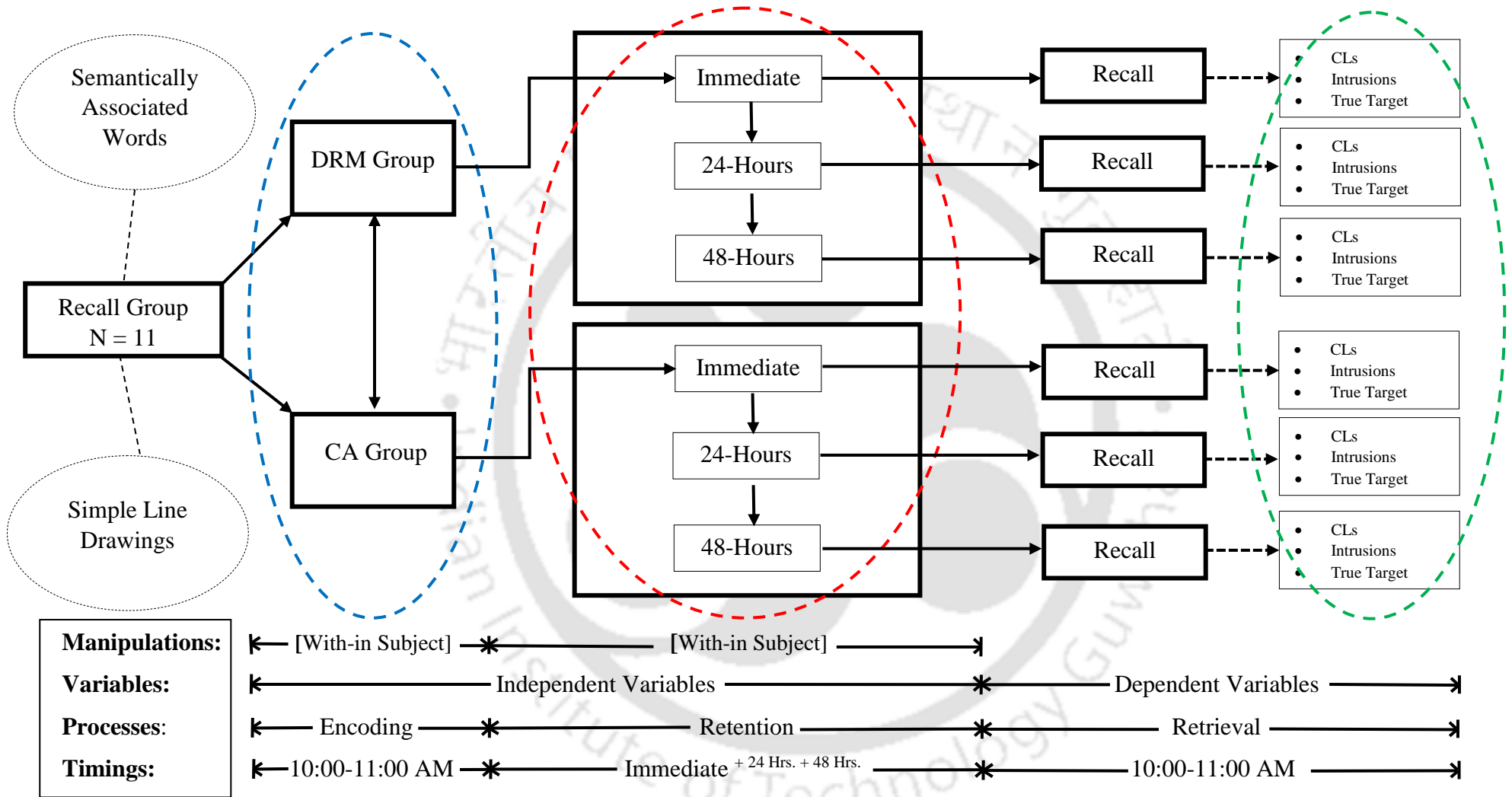


Figure 4.3.11: Effectiveness of False Memory Induction Methods Across three retention Intervals in Recall Test.

(Note: Red dotted circle represents with-in subject manipulation; blue dotted circle represents between subject manipulation, and green dotted circles includes dependent variables)

(Abbreviation: CA=Category Associate Task; CL=Critical Lures)

Procedure:

Subjects in each group were made to study the given lists of stimuli (words or line drawings) and later tested for the same. At the beginning of the experiment, each participant filled behavioral questionnaires that included Mood questionnaire, MMSE, Memory and Attention test, Memory Functioning Questionnaire.

In *category associate method*, total ten category lists with ten exemplar pictures (related to category) in each category list were presented to the subjects with instruction to attend each picture and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/picture with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during learning, but at retrieval, intra-list items were randomly presented. The experiment was designed in E-Prime Version 2.

In *semantic associate method*, total ten lists with ten words in each list were presented to the subjects with instruction to attend each word and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/word with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during the study phase as well as during the test phase. The experiment was designed in E-Prime Version 2.

At *recall*, participants were free to reproduce the list items in for both the semantic and category associate method. In the recall of line drawings, participants reproduced the name of the line drawings, and in the semantic associate method participants have reproduce the learned words. Responses were taken on plain white paper. Distractor task was also introduced between the study phase and retrieval phase to prevent the repetition of list items.

Data analysis

Mean correct responses of studied stimuli (pictures and words), intrusions (pictures and words), and critical lures (picture and words) is calculated for recall test. Repeated measure ANOVA was used to measure the differences between false memory induction methods (SA vs. CA) across retention intervals (immediate, 24 hrs., and 48 hrs.). Bonferroni post hoc analysis was used to examine the interaction levels within the subject.

RESULTS:

Mixed factorial within-subject repeated measure ANOVA 2 [Task Type: (DRM, CA)] x 3 [Retention intervals: (Immediate, 24 Hours, and 48 Hours)] was applied to measure the false recall of words and pictures.

Critical Lures: The main effect of task type (DRM vs. CA) for critical lures pictures and words found to be non-significant [(F_(1,10) = 0.514, p > 0.05, η^2 = 0.049)]. Across retention interval [(F_(2,20) = 0.262, p > 0.05, η^2 = 0.026)] and the interaction between task type (CA vs. DRM) and retention intervals were also found to be non-significant [(F_(2,20) = 0.224, p > 0.05, η^2 = 0.022)]. (see **Table 4.6**)

Intrusions: The main effect of task type for the intrusion pictures and words are found to be non-significant [(F_(1,10) = 2.168, p > 0.05, η^2 = 0.178)]. Across retention interval [(F_(2,20) = 1.297, p > 0.05, η^2 = 0.115)] and the interaction between task type (CA vs. DRM) and retention intervals are also found to be non-significant [(F_(2,20) = 2.890, p > 0.05, η^2 = 0.224)]. (see **Table 4.6**)

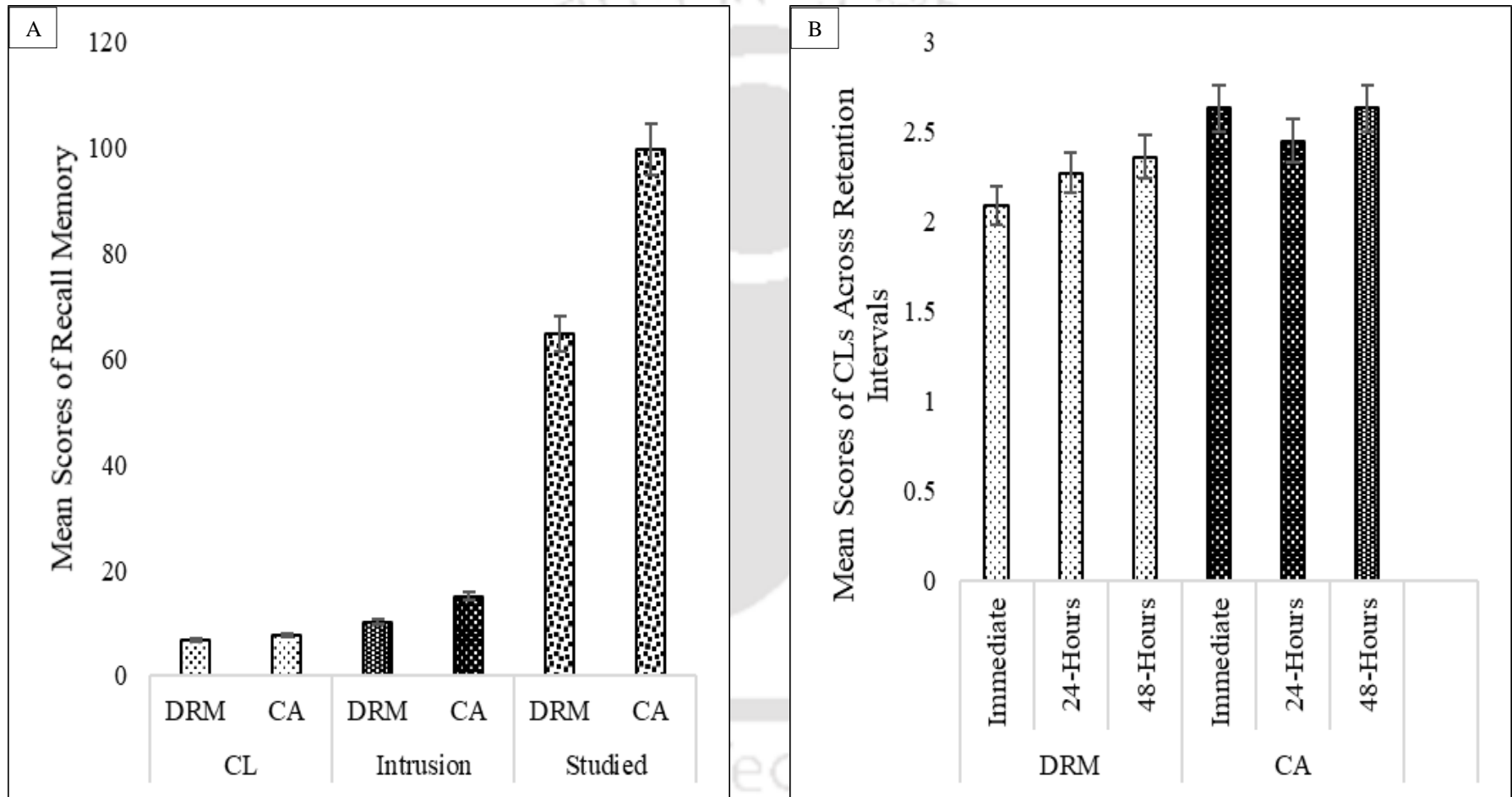
True Targets: The main effect of task type for true targets are found to be significant [(F_(1,10) = 31.759, p < 0.05, η^2 = 0.761)]. Across all the retention intervals found to be significant [(F_(2,20) = 17.125, p < 0.05, η^2 = 0.633)], but the interaction effect between task type and retention interval found to be non-significant [(F_(2,20) = 1.481, p > 0.05, η^2 = 0.129)]. (see **Table 4.6**)



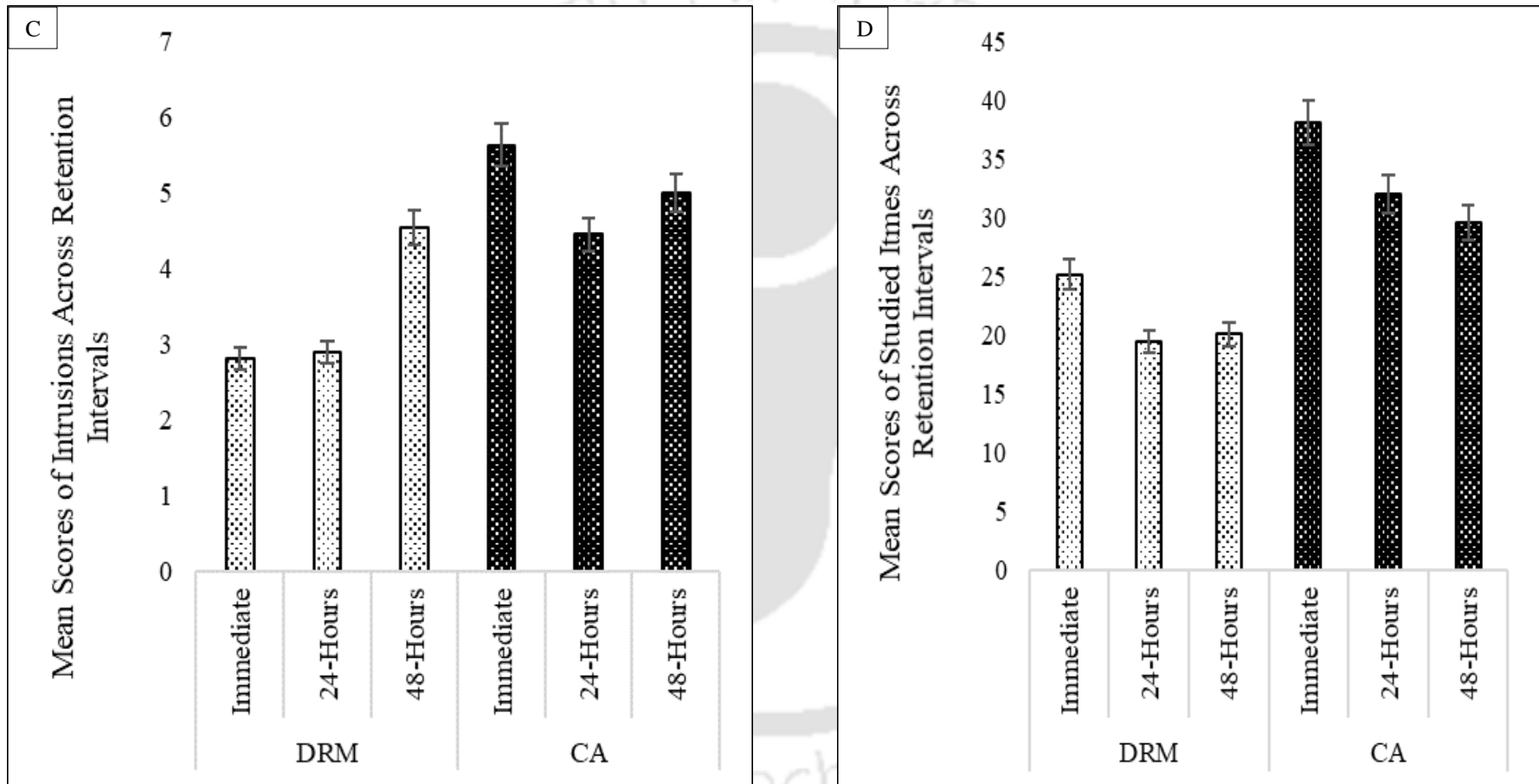
Table 4.6: Mean Scores of Memory Performance in **Recall** Test Across Task Type

Dependent Measure	Task Type					
	DRM Task (for Words)			CA Task (for Pictures)		
	Immediate	24 Hours	48 Hours	Immediate	24 Hours	48 Hours
Critical Lures	2.09 ± 1.57	2.27 ± 1.27	2.36 ± 1.12	2.63 ± 1.43	2.45 ± 1.43	2.63 ± 1.56
Intrusions	2.81 ± 2.40	2.90 ± 2.38	4.54 ± 2.76	5.63 ± 4.58	4.45 ± 3.85	5.00 ± 4.71
True Targets	25.18 ± 6.17	19.45 ± 4.41	20.09 ± 4.70	38.09 ± 9.62	32.00 ± 9.03	29.54 ± 9.85

Graph 4.3.1: Mean scores of recall memory (A) Overall mean scores of CL, Intrusion and Studied items across SA and CA tasks, (B) Mean scores of CLs across retention intervals between DRM and CA task. [$p < 0.05$]

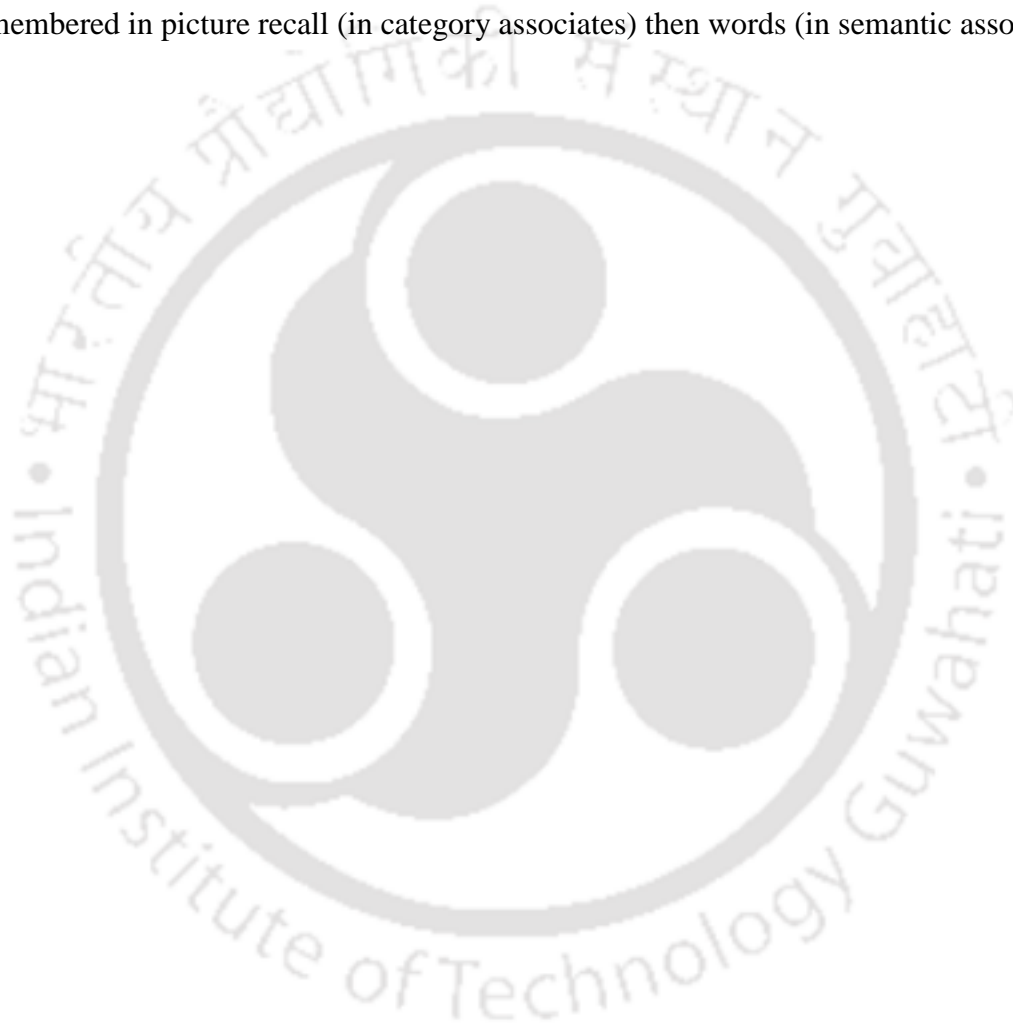


Graph 4.3.2: Mean scores of recall memory, (C) Mean scores of intrusions across retention intervals between DRM and CA task, and (D) Mean scores of studied items across retention intervals between DRM and CA task. [$p < 0.05$]



CONCLUSION:

In recall retrieval strategy, critical lure words (in semantic associates) and critical lure pictures (in category associates) both are remembered equally. Along with critical lures, intrusions also remembered equally across both semantic and category associates. But, the true targets items are better remembered in picture recall (in category associates) than words (in semantic associates).



EXPERIMENT 03-B: Comparing the category associate and semantic associate methods of inducing false memory across recognition retrieval strategy

OBJECTIVE 01: This experiment is aimed at comparing the effectiveness semantic associate (words) and category associate (line drawings) of false memory induction methods across varied retention intervals for recognition retrievals

HYPOTHESIS:

H_{3B-1}: Semantic associates will lead to higher false memory generation than category associates.

H_{3B-2}: Retention interval between learning and retrieval will modulate false memory generation on category associate and semantic associate task

VARIABLES:

Independent variables: Retention intervals (immediate, 24 Hours, 48 Hours)
FM paradigm (line drawings (CA), words (SA))

Dependent variables: Recognition scores of critical lures of pictures and words; intrusion pictures and words; and studied (true target) pictures and words.

DESIGN:

The experiment uses, 2 [Methodology: Category Associate, DRM paradigm] x 3 [Retention intervals; (Immediate, 24 Hours, 48 Hours)] mixed factorial ANOVA design. Number of critical

lures, intrusions, true targets serve as the dependent variable and are used for calculating false memory performance.

METHODOLOGY:

Participants

Thirteen healthy participants (age: mean \pm sd = 19.25 \pm 1.20 years; all males) volunteered for the memory experiment. Volunteers were undergraduate students of IIT Guwahati who were compensated with partial course credit for the participation. All participants were free from serious medical and psychiatric conditions or drug dependence.

Material

Category Associate task: Simple line drawings served as stimuli. Participants studied 10 lists with 10 exemplars of a category in each list. The line drawing used for each category list were extracted from previously developed picture database (Battig & Montague, 1969). Line drawing were presented using e-prime (stimuli presentation software) on the center of the computer screen in sequential order. Line drawing in each list were arranged in descending order of their frequency of availability (Seamon et al., 2000).

Semantic associate task: DRM paradigm was used to induce false memory for pre-selected word lists. Participants studied 10 lists with 10 words in each list. The words used were semantically associates and were extracted from previously developed false memory word database (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959). Words were presented using e-prime software on the center of the computer screen with each word

written in size 14 Time New Roman font. Words on each list were arranged in descending order of backward association strength (BAS). In order to maintain constancy, the within lists factors i.e. word length and, BAS value were made constant across all lists.



Experimental Model of Effectiveness of False Memory Induction Methods:

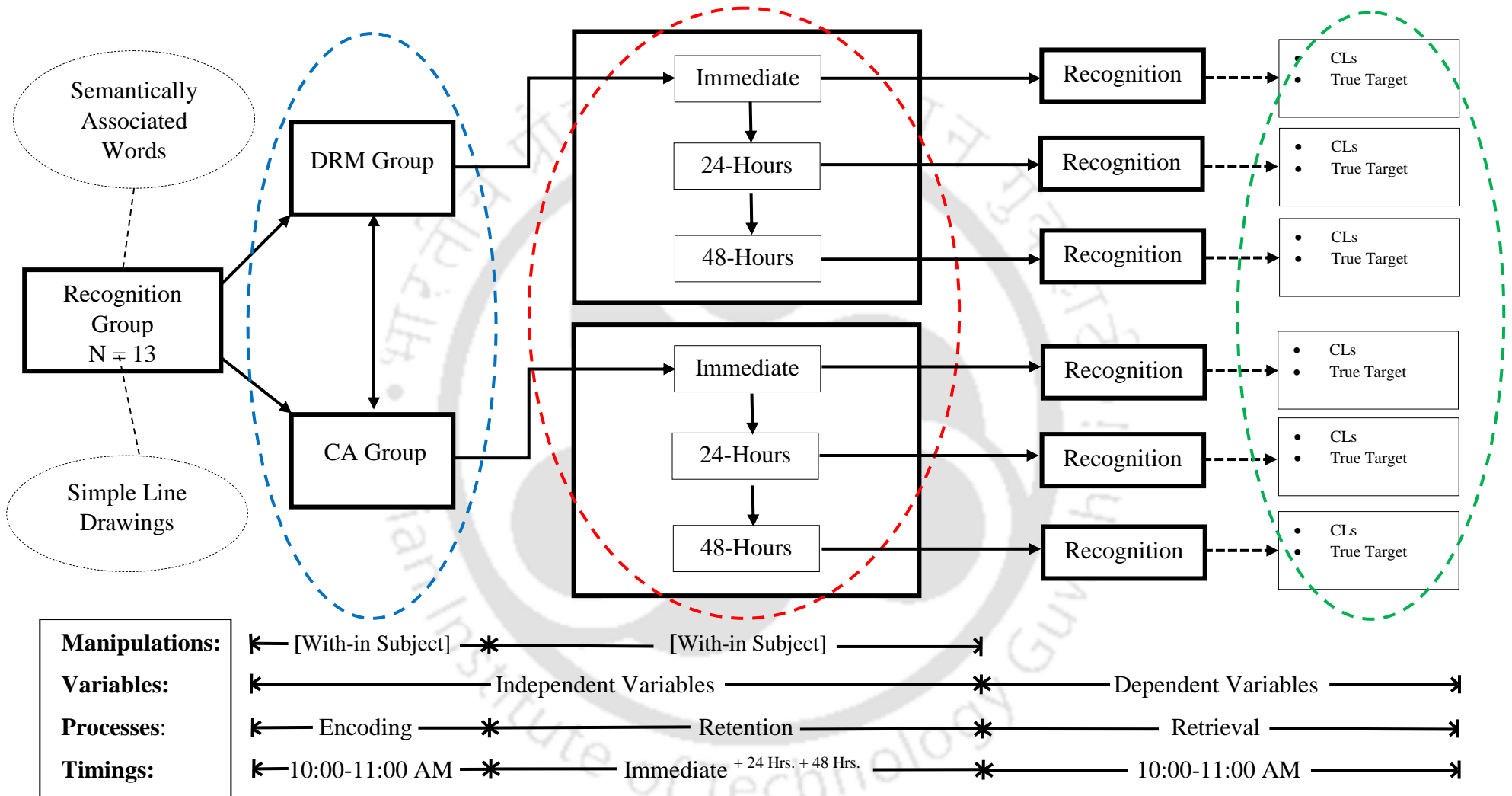


Figure 4.3.12: Effectiveness of False Memory Induction Methods Across three retention Intervals in Recognition Test.

(Note: Red dotted circle represents with-in subject manipulation; blue dotted circle represents between subject manipulation, and green dotted circles includes dependent variables)

(Abbreviation: CA=Category Associate Task; CL=Critical Lures)

Procedure:

Subjects in each group were made to study the given lists of stimuli (words or line drawings) and later tested for the same. At the beginning of the experiment, each participant filled behavioral questionnaires that included Mood questionnaire, MMSE, Memory and Attention test, Memory Functioning Questionnaire.

In *category associate method*, total ten category lists with ten exemplar pictures (related to category) in each category list were presented to the subjects with instruction to attend each picture and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/picture with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during learning, but at retrieval, intra-list items were randomly presented. The experiment was designed in E-Prime Version 2.

In *semantic associate method*, total ten lists with ten words in each list were presented to the subjects with instruction to attend each word and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds/word with an inter-stimulus interval of 2000 milliseconds and interlist interval of 5000 milliseconds. List items were sequentially presented during the study phase as well as during the test phase. The experiment was designed in E-Prime Version 2.

At *recognition phase*, participants provided the old/new recognition test for each presented picture and word. Response generation on the recognition test was self-paced by participants. Each recognition list contains three old items (picture, word) from learning list, three new items (unrelated items) served as distractors, and two critical lure pictures in CA task (one high frequency picture, and one low frequency picture) and one critical lure word in SA task. the whole experiment run for approximately 40 minutes. Distractor task was also introduced between the study phase and retrieval phase to prevent the repetition of list items.

Data analysis

Sensitivity and response bias was measured to analyze the scores of critical lures and true target items. Intrusions (pictures and words) and CLs (pictures and words) are the actual measurements of false memory in both methodologies. Repeated measure ANOVA was used to measure the differences between false memory induction methods (DRM vs. CA) across retention intervals (immediate, 24 hrs., and 48 hrs.). Bonferroni post hoc analysis was used to examine the interaction levels within the subject.

RESULTS:

Mixed factorial within-subject repeated measure ANOVA 2 [Task Type: (DRM, CA)] x 3 [Retention intervals: (Immediate, 24 Hours, and 48 Hours)] was applied to measure the false recognition of words and pictures. In recognition test, sensitivity and response bias was measured to analyze the false memory induction across DRM and CA tasks.

Critical Lure: The main effect of task type (DRM vs. CA) found to be non-significant for critical lures in recognition test [$F_{(1,12)} = 0.009$, $p > 0.05$, $\eta^2 = 0.001$]. Across retention intervals it was found to be significant [$F_{(2,24)} = 4.703$, $p < 0.05$, $\eta^2 = 0.282$], and the interaction between task type and retention interval are also found to be significant [$F_{(2,24)} = 5.526$, $p < 0.05$, $\eta^2 = 0.315$].

The sensitivity values of the recognition of critical lure measures are presented in **Table 4.7**.

Bonferroni post-hoc analysis reveals that in DRM task, across immediate and 24 hours ($p < 0.012$) and across immediate and 48 hours ($p < .007$) of retention the sensitivity of critical lures found significant different, but in CA task the sensitivity of critical lure pictures recognize equally across

all the retention intervals. Across task type, sensitivity of critical lures found more in DRM than CA just after immediate recognition, and in other interval the sensitivity found to be equally (See **Table 4.7**).

The response bias in DRM task for critical lures is conservative after immediate retrieval, but further after 24 hours and 48 hours of retention it became liberal response. In CA task, the response bias was conservative in all the three retention intervals. [See **Table 4.7**]. The main effect of task type [(F_(1,12) = 10.495, p < 0.05, η² = 0.467)] and retention interval [(F_(2,24) = 9.544, p < 0.05, η² = 0.443)] in response bias was found to be significant. The interaction between task type and retention interval found to be non-significant [(F_(2,24) = 0.058, p > 0.05, η² = 0.005)].

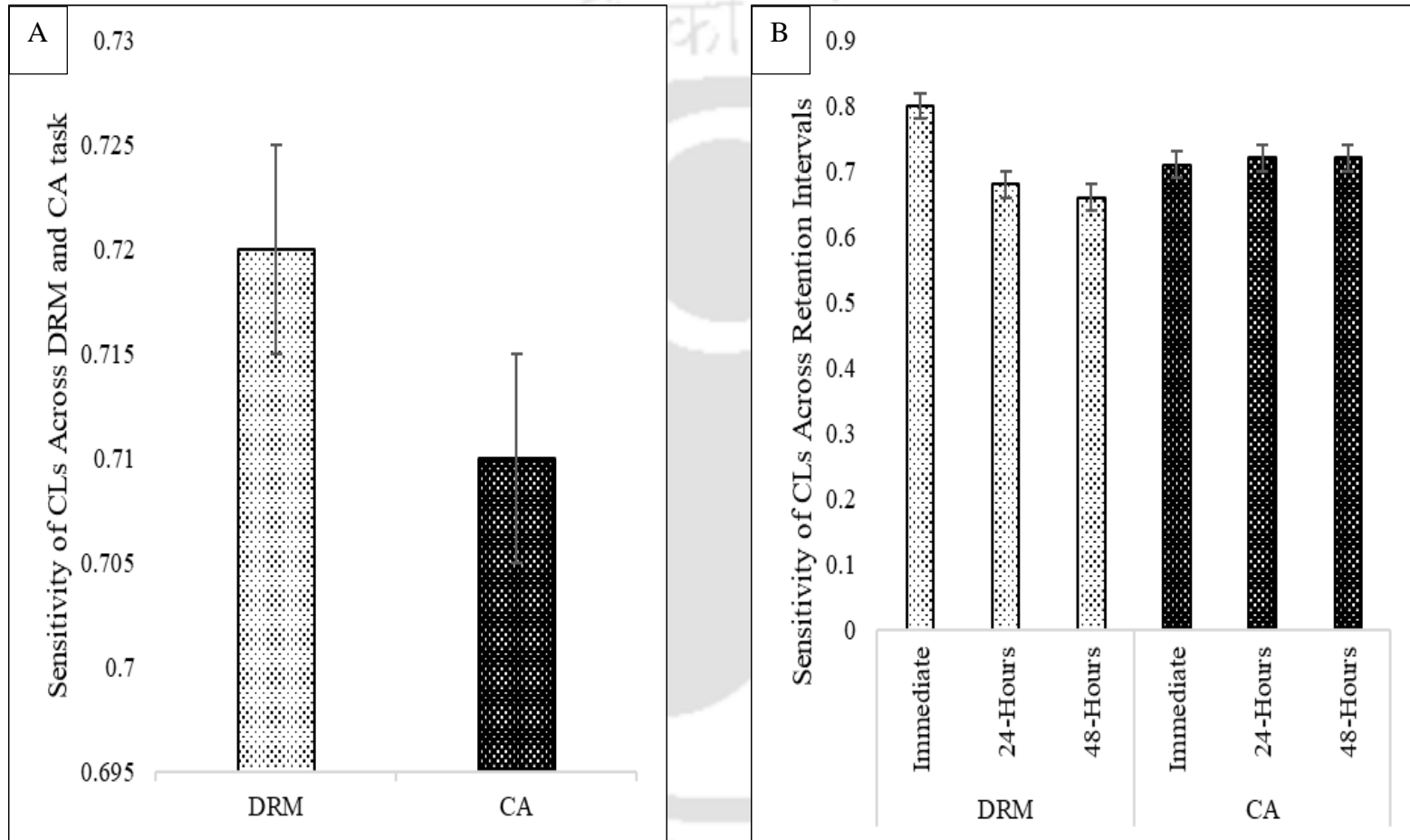
True Targets: The main effect of task type (DRM vs. CA) for true targets are found to be significant [(F_(1,12) = 46.194, p < 0.05, η² = 0.794)]. Across retention intervals [(F_(2,24) = 20.565, p < 0.05, η² = 0.632)] and the interaction between task type and retention interval [(F_(2,24) = 7.681, p < 0.05, η² = 0.390)] are also found to be significant. Mean values of sensitivity are reported in **Table 4.7**.

The response bias of true target pictures in CA task and DRM task, both found initially conservative and then after 24 hours and 48 hours' retention interval it became liberal. [see **Table 4.7**]. The main effect of task type [(F_(1,12) = 0.312, p > 0.05, η² = 0.025)] found to be non-significant. The main effect of retention interval found to be significant [(F_(2,24) = 10.377, p < 0.05, η² = 0.464)], but the interaction between task type and retention interval found to be non-significant [(F_(2,24) = 0.961, p > 0.05, η² = 0.074)].

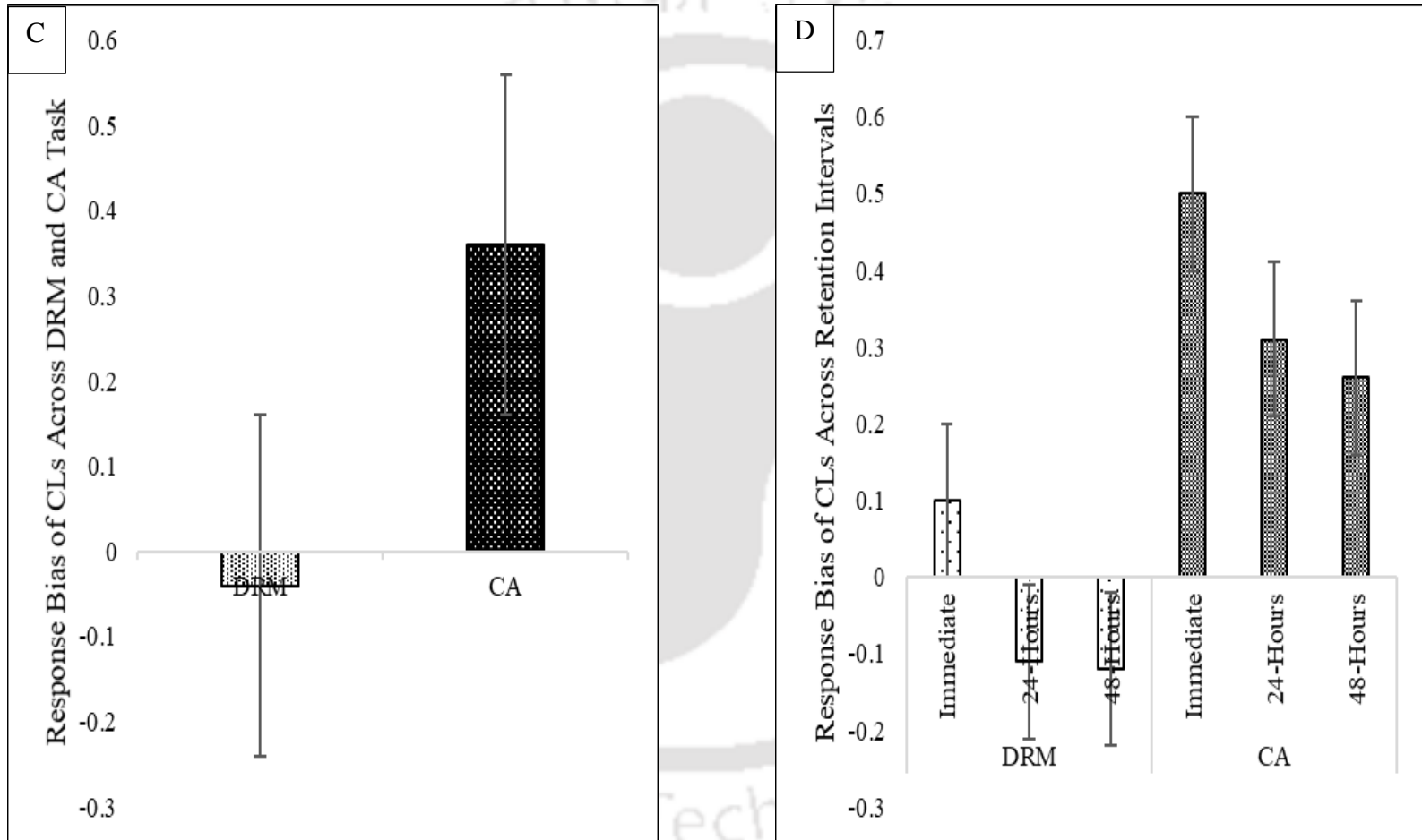
Table 4.7: Sensitivity (A') and Response Bias (B'') of Critical Lures and True Target Items Across Task Type

Dependent Measure	Task Type					
	DRM Task (for Words)			CA Task (for Pictures)		
	Immediate	24 Hours	48 Hours	Immediate	24 Hours	48 Hours
A'						
Critical Lures	.80 ± .07	.68 ± .13	.66 ± .13	.71 ± .11	.72 ± .09	.72 ± .11
True Targets	.83 ± .07	.74 ± .09	.71 ± .10	.95 ± .09	.92 ± .05	.91 ± .06
B''						
Critical Lures	0.10 ± 0.45	-0.11 ± 0.30	-0.12 ± 0.29	0.50 ± 0.39	0.31 ± 0.27	0.26 ± 0.35
True Targets	0.11 ± 0.39	-.011 ± 0.06	-0.14 ± 0.10	0.18 ± 0.71	-0.30 ± 0.47	-0.29 ± 0.69

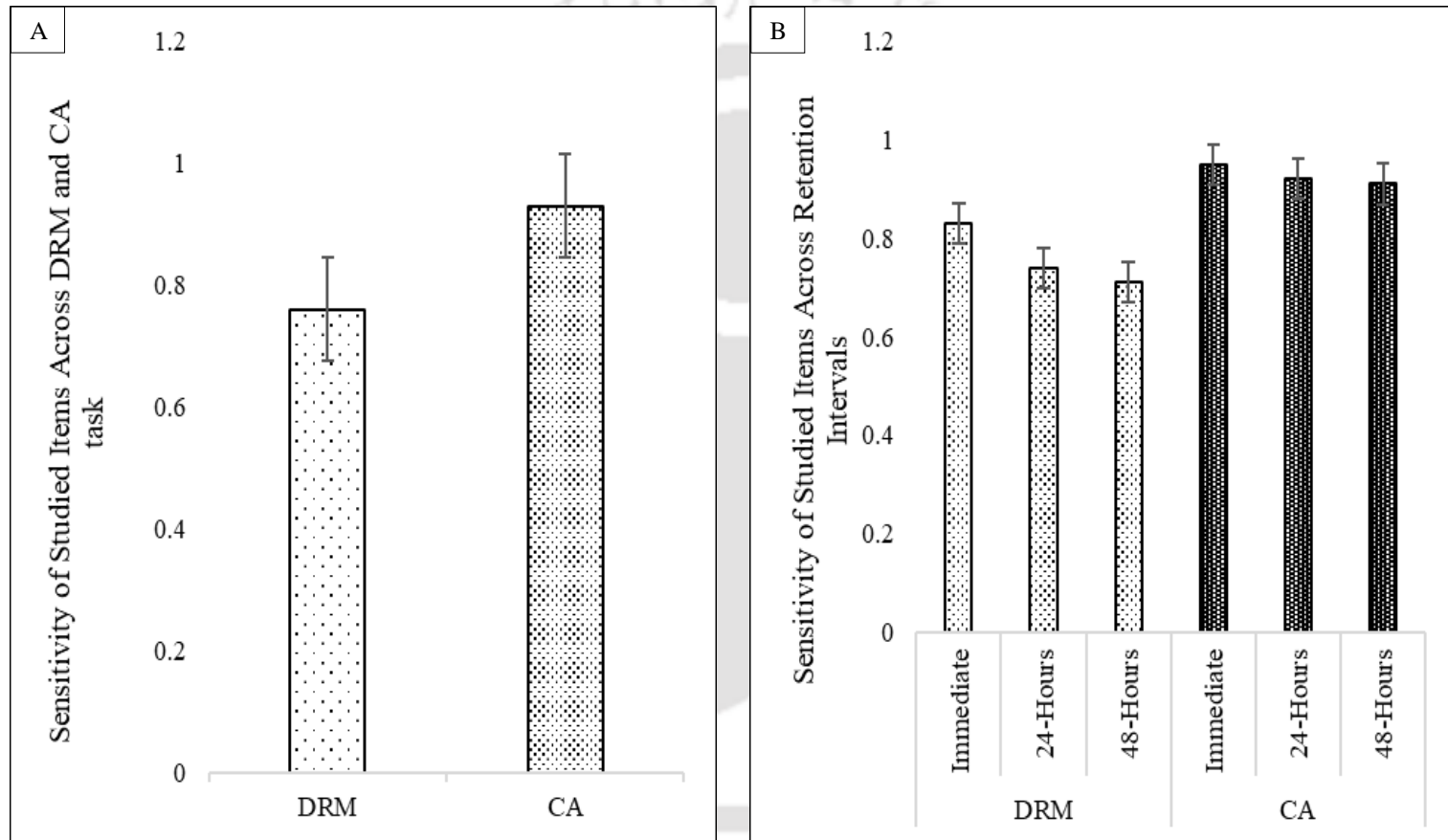
Graph 4.3.3: Mean scores of CLs recognition, (A) Sensitivity of CLs across DRM and CA task, (B) Sensitivity of CLs across retention intervals between DRM and CA Task.



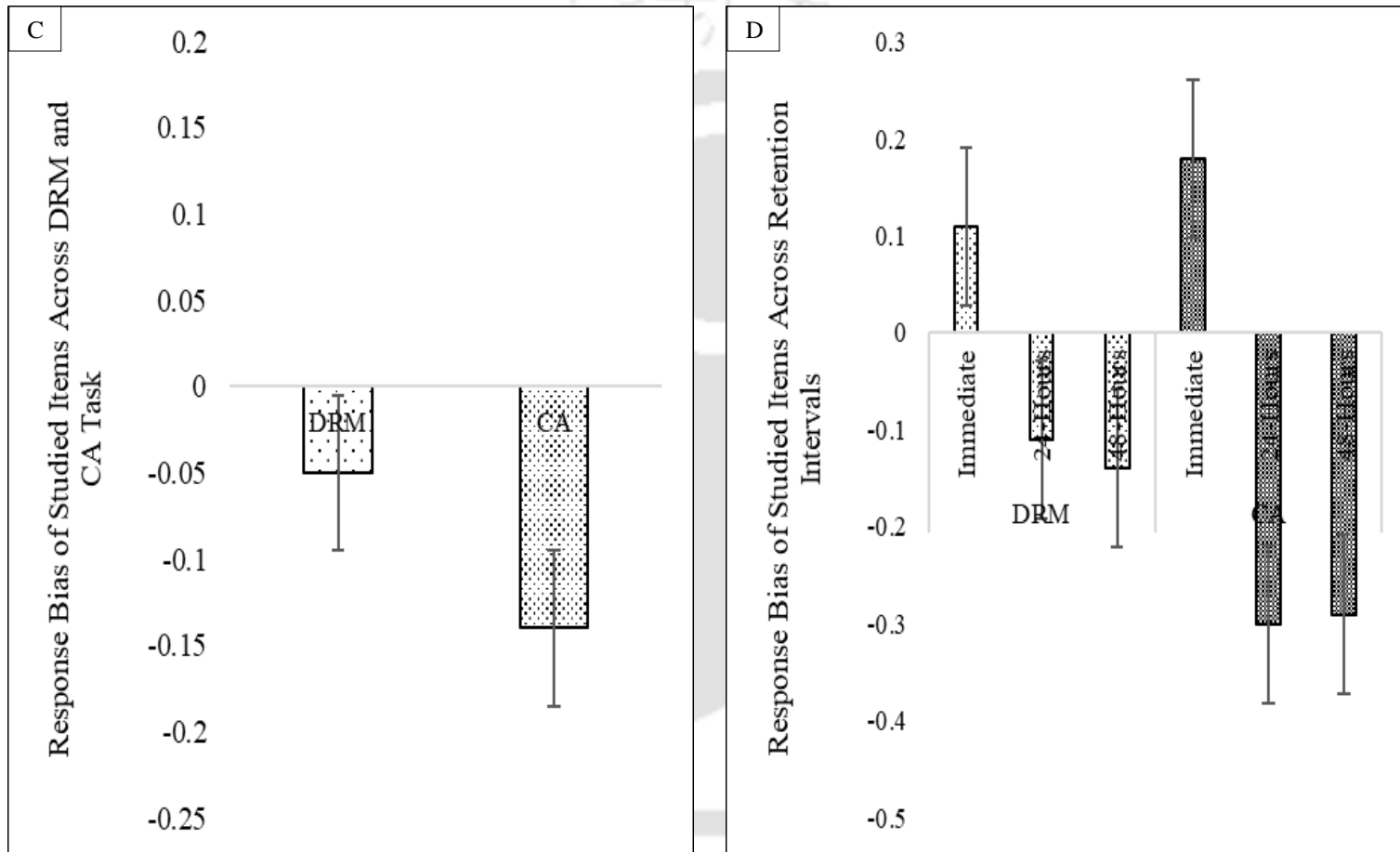
Graph 4.3.4: Mean Scores of, (C) Response bias of CLs across DRM and CA task, and (D) Response bias of CLs across all retention intervals between DRM and CA task.



Graph 4.3.5: Mean scores of studied items recognition, **(A)** Sensitivity of studied items across DRM and CA task, **(B)** Sensitivity of studied items across retention intervals between DRM and CA Task.



Graph 4.3.6: Mean scores of studied items response biases, (C) Response bias of studied items across DRM and CA task, and (D) Response bias of studied items across all retention intervals between DRM and CA task.



CONCLUSION:

This experiment was done to test the effectiveness of false memory induction methodology in recognition test across varied retention intervals. In *recognition* retrieval strategy, the recognition memory is measured in terms of sensitivity and response biases. The sensitivity mean scores are measured for critical lures and true target items across SA and CA methods. It has found that both semantic associate and category associate are equal sensitive for critical lure items, but SA is more sensitive in identification of critical lures items (false memory identifiers) than CA method only when the retrieval was performed immediately. True target items were more sensitive in category associates (for pictures) method then SA method (for words).

DISCUSSION:

In the present study, it was observed that both the semantic associate (words) and category associate (line drawings) method are equally effective in the production of false memory across both recalls as well as recognition retrieval strategies. The true target items are better remembered for pictures of CA methods than words of SA method, hence pictures are more effective in the production of true target items in both recall and recognition test which supports the *picture superiority effect*. This present experiment reveals some interesting findings for both words and pictures in different false memory methods including SA (semantic associate) for words and CA (category associate) task for pictures.

In *recall test* condition, in the present study, we had found that semantic associate and category associate task both induced equal amount of critical lures and intrusions (false memory identifier).

For the amount of recall both for words and pictures, it was hypothesized that the meaning of

simple pictures for their representations and their label are identical (Nelson, Reed, & Walling, 1976). Further, it was observed that false memory recall is influenced by semantic processing (Toglia, Neuschatz, & Goodwin, 1999) via visual presentation and the result showed that there were no differences between pictures and words for false recall. It was assessed that aurally format induced more false recall than words or pictures (Beauchamp, 2002).

In this study, the recall of true target pictures is more than words which reflects that the pictures have more physical characteristics, like their vividness, their meaning (Bousfield, Esterson, & Whitmarsh, 1957) than words. Also, the picture superiority effect (Pavio, 1971, Weldon & Roediger, 1987) explained that the pictures are more in sensory-perceptual details than words (rich in phonetic and orthographic details) leads to increased true target recall of studied items, which is clearly seen in this finding that true target pictorial stimuli are more recalled than words.

In recognition test, the false recognitions in both the task type (semantic associate and category associate) did not found significant different, whereas the true target items found significantly differ. Interestingly, the critical lures were found more in semantic associate task than category associate task when the test was performed immediately but afterward in the delay of 24-hours and 48 hours of delay they were equally identified. Whereas, the true target identification was more in category associates (picture stimuli) than semantic associates (word stimuli). Though the picture stimuli are more vivid and rich in sensory perceptual content (Pavio, 1971, Weldon & Roediger, 1987) leads to more correct hits in category associates than semantic associates. It was previously found that pictorial stimuli are rich in their sensory-perceptual codes and have direct access for their semantic processing, instead the word stimuli are rich in their phonetic, orthographic codes and have lexical access only (Conway & Gathercole, 1990; Nelson, Reed, & McEvoy, 1977).

It was also investigated that false recognition and true recognition both are more relied on semantically associated memory than memory of distinctive perceptual details, furthermore, the

false recognition is less accessible to perceptual details than true recognition (Mather et al., 1997; Norman & Schacter, 1997). This present study finding is in not in-line with previous researches that shows that words leads to more false recognition than pictures. In present study there is not any differences between semantically induced false memory and categorically induced false memory, rather both methods equally effective in producing false memory. It might be due to the differences in the task processing, where in semantic task list items are semantically associated (Deese-McDermott, 1995) with each other and with critical lure item, whereas in the category associate task the list items are categorically associated with each other and the critical lure item is highest frequency in their availability (Hintzman, 1988). Also, this present study is relay on the within-subject design criteria and two different task processing whereas the previous researches are based on between-subject design using only single task semantic associate task (Israel & Schacter, 1997), category associate task (Seamon et al., 2000). Israel and Schacter (1997) found that critical lures words are more remembered than pictorial lures. They had argument that pictures are more informative and distinctive than words. For words, only available perceptual information is present for identification whereas in pictures, additional perceptual details are present which helps in remembering more items (Schacter, Israel & Racine, 1999, Benmergui et al., 2017). In the present study, across the retention intervals it was found that sensitivity of studied items decreased from immediate to 48-hours of delay in both semantic associate task and category associate task, whereas the sensitivity of critical lures in semantic associate task decreased from immediate to 48-hours of delay and in category associate task there is no changes. The studied item's results of pictures are similar to Seamon et al. (2000) result but critical lure did not follow their results. The response bias in the present study is conservative from immediate to delayed retrieval in category associate task which is similar to Seamon et al. (2000). In semantic associate

task the response bias is conservative during immediate retrieval and further in delayed retrieval it became liberal biased.

This is very difficult to compare present findings directly with previous studies as lot of important procedural differences are present in experiments including stimulus formats like line drawings, words, list lengths, category lengths, retention intervals etc. seamon et al. (2000) examined that the reduction in false recognition is not due to the pictorial stimulus, list length or category list etc. rather it is due to the stimuli presentation rate which they use 2000 millisecond/stimuli. In our study, we used 3000 milliseconds/stimuli and found very comparable false recognition of pictures and words.

The underlying process and underlying representation of semantic associates (for words) and category associates (for Pictures) can be explained by implicit activation hypothesis (Underwood, 1965) and fuzzy trace theory (Brainerd, & Reyna, 1998). According to Implicit activation hypothesis, participants will activate the representations of related non-presented exemplars of category and semantic associates, which they have studied during encoding phase. High-frequency critical lure exemplars will have activated more than low-frequency critical lures when the associative strength of studied exemplars will strong in the category list, but this hypothesis is cannot explains all the assumptions of false memory induction. For example, it is not applicable for the explanation of differential effect of retention intervals for correct and false recognitions. It is observed that over 24 hours of retention interval, the true target hits are going to decreased and critical lure identification increases (Payne et al., 1996). Our finding is same as the true targets are decreasing after 24 hours-delay and 48 hours-delay, whereas the critical lures identifications increases but not significantly after 24 hours-delay. For words, the critical lures also decrease after 24 hours-delay and 48 hours-delay significantly. The differential effect of retention intervals can be interpreted with the understanding of fuzzy trace theory, which explains that the memory traces

are presented in two form (Brainerd et al., 1995a, b; Reyna & Brainerd, 1995), viz. the *verbatim trace* which stores the surface details of the stimuli and *gist trace* which store the theme or gist of stimuli. True recognition is associated with verbatim traces and false recognitions of stimuli are largely associated with gist trace. In semantic associates (Word) and category associates (picture) procedures, false recognitions of related non-presented stimuli are encountered due to the gist representations. In semantic associates, the theme words of the list items impart the gist representation (e.g. *sleep* for the list of *night, pillow, dark, dream* etc.), whereas the in category associates, the theme of the list items impart the abstract category name as the gist representation (e.g. *professions* for *lawyer, electrician, plumber* etc.). The concrete name for gist representation of *profession* category would be *doctor* as it representing the prototypical features or the category profession which is the high-frequency critical lure.

This present study has found the semantic associate and category associates both are equally effective in induction of false memory. This study is important as it found the effectiveness of false memory induction methods across words and pictures with three retention intervals. We have found that both semantic associates and category associates both can induced false memory and both can be explained with the implicit activation of critical lures and gist representation of critical lures explained by fuzzy trace theory.

EXPERIMENT 04: SLEEP NIGHTS AND FALSE MEMORY**INTRODUCTION:**

At the beginning of 20th century, the crystallized nature of memory was challenged and the reconstructive nature was explained by Bartlett (1932) in their schema studies, Binet (1900), and Piaget (1960). Further in the recent era, the reconstructive nature was investigated including false recall of prose passages (Hasher & Griffin, 1978; Sulin & Dooling, 1974), confusion of old and new sentences based on thematic abstraction (Bransford & Franks, 1971), slide sequences (Loftus, Miller & Burns, 1978), video tapes (Loftus & Palmer, 1974). In 1995, a famous false memory paradigm was developed by Roediger and McDermott popularly known as *DRM paradigm* made false memory research possible in laboratory settings (Roediger & McDermott, 1995). Semantic association among list items is the basic principle of DRM paradigm. Category associates are also having potential to induce false memory (Hintzman, 1988). Word as a category exemplars were investigated in category associated false memory formation in children (Brainerd, Reyna, and Kneer, 1995b). False memory formation for pictures in category associates also has been studied, but the available literature is very less and not fully clear, that why more theoretical support is needed to understand false memory mechanism clearly.

In mnemonics, sleep played a vital role (Jenkins & Dallenbach, 1924; Payne, 2011; Payne et al., 2008) and sleep stages together can help in consolidation of newly acquired information (Buzsaki, 1998; Smith, 2001; Stickgold, 2005), it controls reactivation and redistribution of information from the hippocampus to neocortex of the brain (Diekelmann & Born, 2010). It was also observed that sleep helps in the integration of novel words into mental lexicon (Gaskell & Dumay, 2003). The relationship between sleep and false memory begins at this time, but still this relationship is very

unclear. The first investigation to find out the relationship between sleep and false memory was studied by Diekelmann, Landolt, Lahl, Born, and Wagher (2008) using DRM task. They had investigated the relationship of sleep and false memory with recognition test using three groups *viz.* nocturnal sleep, nocturnal sleep deprivation, and daytime wake groups and found that sleep deprivation leads to more false recognition rates as compare to nocturnal sleep. During sleep deprivation, the prefrontal cortex (PFC) activity weakens, which is very essential for source monitoring and is related to decreases false recognition (Curran et al., 2001). But another research group had found no effect on true recognition memory and decreased false recognition when stimuli were presented aurally and visually with 12 hours of sleep and daytime wake groups (Fenn et al., 2009). They explained these findings theoretically by saying that sleep might helpful in consolidation of verbatim as well as item specific details of information which increases the source-monitoring process and hence results in decreased in false memories. These findings were interpreted on the basis of activation/monitoring principles of false memory formation (Roediger, Balota, & Watson, 2001; Roediger & McDermott, 1995, 2000), which argued that the semantic network activation is spread with the help of presented studied items of list which in turns results into activation of unstudied critical lure words. Later, on retrieval time the participants unable to monitor the source of memories and became vulnerable to false memories. Fenn et al. (2009) argued that sleep helps in increasing the source-monitoring process which marks into reduction of false memories. However, the recognition test can also found reduced false memory performances as the presentation of words during recognition reactivates the sensory details of the studied words and restore the encoding context which leads to source-monitoring (Cabeza et al., 2001), but these findings are not in-line with the finding of Diekelmann et al. (2008) as they did not found any difference in memory performance across sleep in false memory recognition test.

The impact of sleep on false recall was first studied by Payne and colleagues (Payne et al., 2009) and found that full night sleep helps in increasing the false recall of critical lure words in DRM task as compare to daytime wakefulness (Diekelmann, Born, & Wagner, 2010). In addition, with full night sleep study, Payne et al. (2009) also conducted a 90-minute nap study results into increased false recall. Fuzzy trace theory (Reyna and Brainerd, 1995) supports the findings of Payne et al. (2009) as false memories are dependent on the gist traces of the encoded information (Reyna and Kiernan, 1994) in DRM paradigm. In support of the Payne et al. (2009), another study was conducted in 2012 by McKeon, Pace-Schott, and Spencer and they had found the false recall rates were lower than Payne's false recall rates. Recently in 2017, Pardilla-Delgado, and Payne had investigated that long delay of 48 hours' post-sleep false memory performance as well as true memory. They also found the negative correlation between slow-wave sleep (SWS) and false memory, which might be the unfavorable for gist processing (Pardilla-Delgado, & Payne, 2017). Till date, there is not clear well known theoretical explanation for the post-sleep formation of false memories.

It was seen that research on sleep and false memory was started in 2008 and DRM task was used to induce the false memory. But the impact of sleep on false memory through the CA (category associate) task is still not researched. This study is in our knowledge is the first study to investigate the impact of sleep on false memory through category associate task. False memories induction by category associates was first introduced in 1988 by Hintzman. In categorical associative procedure of false memory creation, few exemplars per category are presented to subjects randomly and at the time of recognition test subjects have to distinguish studied exemplar and related non-studied exemplars (Hintzman, 1988). He found that greater exposure of categorical items leads to more false recognition of related non-studied exemplars. For example, *reading material* is category for *booklet, pamphlet, comic book, broacher* (possible exemplars) etc. false memory for category

associates was investigated on children (Brainerd, Reyna & Kneer, 1995) and found more false recognition in younger children than older children. Black and white (Strack & Bless, 1994) and colored (Koutstaal & Schacter, 1997) Pictures were also used as stimuli for false memory effect for category associate. The false memory induction through category associates, most of the research has been done with recognition of words (Brainerd, Reyna & Kneer, 1995b; Brainerd & Reyna, 1996; Brainerd, Reyna, & Brandse, 1995a; Seamon et al., 2000), picture recognition (Strack & Bless, 1994; Koutstaal & Schacter, 1997; Israel & Schacter, 1997; Schacter, Israel, & Racine, 1999). Beauchamp in 2002, studied that aural stimulus presentation modality leads to more false recall of words and pictures than visually presented items. Recently, the work of Beauchamp was replicated and found that false recall of picture alone condition was less than words alone (Benmergui, McKelvie, & Standing, 2017). They presented stimuli picture without their name tagging. Theoretical explanation of false memory creation for category associates is also supported by Underwood's activation hypothesis (*implicit activation response hypothesis*) that during study phase subject is faced the set of exemplar of the same category. At the encoding time, activation of non-studied category items according their associative strength and frequency happens, and finally at retrieval time activated category leads to activation of non-studied exemplars as false memory.

The present study dedicated to investigate that how does the experimental nights (sleep and sleep deprivation) can have benefited the false memory induced through category associate task using simple line drawings. 48 hours of retention interval was used to retrieve the learned items using recall and recognition procedure. The retention interval of 48 hours was used in this study to check whether the sleep is actively or passively participated in the formation of false memory through category associate task (Pardilla-Delgado, Payne, 2017). The memory performance was measured with free recall test and recognition test to evaluate the sensitivity and biasness.

EXPERIMENT 04-A: Effect of experimental nights in the induction of category associated false memories

OBJECTIVE 01: This study aimed is to find the effect of sleep and sleep deprivation nights in the induction of category associated false memories through recall retrieval strategy

OBJECTIVE 02: This study aimed is to find the effect of sleep and sleep deprivation nights in the induction of category associated false memories through recognition retrieval strategy

HYPOTHESIS:

H_{4A-1}: Performance on the category associated induced false memory (critical lures) will increase in sleep in comparison to sleep deprivation in recall test

H_{4A-2}: Performance on the category associated induced false memory (critical lures) will increase in sleep in comparison to sleep deprivation in recognition test

VARIABLES:

Independent variables: Experimental nights (Sleep, and Sleep deprivation)

Dependent variables: Recall and recognition scores of critical lure pictures, and studied (true target) pictures.

DESIGN:

This experiment uses a one-way repeated measure ANOVA to calculate the effect of experimental nights in the induction of category associated false memory. Mean scores of critical lures pictures,

intrusions (in case of recall), and true target pictures are served as the dependent variable. Critical lure pictures are used for calculating the false memory performance.

METHOD:

Participant

Total 14 undergraduate students (all male) of age between 18-25 (Mean \pm SD = 19.03 \pm 1.08) were participated in this study. They all were from Indian Institute of Technology (technical institute), and compensated with partial course credit and monetary reward. All the participants were screened after filling self-reported sleep questionnaire (ESS and PSQI) and consent form. All participants were free from any psychiatric, psychological abnormality and instructed to avoid any stimulants like tea and coffee for 24 hours before night experiments.

Material

Simple line drawing pictures of 597 x 843 pixels with 72 dpi (high) resolution were used to induce false memory from pre-selected pictures lists. Same participant was participated in both recognition and recall test in the night experiments. Subjects first perform recall test and then perform recognition test and a distractor task was introduced between both test to prevent the repetition of list items. Each subject studied 10 category lists with 10 line drawing pictures in each lists. The line drawing pictures used in each category list were categorically associated and were extracted from previously developed picture database (Battig & Montague, 1969). Line drawing pictures were presented using e-prime on the center of computer screen with sequentially ordered. Line drawing pictures in each list were arranged in descending order of their frequency of availability (Seamon et al., 2000).

Procedure

At the beginning of the experiment, each participant filled behavioral questionnaires that included Mood questionnaire, MMSE, Memory and Attention test, Memory Functioning Questionnaire, and Epworth Sleep Scale (ESS), Pittsburg Sleep Quality Index (PSQI) was performed to assess the sleep quality of participants. Following these behavioral questionnaires, they performed the encoding session in which they studied the 10 category associated lists of simple line drawings visually on the computer. Encoding session was held at 9:30 PM and test session performed after 48 hours later on 9:30 PM.

In *category associate (CA) method*, total ten category lists with ten exemplar pictures (related to category) in each category list were presented to the subjects with instruction to attend each picture and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds per picture with an inter-stimulus interval of 2000 milliseconds. List items were sequentially presented during study phase, but at the time of test phase intra-list items were randomly presented during recognition test. The experiment was designed in e-Prime Software Version 2.0.10.353.

Following the encoding session, participants were prepared for sleep recording (polysomnography) using polysmith sleep amplifier. They put in bed approximately at 10:45 PM and light off at 11:00 PM and slept for approximate 8 hours of sleep. Sleep data was collected using sleep montage including EEG (4 channel: C3, C4, O3, O4), EMG (2 channel), EOG (2 channel: left EOG, right EOG) with the contralateral references of mastoid channel (A1, A2) electrodes. One ground (Z) was also channeled. In the morning, all the surface electrodes were removed and instructed participants to come back after 48 hours for memory test session.

The retrieval session included two test, *viz.* recognition followed by recall test. At *recognition phase*, participants provided the old/new judgment for each presented pictures. Responses generated on the recognition test was self-paced by participants. Each recognition list contained

three old stimuli (pictures) from learning list, three new stimuli (unrelated stimuli) served as distractor, and two critical lure pictures (one high frequency picture, and one low frequency picture). The whole experiment runs for approximately 40 minutes. During *recall phase*, participants were free to recall the list items. In the recall of pictures, participants have to recall the name of the pictures. All the responses were taken on plain white paper. There was unlimited time for recall the studied lists items. Distractor task was also introduced between recognition test and recall test to prevent repetition of list items.

Memory Measurement

In the *free recall test*, three categories are made viz. true target pictures (previously studied pictures during learning time), critical lure pictures (categorically associated unrepresented pictures: *false memory identifier*), and intrusion pictures (unrepresented pictures). The mean scores of recall test was analysed to test the hypothesis. In *recognition test*, first the raw memory measure was calculated and then using non-parametric signal detection measurements the discriminability/sensitivity and the response bias were calculated for final analysis (Pardilla-Delgado & Payne, 2017). During raw memory measures, the true targets rates was defined as the *hit rate* [**H**], which is calculated as; “old” response given to previously learned picture divided by total number of presented study pictures. The *false rate* is defined as false alarm rate to critical lures [**FAC**], which is calculated as; “old” response given to related lure pictures divided by total number of related lure pictures which were presented. The *foil rate* is defined as false alarm rate to foils [**FAF**], which is calculated as; “old” response given to unrelated foils divided by total number of unrelated foils presented. Using non-parametric signal detection, *discriminability/sensitivity* was calculated as A' [hit rate (H) and foil rate (FAF) for true

recognition, and false rate (FAC) and foil rate (FAF) for false recognition] with their response bias B'' (Donaldson, 1992; Snodgrass & Corwin, 1988).

The calculating formula for *true recognition* are: $A' = \frac{1}{2} + [(H-FAF) (1+H-FAF)] / [4H(1-FAF)]$, when $H \geq FAF$ and $A' = \frac{1}{2} + [(FAF-H) (1+FAF-H)] / [4FAF(1-H)]$ when $FAF \geq H$.

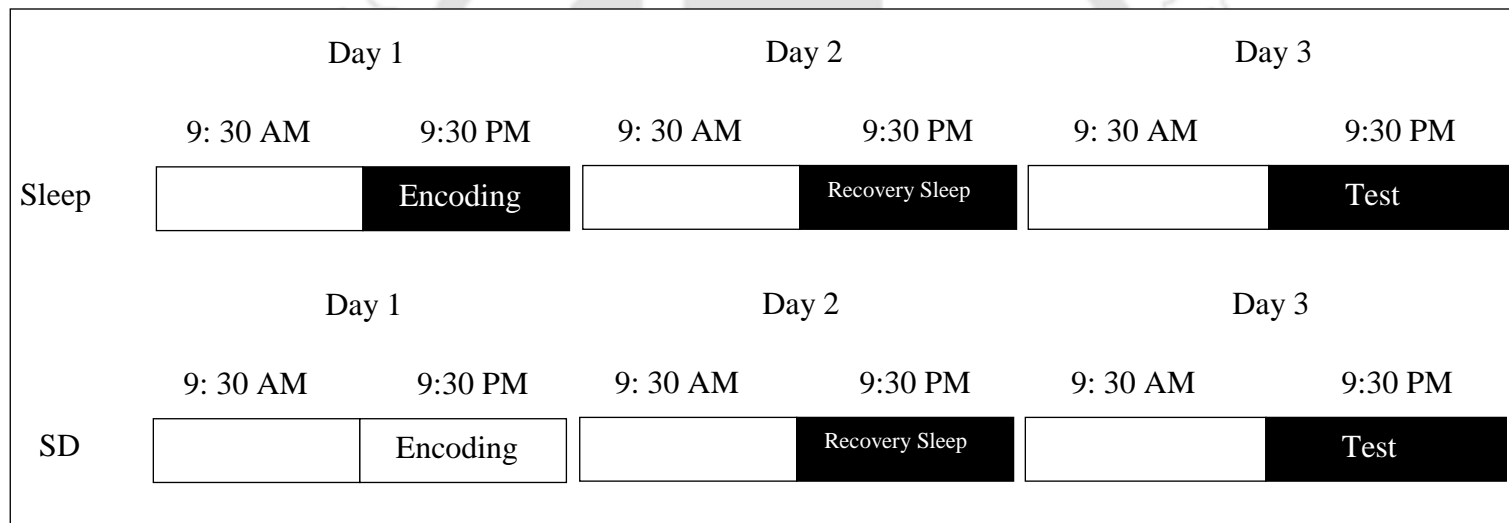
The calculating formulas for *false recognition* are: $A' = \frac{1}{2} + [(FAC-FAF) (1+FAC-FAF)] / [4FAC(1-FAF)]$ when $FAC \geq FAF$ and $A' = \frac{1}{2} + [(FAF-FAC) (1+FAF-FAC)] / [4FAF(1-FAC)]$ when $FAF \geq FAC$.

The calculating formulas for *response bias* for *true targets* are: $B'' = [H(1-H) - FAF(1-FAF)] / [H(1-H) + FAF(1-FAF)]$ when $H \geq FAF$ and $B'' = [FAF(1-FAF) - H(1-H)] / [FAF(1-FAF) + H(1-H)]$ when $FAF > H$.

The calculation formulas for *response bias* to *false items* are: $B'' = [FAC(1-FAC) - (FAF(1-FAF))] / [FAC(1-FAC) + FAF(1-FAF)]$ when $FAC \geq FAF$ and $B'' = [FAF(1-FAF) - FAC(1-FAC)] / [FAF(1-FAF) + FAC(1-FAC)]$ when $FAF > FAC$.

The A' values varies between the range from 0.00 to 1.00 where the higher score of A' indicates the greater sensitivity and low score indicates lower sensitivity. The response bias varies from -1.00 to $+1.00$ where the negative value of response bias indicates the *liberal bias*, positive value of response bias indicates the *conservative bias*, and if the value of response bias is equal to zero then it indicates the *neutral bias*.

Figure 4.4.13: Experimental Night Protocol for Category Task. Sleep group encoded the category lists on day 1 at 9:30 PM and later on 3rd day of the encoding, the test for memory performance was conducted at 9:30 PM. During sleep deprivation (SD) condition, the encoding was performed at 9:30 PM and subject were wake for whole night and on 3rd day the test was conducted at 9:30 PM. Day 2, nights were recovery sleep nights for all the participants of each group.



Experimental Model of False Memory Induction across Sleep and Sleep Deprivation in CA Task:

(A). For Recall Test:

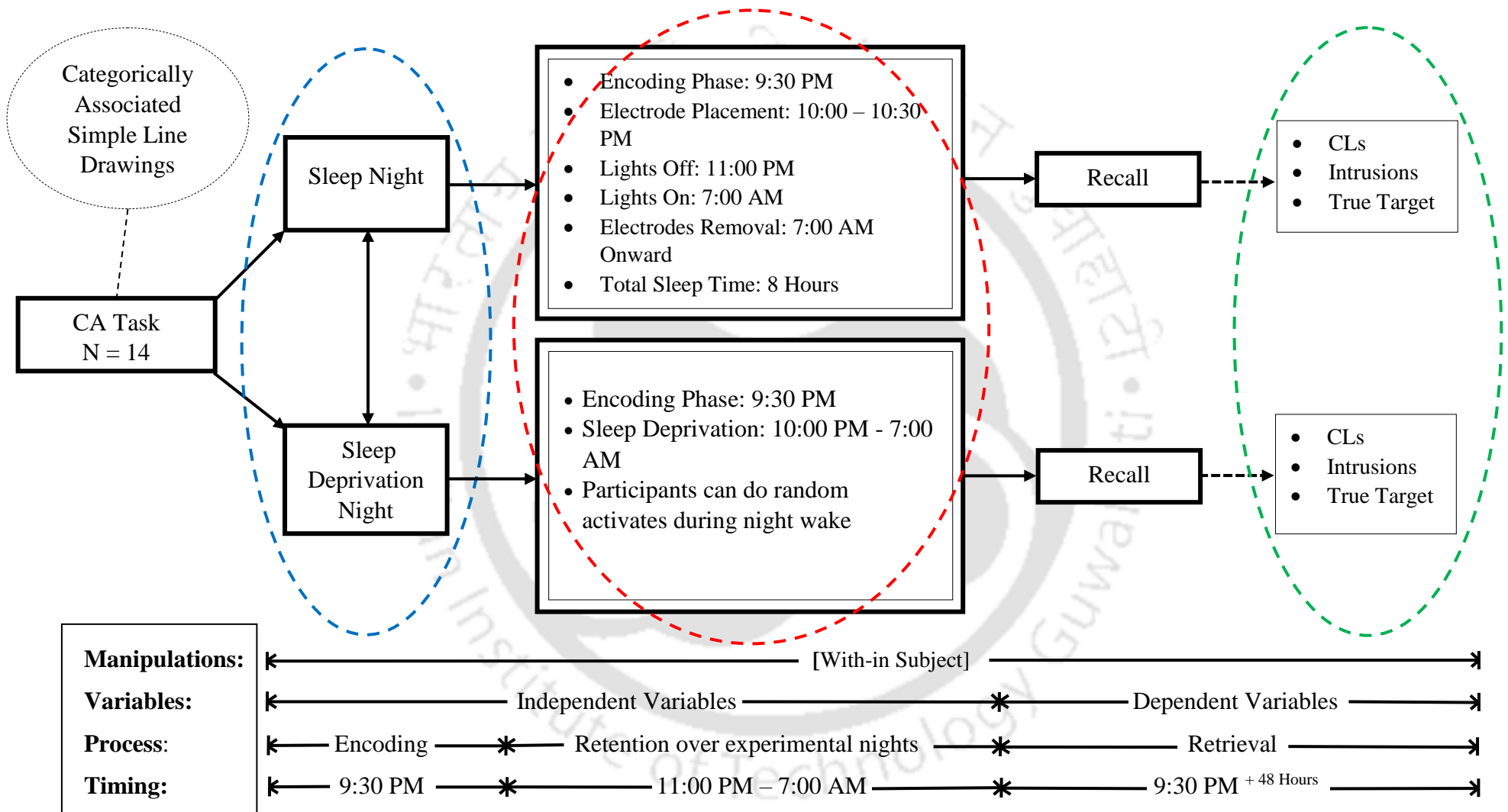


Figure 4.4.14: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recall Test in Category Task.

(Note: Red dotted circle represents processing during experimental nights; blue dotted circle represents with-in subject manipulation, and green dotted circles includes dependent variables)

(Abbreviation: CA=Category Associate Task; CL=Critical Lures)

(B). For Recognition Test:

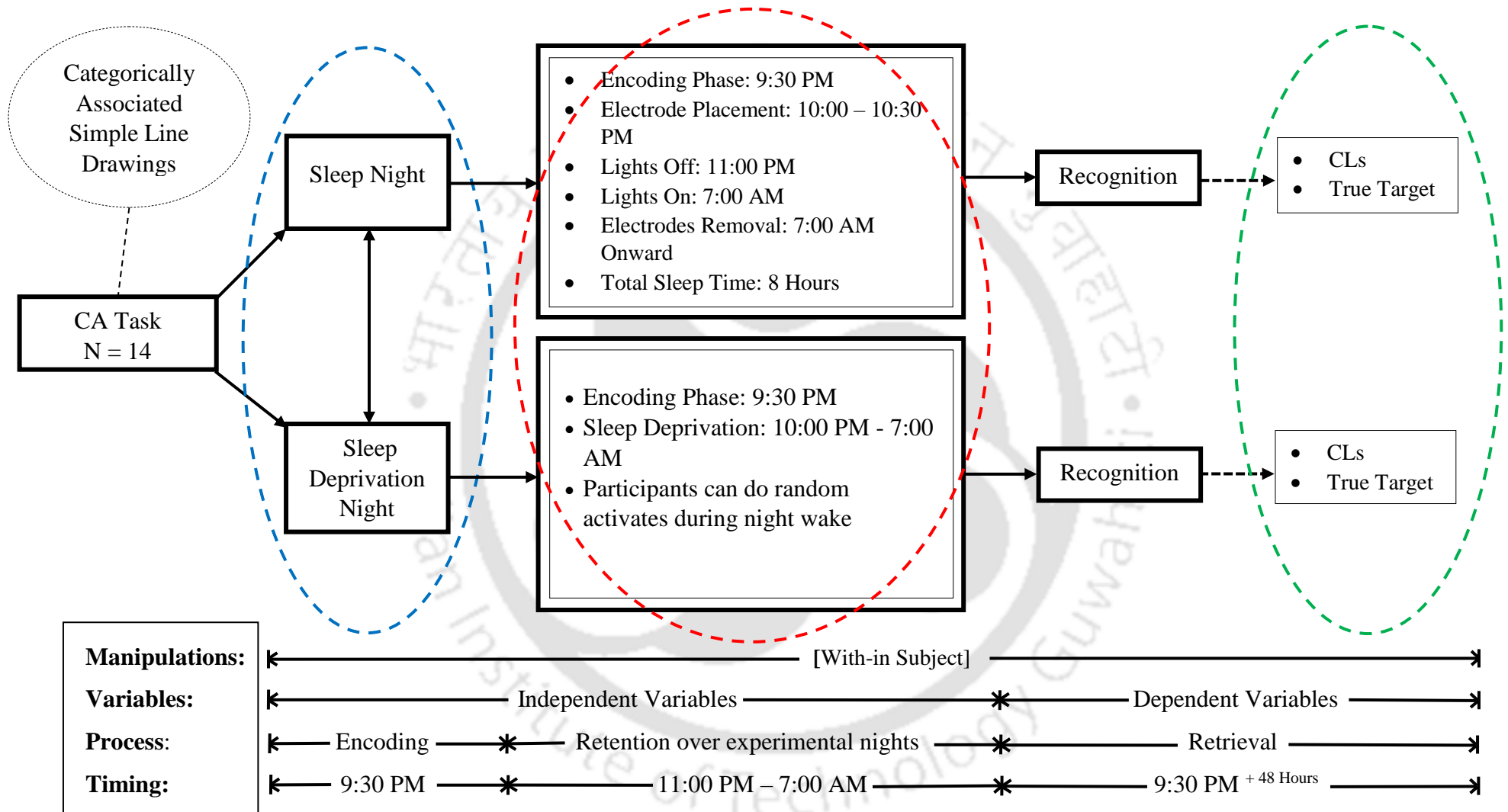


Figure 4.4.15: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recognition Test in Category Task.

(Note: Red dotted circle represents processing during experimental nights; blue dotted circle represents with-in subject manipulation, and green dotted circles includes dependent variables)
 (Abbreviation: CA=Category Associate Task; CL=Critical Lures)

Statistical analysis

A mixed factorial ANOVA was used to analyze the data for false memory measurements. Experimental nights (full night sleep, sleep deprivation) were the manipulating variables, and mean scores of true targets (studied items), critical lures (unstudied items), intrusions were dependent variables. The mean score of critical lures items and intrusions were actual measurements of false memory. Total sleep time, sleep latencies, sleep efficiencies, % of each sleep stages were the measurements for sleep analysis.

RESULT:

1. *The effect of experimental nights in the generation of false memory in recall:* A one-way repeated measure ANOVA was conducted to compare the effect of sleep and sleep deprivation on critical lures. Additionally, the intrusions, and studied items were also measured. There was a significant effect of sleep [$F_{(1,13)} = 6.158, p < 0.05, \eta^2 = 0.321$] on false memory was reported which suggest that sleep increases the false recall of critical lures. Additionally, a non-significant difference was noticed on intrusion [$F_{(1,13)} = 1.603, p > 0.05, \eta^2 = 0.110$] and true targets [$F_{(1,13)} = 0.454, p > 0.05, \eta^2 = 0.034$] measures across experimental nights. The mean values of memory performance are presented in **Table 4.8** (see **graph 4.4.4**).
2. *The effect of experimental nights in the generation of false memory in recognition:* A one-way repeated measure ANOVA to conducted to measure the discriminability/sensitivity of critical lure pictures, true target along with their response bias. The recognition test in this study will support the idea that sleep benefited (in comparison to sleep deprivation) the formation of false memory for simple line drawings through category associates task. A one-way repeated

measure ANOVA was conducted to compare the effect of experimental nights (sleep vs sleep deprivation) on critical lures, true targets items.

There was significant effect of sleep in the induction of critical lure pictures [$F_{(1,13)} = 12.763$; $p < 0.05$; $\eta^2 = 0.495$; discriminability/sensitivity scores for sleep = 0.80 and for sleep deprivation = 0.68]. The response bias analysis for false memory found to be significantly different between sleep and sleep deprivation in critical lures [$F_{(1,13)} = 16.36$; $p < 0.05$; $\eta^2 = 0.557$]. It was seen that full night sleeping soon after learning leads to conservative bias, whereas learning after sleep deprivation leads to liberal bias [sleep = 0.274, sleep deprivation = - 0.019]. All the mean values and standard deviations are shown in **Table 4.8**.

There was a significant effect of sleep was also seen in the formation of true target picture items [$F_{(1,13)} = 10.213$; $p < 0.05$; $\eta^2 = 0.440$; discriminability/sensitivity scores for sleep = 0.90 and for sleep deprivation = 0.78]. For the true target items, the response bias analysis found to be non-significant [$F_{(1,13)} = 0.401$; $p > 0.05$; $\eta^2 = 0.234$]. The liberal response bias was found in both the sleep and sleep deprivation conditions [sleep = - 0.125, sleep deprivation = - 0.364]. All the mean values and standard deviations are shown in **Table 4.8**.

3. *Measurements of sleep parameters:* Sleep was monitored using Nihon-Kohden sleep-monitoring system. The polysomnographic report reveals that total sleep time (TST), Total recording time (TRT), sleep onset latency (SOL), % efficiency, all the individual sleep stages was calculated to evaluate the sleep quality. The Polysomnographic statistics is presented in **Table 4.9**.

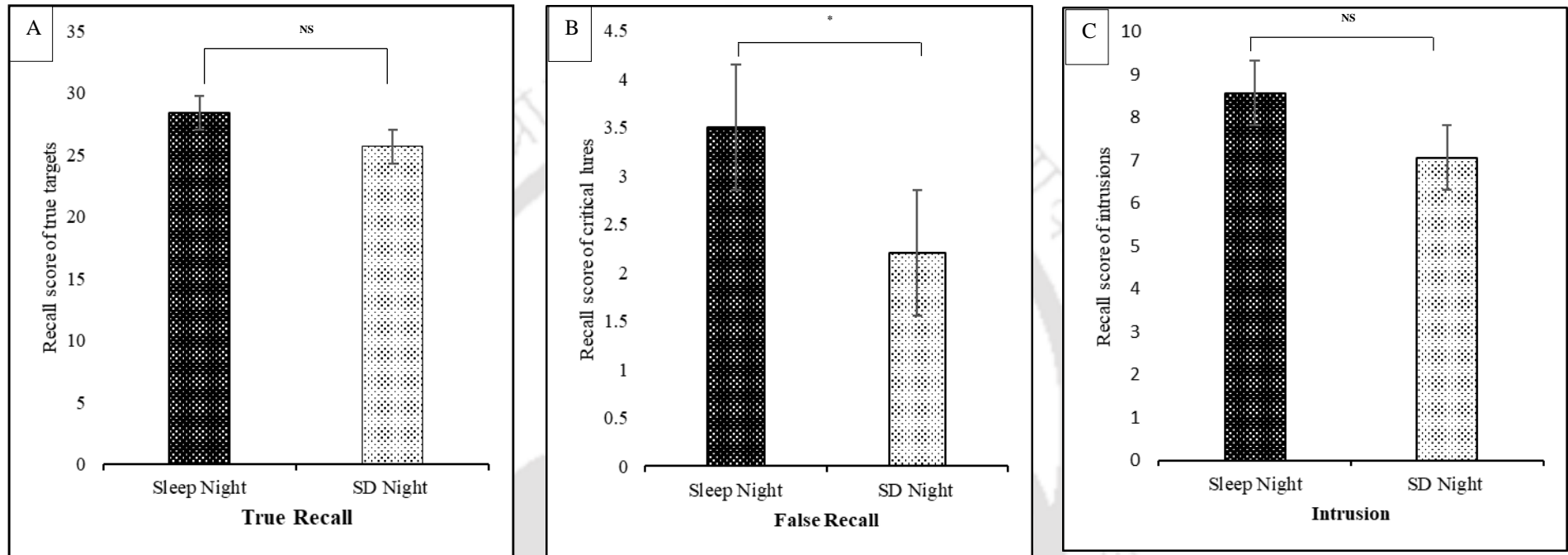
Table 4.8: Mean Scores of Recall and Recognition Memory Across Sleep Nights in Category Associates. [Mean (Standard Deviation)]

Dependent Measure	After Sleep Night	After Sleep Deprivation Night
Recall Test		
Critical Lure *	3.50 (1.69)	2.21 (1.42)
Intrusion	8.57 (5.37)	7.07 (6.46)
True Targets	28.35 (12.16)	25.64 (11.92)
Recognition Test		
Critical Lure Sensitivity (A') *	0.80 (0.08)	0.68 (0.08)
True Target Sensitivity (A') *	0.90 (0.05)	0.78 (0.13)
Critical Lure Bias (B'') *	0.274 (0.32)	- 0.019 (0.15)
True Target Bias (B'')	- 0.125 (0.46)	- 0.364 (0.37)

(* < 0.05 between sleep and sleep deprivation)

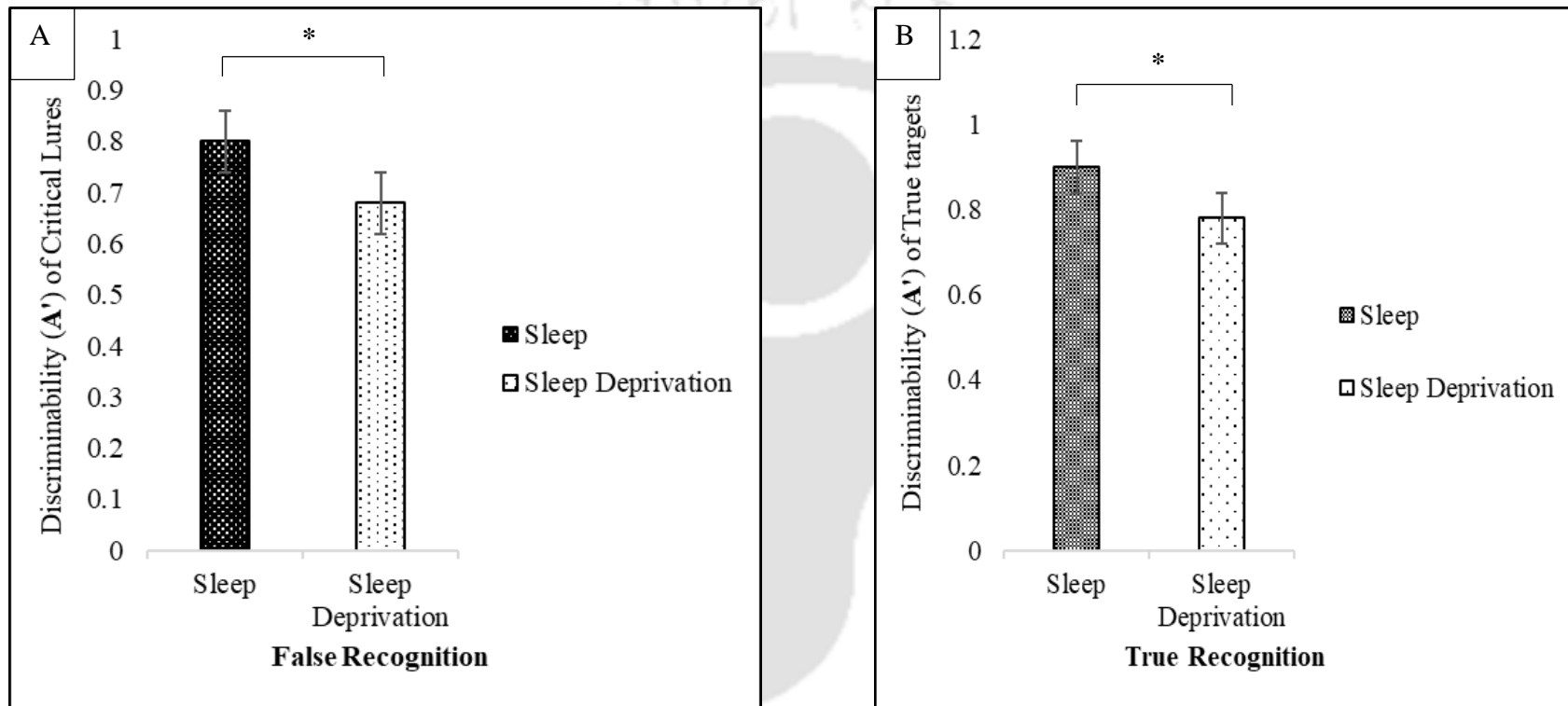
Table 4.9: Descriptive Statistics of Polysomnographic Report of Experimental Night in Category Associates [Mean and SD]

Sleep Parameters	Mean	Standard Deviation
TIB (Time in Bed in min)	492.17	24.28
TST (Total Sleep Time in min)	417.14	53.83
SOL (Sleep Onset Latency in min)	8.21	5.51
REM Latency (min)	88.03	33.47
% Efficiency	84.47	10.44
Stage S ₁ (min)	3.35	2.79
Stage S ₁ %	0.85	0.74
Stage S ₂ (min)	253.82	42.04
Stage S ₂ %	60.67	4.86
Stage S ₃ (min)	15.10	11.82
Stage S ₃ %	3.71	2.90
Stage S ₄ (min)	44.03	20.32
Stage S ₄ %	10.65	4.67
REM (min)	100.82	21.15
REM %	24.10	3.53
Wake (min)	7.60	5.54
Wake %	4.20	0.86

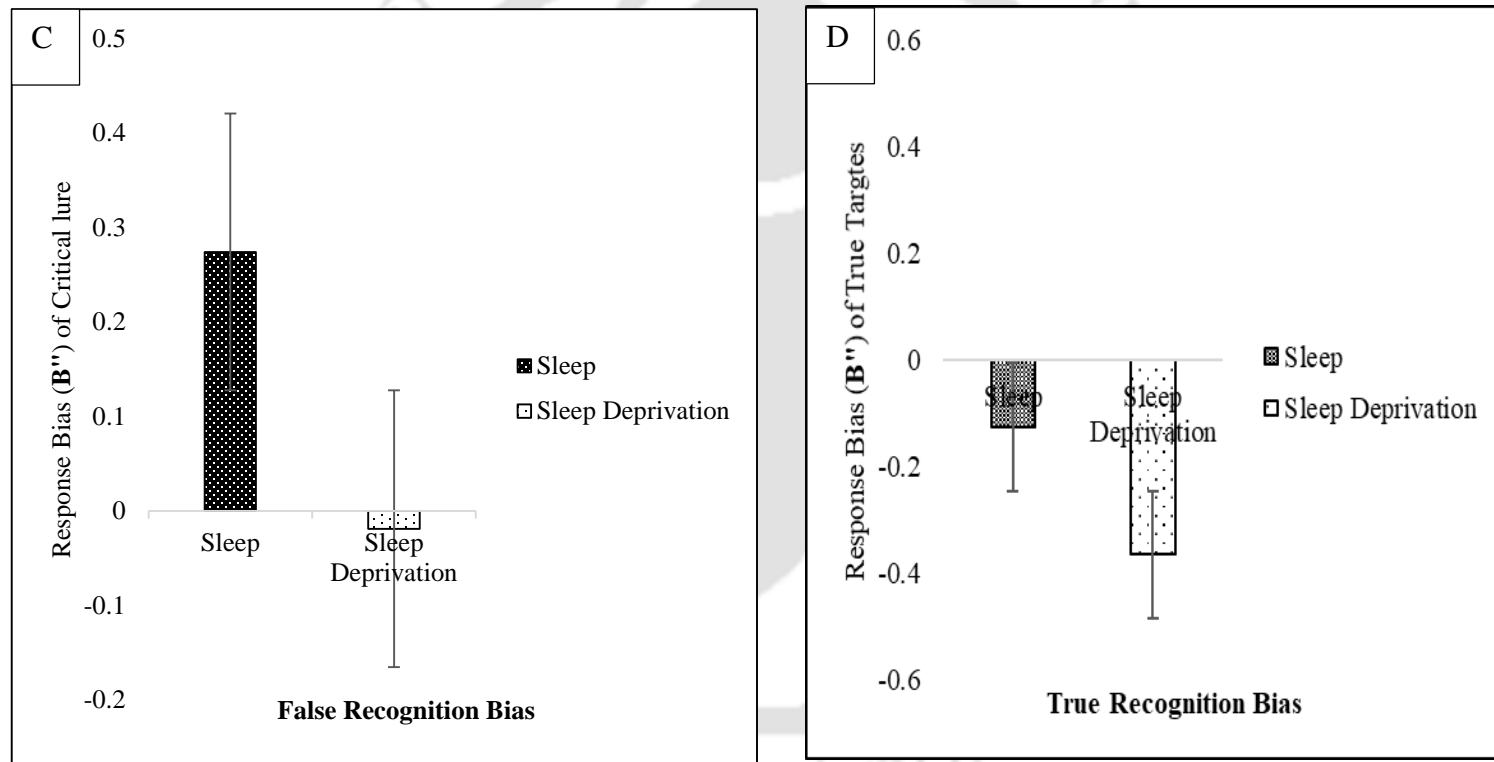


Graph 4.4.7. Number of pictures recalled. (A) true recall of picture items. (B) false recall of critical lure picture items. (C) false recall of intrusion picture items. Comparisons are across sleep and sleep deprivation nights for recall of true target, critical lures and intrusions. (* represents the p-value where, $p < 0.05$; NS = non-significant; Error bars denotes SE)

Graph 4.4.8: The Recognition Memory was measured by A' (**Sensitivity**), for (A) Critical lure pictures (False Memory) and (B) True target pictures. (* represents the p-value where, $p < 0.05$ and the error bars denotes the SE).



Graph 4.4.9: The Memory Response bias calculated by B'' for (C) Critical lure pictures (False memory) and (D) True target pictures.



CONCLUSION:

The experimental nights significantly modulate the false memory through category associates. The full night sleep in comparison to sleep deprivation, significantly benefited both false recall and false recognition memory of simple line drawing pictures through category associate task. soon after the learning sleep and sleep deprivation nights were intervened and after 48 hours of delay the recall and recognition test was performed, and found that in recall test the false recall of critical lure pictures were identified more after sleep night than sleep deprivation night, whereas for intrusion and true targets it was found to be equal in both sleep and sleep deprivation. Also, this was found that the sleep night group scores higher sensitivity than sleep deprivation group for critical lure pictures (sleep = .80, and sleep deprivation = .68), and for the true target pictures the sensitivity was higher in sleep than sleep deprivation (sleep = .90. and sleep deprivation = .78). The response bias is found to be liberal biased for both critical lure and true targets in sleep deprivation night which can be predicted that during sleep deprivation the prefrontal cortex (PFC) got impaired and might get into poorer source monitoring (Curran, Schacter, Johnson, & Spinks, 2001), and participants gave *yes* response continuously.

DISCUSSION:

This present study is dedicated to find out the role of experimental nights (sleep vs. sleep deprivation) in the generation of false memories through category associated task by presenting simple line drawing pictures. The critical lure pictures were falsely identified both in recall and recognition test effectively after 48 hours of delay in sleep night conditions. Previous studies suggested that DRM (semantic associate) task (Roediger & McDermott, 1995) and Category

associated task (Hintzman, 1988) both are effective in the formation of false memories. Hintzman (1988) found that studied exemplars were found higher than false recognition of related non-studied exemplars, same as in this study the studied exemplars recognized more than that of related non-studied exemplars. The basic difference between these two study is that Hintzman (1988) conducted study during day time with words whereas the present study found the role of sleep in formation of false memory in category associates with the simple line drawing pictures. The black and white pictures slides (Strack & Bless, 1994) and color pictures (Koutstaal & Schacter, 1997) were used in category associates task and found the increased false recognition of related non-studied exemplars. False memory for different age group in category associates found that false recognition of category related non-studied pictures after the delay of 3-days (Seamon et al., 2000). All these finding were supported by the *implicit activation response hypothesis* (Underwood, 1965) and *fuzzy trace theory* (Reyna & Brainerd, 1995). This present study found the similar result as previous studies found (Strack & Bless, 1994; Koutstaal & Schacter, 1997) but the only difference was that the finding of the present study findings is based on experimental nights i.e. across sleep and sleep deprivation whereas previous findings are results of day timing experiments. In the present study, soon after the learning sleep and sleep deprivation nights were intervened and after 48 hours of delay the recognition test was performed and found the higher sensitivity for critical lure pictures after sleep than sleep deprivation (Sleep = .80 and Sleep deprivation = .68), and for true target pictures also the sensitivity was higher in sleep than sleep deprivation (Sleep = .90 and Sleep deprivation = .78). These findings can also be supported by previous findings (Tamminen et al., 2010) which shows that sleep helps in integration of new information with the help of spindle activity both in recall and recognition of encoded information. During sleep, spindle activity integrates the lexical overnight. These current findings after night wake condition (sleep deprivation) are very similar to Seamon et al. (2000) findings as they had found that after

3-day delay true targets found equal to .93 and critical lure sensitivity was .69 and the response bias was conservative for both true targets and critical lures, but in current study the response bias are found to be liberal bias for both critical lure and true targets which can be predicted that during sleep deprivation the prefrontal cortex (PFC) got impaired and might get into poorer source monitoring (Curran, Schacter, Johnson, & Spinks, 2001) and participants gave *yes* response continuously. In the current study, false recall and false recognition both are higher in full night sleep in comparison to sleep deprivation. These findings can be supported by the explanation of fuzzy trace theory (Reyna & Brainerd, 1995; Reyna & Kiernan, 1994) which stated that memory are composed of *verbatim traces* (specific contextual details) and *gist traces* (General meaning of information), where true memories are based on both verbatim as well as gist traces and critical lures are based on only gist traces. So the current findings are supported by fuzzy trace theory as previous findings are also supported by this explanation that sleep might generally benefit the memory performances which are depend on the gist processing. Payne and colleagues found that in DRM (semantic associate) task, false recall of critical lures was increased after full night sleep (Diekelmann, Born, & Wagner, 2010; Payne et al., 2009) and 90-minute nap (Payne et al., 2009) in comparison to daytime wake. Interestingly, there were no differences found in true recall across sleep and sleep deprivation (Diekelmann, Born, & Wagner, 2010) and the current results are consistent with these findings. It was already found that sleep actively participates in modulating the memory representations in the brain (Gais & Born, 2004; Schabus et al., 2004; Marshall et al., 2006). In the present study, sleep might have benefited the gist processing of information of categorical picture items and at the time of retrieval the false recall and false recognition both happened. Smith et al. (2002) found that false memory in categorical repetitions are formed due to their *meaning/gist* traces at the time of testing. In the current study, it was found that the response bias also shifted across experimental nights. Soon after sleep, the false recognition showed

conservative response bias whereas, after sleep deprivation the response bias for false recognition was liberal. For the true target items, across both the sleep and sleep deprivation nights the response bias found to be liberal. Previously it was found that sleep increases (Hu et al., 2006; Sterpenich et al., 2007), and decreases (Atienza & Cantero, 2008) the response bias in recognition. Some finding showed that there is no effect on bias (Baran, Pace-Schott, Ericson, & Spencer, 2012; Sterpenich et al., 2009; Wagner, Kashyap, Diekelmann, & Born, 2007). They argue that, although there is not any exact neural mechanism for response bias but they had found that increased acetylcholine (ACh) during REM sleep stage can shifts the response bias. Low level of ACh in Alzheimer's disease found to be associated with liberal response bias (Fuld, Katzman, Davies, & Terry, 1982). Hu et al. (2006) found that increased level of ACh during sleep is responsible for conservative response bias. In this current study, the false recognition is conservative response biased and sleep deprivation showed liberal response biased.

Finally, in conclusion here, we have found that experimental nights significantly modulate the false memory through category associates as semantic associate task in previous findings. The full night sleep in comparison to sleep deprivation, significantly benefited the false recall and false recognition memory of simple line drawing pictures through category associate task. Fuzzy trace theory and source monitoring hypothesis can explain the formation of the false memories through category associates task in experimental nights.

EXPERIMENT 04-B: Effect of experimental nights in the induction of semantic associated false memories

OBJECTIVE 01: This study aimed is to find the effect of sleep and sleep deprivation nights in the induction of semantic associated false memories through recall retrieval strategy

OBJECTIVE 02: This study aimed is to find the effect of sleep and sleep deprivation nights in the induction of semantic associated false memories through recognition retrieval strategy

HYPOTHESIS:

H_{4B-1}: Performance on the semantic associated induced false memory (critical lures) will increase in sleep in comparison to sleep deprivation in recall test

H_{4B-2}: Performance on the semantic associated induced false memory (critical lures) will increase in sleep in comparison to sleep deprivation in recognition test

VARIABLES:

Independent variables: Experimental nights (Sleep, and Sleep deprivation)

Dependent variables: Recall and recognition scores of critical lure words, and studied (true target) words.

DESIGN:

This experiment uses repeated measure ANOVA to calculate the effect of experimental nights in the induction of semantic associated false memory. Mean scores of critical lures words, intrusions (in case of recall), and true target words are served as the dependent variable. Critical lure words are used for calculating the false memory performance.

METHOD:*Participant*

Total 16 undergraduate college students (all male) of age between 18-25 (Mean \pm SD = 19.68 \pm 0.70) were participated in this study. They all were from Indian Institute of Technology (technical institute), and compensated with partial course credit and monetary reward. All the participants were screened after filling self-reported sleep questionnaire (ESS and PSQI) and consent form. All participants were free from any psychiatric, psychological abnormality and instructed to avoid any stimulants like tea and coffee for 24 hours before night experiments.

Material

Semantic associate induced false memory was tested using the Deese-Rodieger-McDermott (DRM) paradigm which utilizes lists of semantically associated words. Participants took part on both the sleep and deprivation night. At retrieval sessions subjects first completed the recall test followed by recognition test with a distractor task introduced in between them to check active rehearsals of list words. Participants studied 10 lists with 10 words in each lists at encoding. The words used were semantic associates and were extracted from previously developed false memory

word corpus (Stadler, Roediger & McDermott, 1999; Roediger & McDermott, 1995; Roediger et al., 2001; Deese, 1959a, 1959b). Words were presented using e-prime on the center of computer screen with each word written in size 14 Time New Roman font. Words on each list were arranged in descending order of backward association strength (BAS). In order to maintain constancy, the within lists factors i.e. word length and, BAS value were made constant across all lists.

Procedure

At the beginning of the experiment, each participant filled behavioral questionnaires that included Mood questionnaire, MMSE, Memory and Attention test, Memory Functioning Questionnaire, and Epworth Sleep Scale (ESS), Pittsburg Sleep Quality Index (PSQI) was performed to assess the sleep quality of participants. Following these behavioral questionnaires, they performed the encoding session in which they studied the 10 semantically associated lists of words visually on the computer. Encoding session was held at 9:30 PM and test session performed after 48 hours later on 9:30 PM.

In *semantic associate (DRM) method*, total ten word lists with ten words (semantically related) in each list were presented to the subjects with instruction to attend each word and be prepared for a later retrieval test. The lists were presented at the rate of 3000 milliseconds per word with an inter-stimulus interval of 2000 milliseconds. List items were sequentially presented during study phase, but at the time of test phase intra-list items were randomly presented during recognition test. The experiment was designed in e-Prime Software Version 2.0.10.353.

Following the encoding session, participants were prepared for sleep recording (polysomnography) using polysmith sleep amplifier. They put in bed approximately at 10:45 PM and light off at 11:00 PM and slept for approximate 8 hours of sleep. Sleep data was collected using sleep montage including EEG (4 channel: C3, C4, O3, O4), EMG (2 channel), EOG (2

channel: left EOG, right EOG) with the contralateral references of mastoid channel (A1, A2) electrodes. One ground (Z) was also channeled. In the morning, all the surface electrodes were removed and instructed participants to come back after 48 hours for memory test session.

The retrieval session included two test, viz. recognition followed by a recall test. At *recognition phase*, participants provided the old/new judgment for each presented word. Responses generated on the recognition test was self-paced by participants. Each recognition list contained three old stimuli (words) from learning list, three new stimuli (unrelated stimuli) served as distractor, and one critical lure word (highest BAS value). The whole experiment runs for approximately 40 minutes. At *recall phase*, participants were free to recall the list items. In the recall of words, participants have to recall the learned words. All the responses were taken on plain white paper. There was unlimited time for recall the studied lists items. Distractor task was also introduced between recognition test and recall test to prevent repetition of list items.

Sleep Experiment-04-B

Experimental Model of False Memory Induction across Sleep and Sleep Deprivation in DRM Task:

(1). For Recall Test:

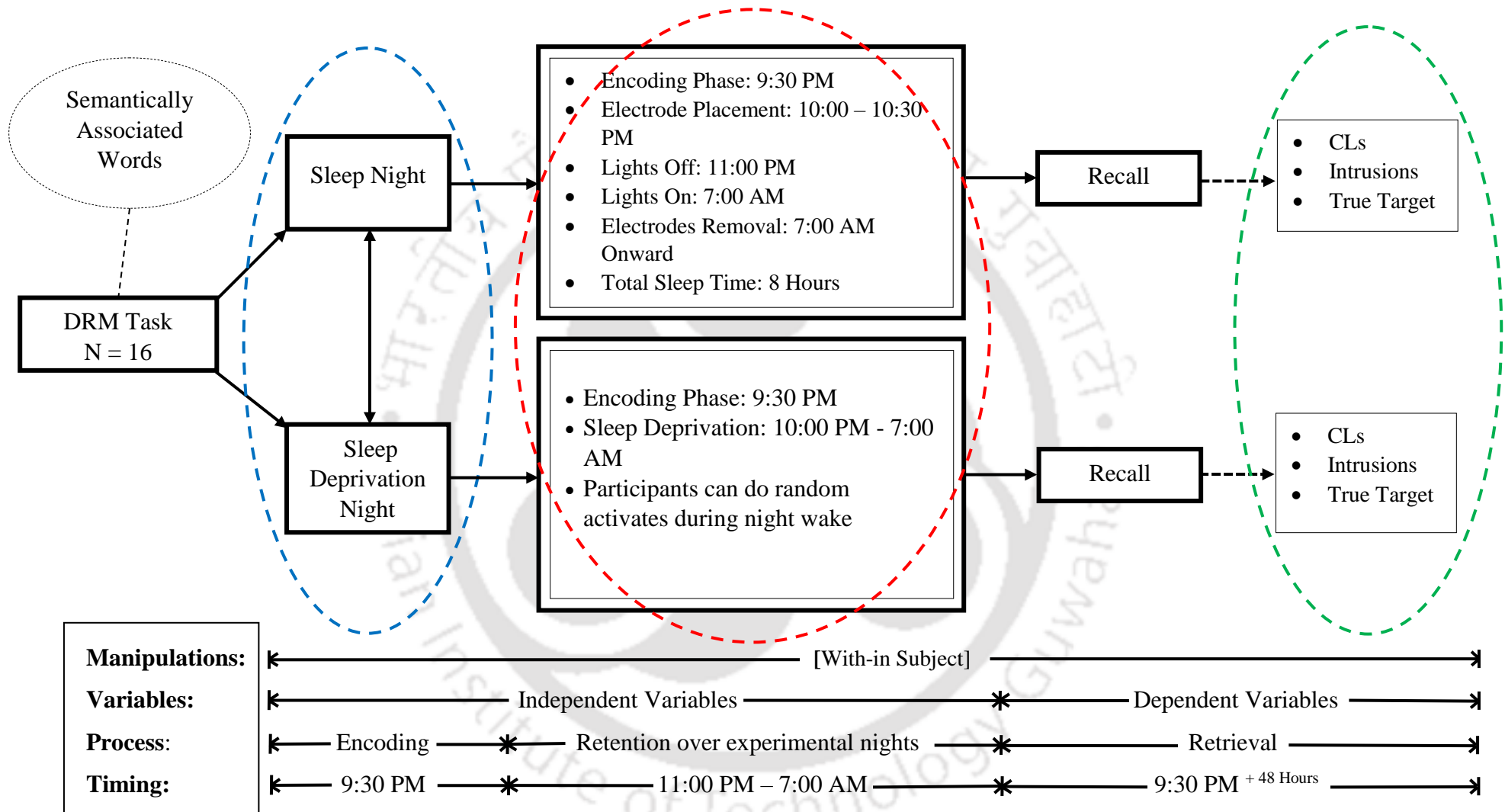


Figure 4.4.16: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recall Test for Semantic Task.

(Note: Red dotted circle represents processing during experimental nights; blue dotted circle represents with-in subject manipulation, and green dotted circles includes dependent variables)

(Abbreviation: CA=Category Associate Task; CL=Critical Lures)

Experimental Model of False Memory Induction across Sleep and Sleep Deprivation in DRM Task:

(2). For Recognition Test:

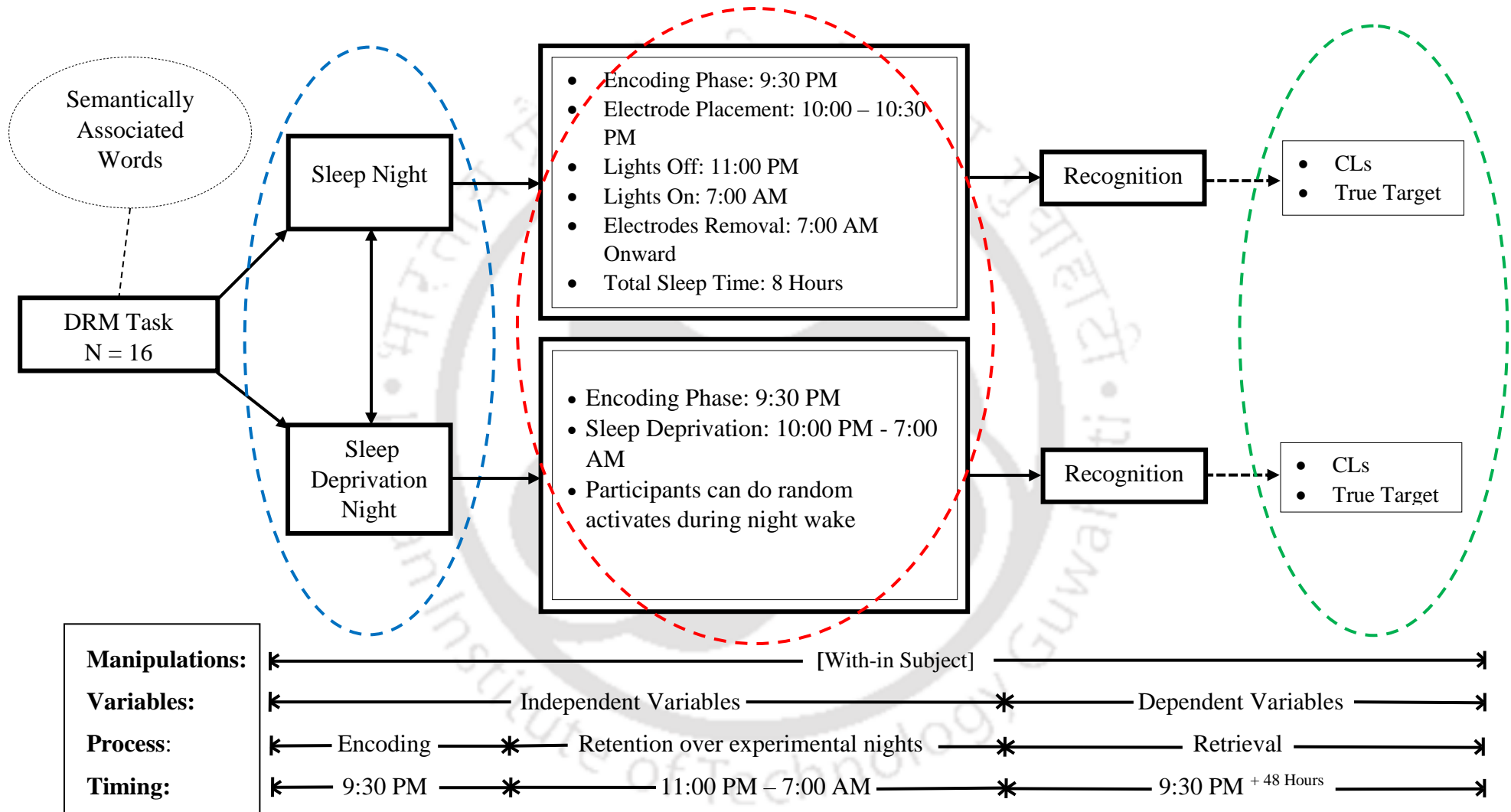


Figure 4.4.17: False Memory Induction in Experimental Nights Across Sleep and Sleep Deprivation in Recognition Test in Semantic Task.

(Note: Red dotted circle represents processing during experimental nights; blue dotted circle represents with-in subject manipulation, and green dotted circles includes dependent variables) (Abbreviation: CA=Category Associate Task; CL=Critical Lures)

Memory Measurement

In the free recall test, three categories are made *viz.* true target words (previously studied words during learning time), critical lure words (semantically associated unpresented words: false memory identifier), and intrusion words (unpresented words). The mean scores of recall test was analyses to test the hypothesis. In recognition test, first the raw memory measures were calculated and then using non-parametric signal detection measurements the discriminability/sensitivity and their response bias were calculated for final analysis (Pardilla-Delgado & Payne, 2017). During raw memory measures, the true targets rates was defined as the *hit rate* [**H**], which is calculated as; “old” response given to previously learned words divided by total number of presented study words. The *false rate* is defined as false alarm rate to critical lures [**FAC**], which is calculated as; “old” response given to related lure words divided by total number of related lure words which were presented. The *foil rate* is defined as false alarm rate to foils [**FAF**], which is calculated as; “old” response given to unrelated foils divided by total number of unrelated foils presented. Using non-parametric signal detection, *discriminability* was calculated as A' [hit rate (H) and foil rate (FAF) for true recognition, and false rate (FAC) and foil rate (FAF) for false recognition with their response bias B” (Donaldson, 1992; Snodgrass & Corwin, 1988).

The calculating formula for *true recognition* are: $A' = \frac{1}{2} + \frac{[H - FAF]}{[4H(1 - FAF)]}$, when $H \geq FAF$ and $A' = \frac{1}{2} + \frac{[FAF - H]}{[4FAF(1 - H)]}$ when $FAF \geq H$.

The calculating formulas for *false recognition* are: $A' = \frac{1}{2} + \frac{[FAC - FAF]}{[4FAC(1 - FAF)]}$ when $FAC \geq FAF$ and $A' = \frac{1}{2} + \frac{[FAF - FAC]}{[4FAF(1 - FAC)]}$ when $FAF \geq FAC$.

The calculating formulas for *response bias* for *true targets* are: $B'' = [H(1-H) - FAF(1-FAF)] / [H(1-H) + FAF(1-FAF)]$ when $H \geq FAF$ and $B'' = [FAF(1-FAF) - H(1-H)] / [FAF(1-FAF) + H(1-H)]$ when $FAF > H$.

The calculation formulas for *response bias* to *false items* are: $B'' = [FAC(1-FAC) - (FAF(1-FAF))] / [FAC(1-FAC) + FAF(1-FAF)]$ when $FAC \geq FAF$ and $B'' = [FAF(1-FAF) - FAC(1-FAC)] / [FAF(1-FAF) + FAC(1-FAC)]$ when $FAF > FAC$.

The A' values varies between the range from 0.00 to 1.00 where the higher score of A' indicates the greater sensitivity and low score indicates lower sensitivity. The response bias varies from -1.00 to +1.00 where the negative value of response bias indicates the *liberal bias*, positive value of response bias indicates the *conservative bias*, and if the value of response bias is equal to zero then it indicates the *neutral bias*.

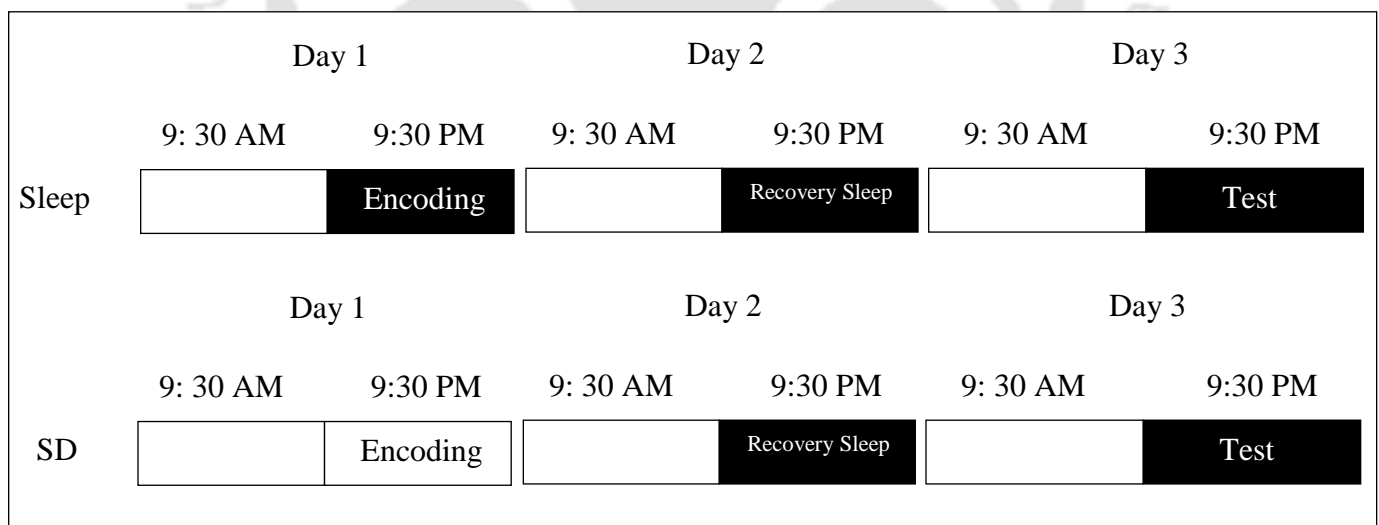


Figure 4.4.18: Experimental Night Protocol for Semantic Task. Sleep group encoded the lists on day 1 at 9:30 PM and later on 3rd day of the encoding, the test for memory performance was conducted at 9:30 PM. During sleep deprivation (SD) condition, the encoding was performed at 9:30 PM and subject were wake for whole night and on 3rd day the test was conducted at 9:30 PM. Day 2, nights were recovery sleep nights for all the participants of each group.

Statistical analysis

A mixed factorial ANOVA was used to analyze the data for false memory measurements. Experimental night conditions (full night sleep, sleep deprivation) were the manipulating variables, and mean scores of true targets (studied items), critical lures (unstudied items), intrusions were dependent variables. The mean score of critical lures items and intrusions were actual measurements of false memory. Total sleep time, sleep latencies, sleep efficiencies, % of each sleep stages were the measurements for sleep analysis.

RESULT:

1. *The effect of experimental nights in the generation of false memory in recall:* A one-way repeated measure ANOVA was conducted to compare the effect of sleep and sleep deprivation on critical lures. Additionally, the intrusions, and studied items were also measured. There was a non-significant effect of experimental nights [$F_{(1,15)} = 1.188, p > 0.05, \eta^2 = 0.073$] on false memory was reported which suggest that sleep and sleep deprivation both nights are equally producing the critical lures. Additionally, a non-significant difference was also noticed on intrusion [$F_{(1,15)} = 0.378, p > 0.05, \eta^2 = 0.025$] and true targets [$F_{(1,15)} = 0.028, p > 0.05, \eta^2 = 0.002$] measures across experimental nights. The mean values of memory performance are presented in **Table 4.10** (see **graph 4.4.6**).

2. *The effect of experimental nights in the generation of false memory in recognition:* A one-way repeated measure ANOVA was conducted to measure the discriminability/sensitivity of critical lure words, true targets along with their response bias. The recognition test in this study

support the idea that experimental nights (sleep and sleep deprivation) are equal sensitive in identification of critical lures in semantic associates.

There was non-significant effect of sleep in formation of critical lure pictures [$F_{(1,15)} = 1.463$; $p > 0.05$; $\eta^2 = 0.089$; discriminability/sensitivity scores for sleep = 0.70 and for sleep deprivation = 0.74]. The response bias analysis for false memory found to be liberal biased for both experimental nights [for sleep = - 0.03; for sleep deprivation = - 0.03]. All the mean values and standard deviations are shown in **Table 4.10**.

There was non-significant effect of experimental nights was observed in the formation of true target words [$F_{(1,15)} = 0.351$; $p > 0.05$; $\eta^2 = 0.023$; discriminability/sensitivity scores for sleep = 0.72 and for sleep deprivation = 0.73]. For the true target items, the response bias analysis found to be conservative in both the sleep and sleep deprivation conditions [sleep = 0.0162, sleep deprivation = 0.0063]. All the mean values and standard deviations are shown in **Table 4.10**.

- Measurements of sleep:* Sleep was monitored using Nihon-Kohden sleep-monitoring system. The polysomnographic report reveals that total sleep time (TST), Total recording time (TRT), sleep onset latency (SOL), % efficiency, all the individual sleep stages was calculated to evaluate the sleep quality. The Polysomnographic statistics is presented in **Table 4.11**.

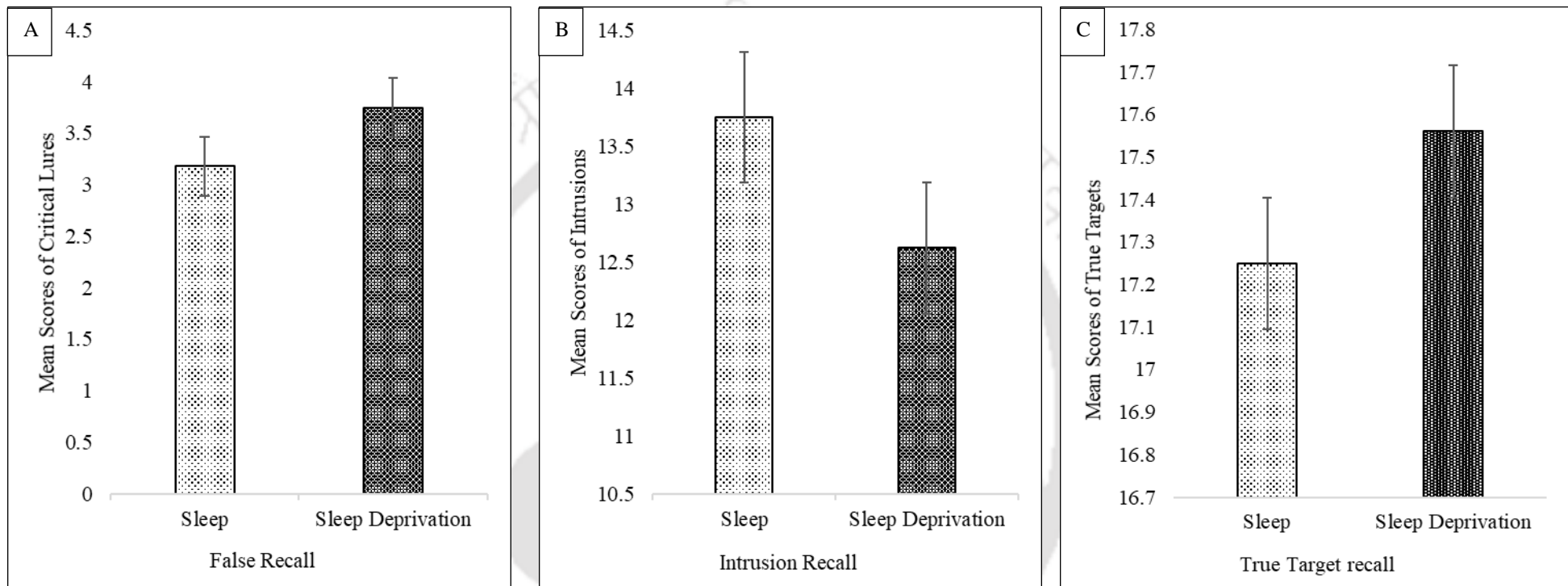
Table 4.10: Mean Scores of Recall and Recognition Memory Across Sleep Nights in Semantic Associates [Mean (Standard Deviation)]

Dependent Measure	After Sleep Night	After Sleep Deprivation Night
Recall Test		
Critical Lure	3.18 (1.37)	3.75 (1.48)
Intrusion	13.75 (9.25)	12.62 (10.48)
True Targets	17.25 (6.81)	17.56 (6.89)
Recognition Test		
Critical Lure Sensitivity (A')	0.70 (0.09)	0.74 (0.10)
True Target Sensitivity (A')	0.72 (0.09)	0.73 (0.11)
Critical Lure Bias (B'')	- 0.03 (0.23)	- 0.03 (0.23)
True Target Bias (B'')	0.016 (0.18)	0.006 (0.26)

(* < 0.05 between sleep and sleep deprivation)

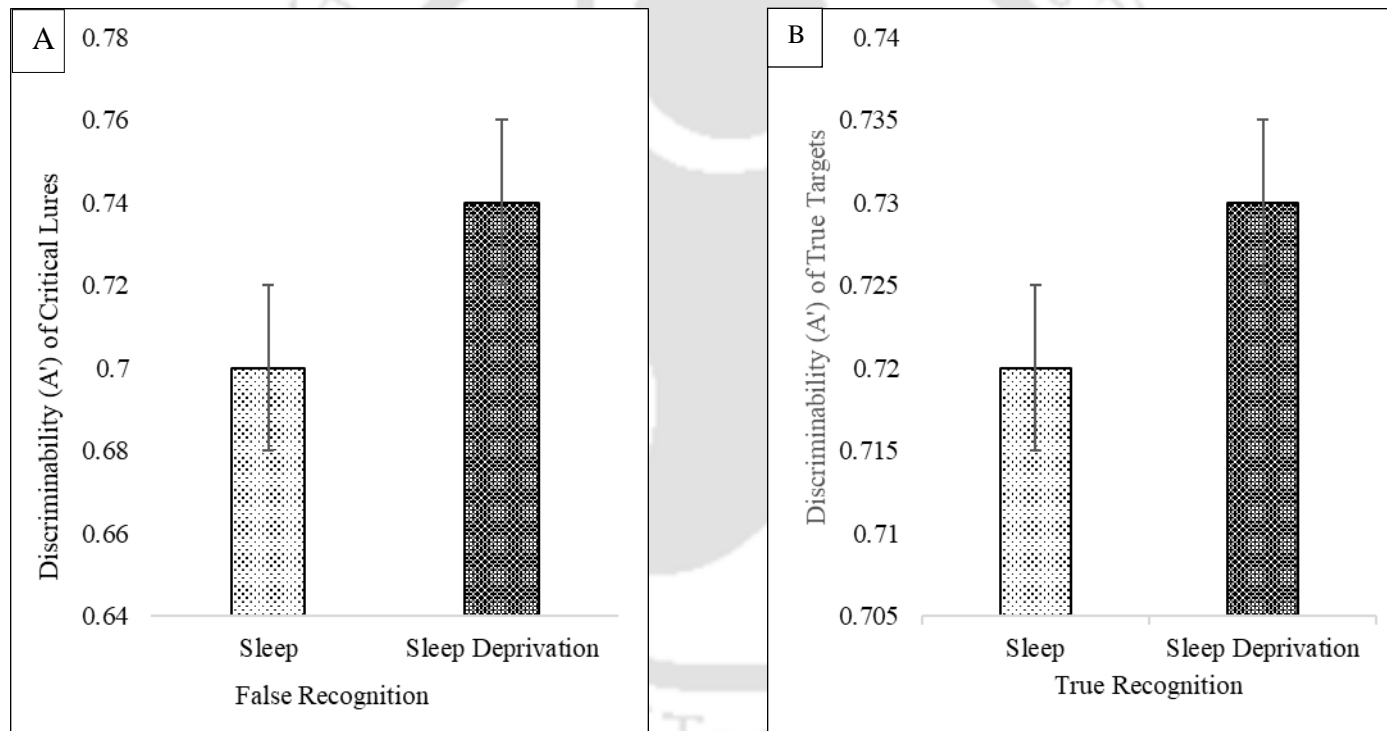
Table 4.11: Descriptive Statistics of Polysomnographic Report of Experimental Night for Semantic Associates [Mean and SD]

Sleep Parameters	Mean	Standard Deviation
TIB (Time in Bed in min)	500.00	14.97
TST (Total Sleep Time in min)	417.50	43.06
SOL (Sleep Onset Latency in min)	15.62	20.17
REM Latency (min)	74.28	36.70
% Efficiency	83.57	9.08
Stage S ₁ (min)	2.93	3.54
Stage S ₁ %	0.77	0.92
Stage S ₂ (min)	251.40	42.11
Stage S ₂ %	59.96	6.60
Stage S ₃ (min)	11.68	6.83
Stage S ₃ %	2.90	1.81
Stage S ₄ (min)	48.53	20.82
Stage S ₄ %	11.61	5.20
REM (min)	103.21	18.52
REM %	24.80	4.30
Wake (min)	14.43	25.53
Wake %	2.87	5.17

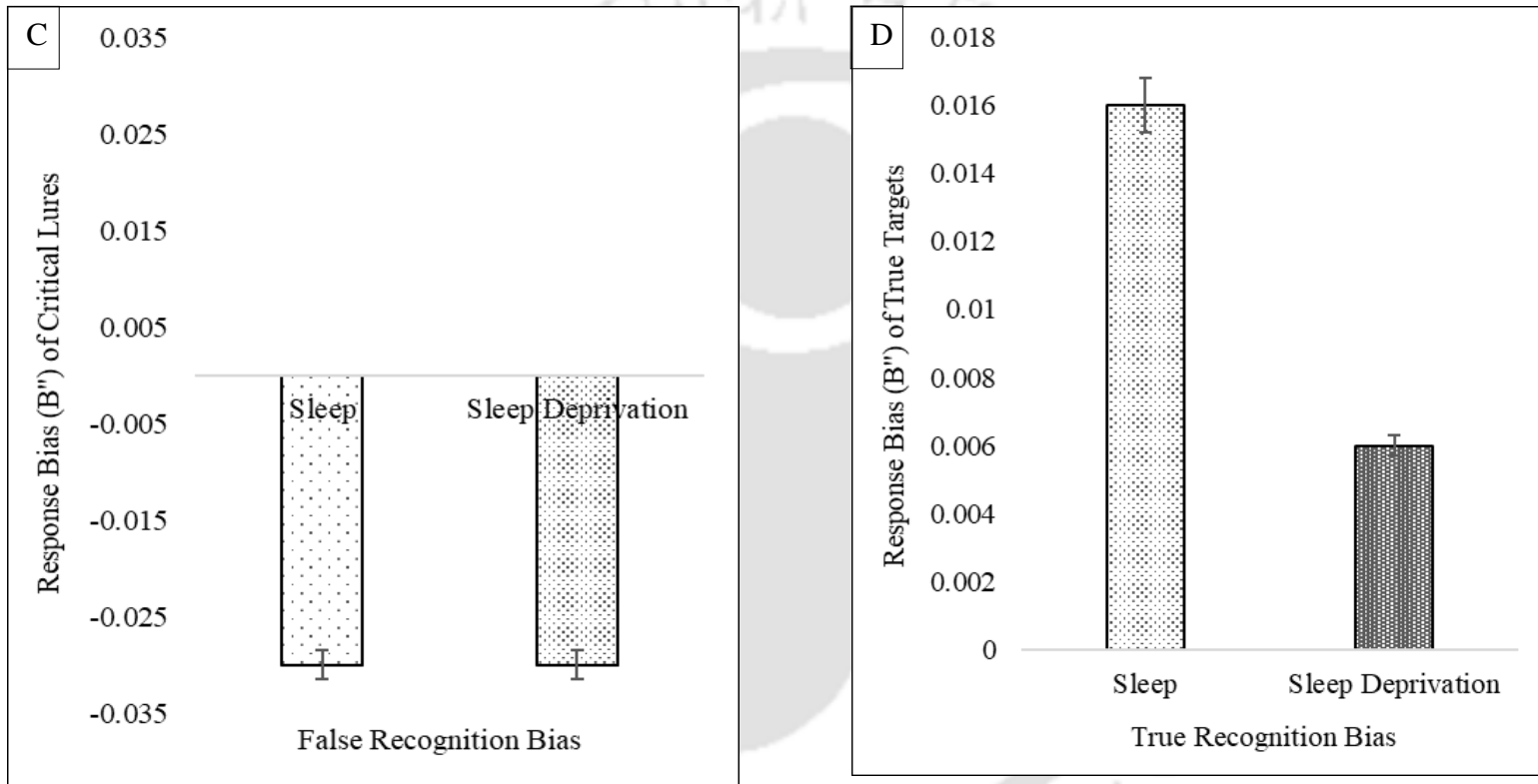


Graph 4.4.10. Number of words recalled. (A) False recall of critical lure items. (B) false recall of intrusion words. (C) True recall of studied word items. Comparisons are across sleep and sleep deprivation nights for recall of true target, critical lures and intrusions. (* represents the p-value where, $p < 0.05$; NS = non-significant; Error bars denotes SE)

Graph 4.4.11: The recognition memory was measured by A' , for (A) Critical lure words (False Memory) and (B) True target words. (* represents the p-value where, $p < 0.05$ and the error bars denotes the SE).



Graph 4.4.12: The memory response bias calculated by B'' for (C) Critical lure words (False memory) and (D) True target words.



CONCLUSION:

In this current study, it was found that sleep did not affect memory for targets, critical lures, and intrusions. The recognition of critical lure words and true target words all are equally retrieved after the 48 hours of retention soon after sleep and sleep deprivation. Although, the mean sensitivity of critical lure words is higher in sleep deprivation condition than sleep but are not significantly differ. The response biases for critical lures are liberal for both sleep and sleep deprivation nights, whereas in true target words the response bias are conservative for both sleep and sleep deprivation nights.

DISCUSSION:

This study was conducted to examine the role of experimental nights *viz.* sleep and sleep deprivation in the retrieval of false memory. Retrieval of word items was recorded after 48 hours of retention from the full night sleep and sleep deprivation nights. The previous study investigated the role of full night sleep and 48 hours (Pardilla-Delgado, & Payne, 2017), 12 hours (Payne et al., 2009) of delay with full day of wakefulness.

Previous studies (McKeon et al., 2012; Payne et al., 2009) reveals that sleep might increase both true and false memory performances in semantic associate task (DRM task). Payne et al. (2009) were strongly inclined for selective protection of gist-based false memory, but in this current study there is no any significant increase in both true and false recall and false recognition across sleep and sleep deprivation nights. This might be due to the lack of statistical power of the critical lure words. We used total 10 word lists which is in between the range of 8 lists (Payne et al., 2009) and 16 lists (Pardilla & Payne, 2017). Also, in this study, the retention delay was only 48 hours whereas

12 hours (Payne et al., 2009), 24 hours, and 48 hours (Pardilla & Payne, 2017) was used in previous study. The inspection of false recall and false recognition scores quite similar to previous studies. The false recall was average of 4.11 (Pardilla & Payne, 2017; 16 list words used) after 48 hours of delay in sleep group, whereas in this current study it is found to be 3.18, and 3.6 was in Payne et al. (2009) which is very close to the current study score. For the intrusion words in recall test, current study follows the same non-significant results as Payne et al. (2009) got. The insignificant results found in recognition test of this current study can be explained with the explanation of previous study (Neuschatz, Benoit, & Payne, 2003). One of the past study reveals that recognition task is assisted by source monitoring (Cabeza et al., 2001). They had found that, participant's hippocampal activity is similar to true and false words in a fMRI scanner and along with that the activity in parahippocampal gyrus region was more fired for true words than false one. This variation in the activation of parahippocampal gyrus advocates the reactivation of perceptual information of true words which supports the source monitoring and which leads to decrease in false recognition (Neuschatz, Benoit & Payne, 2003). This current study is very similar to previous studies (Pardilla & Payne, 2017; Payne et al., 2009) but some modifications are implemented in experiment design. They used mixed factorial design for their data analysis, whereas in this current study within subject design was used. In the previous studies, the comparison groups were sleep, daytime wake, and nap sleep, whereas in the current study only sleep and nocturnal sleep deprivation groups were made. This might be the cause for non-significant results in true and false recall and recognition tests. One of the limitation of previous study (Pardilla & Payne, 2017) was added in this current study. They perform the recognition test first and then perform the recall test, but in this study the recall test was first performed and then recognition was taken out. This counterbalancing of the memory test does not affect the retrieval of false memory in both studies. Both study get the non-significant results in false recall and recognition tests.

In the recognition memory test, sensitivity and their response biases both are very important measures. But, there is no any relationship between sensitivity and response bias as such. Although, there is not very clear exact neural explanation for memory response bias in sleep research. It was observed that, sleep can increase (Hu et al., 2006; Sterpenich et al., 2007), decrease (Atienza & Cantero, 2008) or no effect on recognition memory response biases (Baran, Pace-Schott, Ericson, & Spencer, 2012, Sterpenich et al., 2009; Wagner, Kashyap, Diekelmann, & Born, 2007). In the current study, the response bias for false recognition in both sleep and sleep deprivation was found to be *liberal*, whereas as in true word recognition, it was *conservative* for both sleep and sleep deprivation. The response bias results for false recognition are consistent with previous study (Pardilla & Payne, 2017) but the exact explanation for these biases are not very clear. Although, the neuro-chemical explanation was explained (Hu et al., 2006) that Acetylcholine elevation in sleep time is responsible for conservative bias. In contrast, the low level of cortical ACh (Acetylcholine) might associated with liberal bias (Fuld, katzman, Davis, & Terry, 1982).

CHAPTER 05: GENERAL DISCUSSION

ANSWERS TO THE RESEARCH QUESTIONS OF THIS STUDY

This present thesis is primarily aimed examining false memory generation. The present thesis compares two popular false memory induction methodologies namely the semantic and category associate in terms of their effectiveness of false memory generation. Additionally, the role of retrieval strategies if any, on false memory generation has also been evaluated across various delays between encoding and retrieval. This has done to ascertain whether false memories are affected by retrieval delays. A second, major goal of the present thesis is to investigate whether sleep following encoding modulates false memory generation and whether this relation is affected by the use of varied methodology and retrieval strategy.

The *first research question* was to compare the false memory induction methods with respect to their relative effectiveness for false memory generation. For the induction of false memory there are seven effective methods in human, two of which stand out in terms of popularity among researchers. These are the semantic associate (DRM task using words) and category associate (CA task using simple line drawings). A number of researchers have used these methods in their study of false memory (Toglia, Neuschatz, & Goodwin, 1999; Israel & Schacter, 1997; Anderson & Bower, 1973; Collins & Loftus, 1975; Hall & Kozlovf, 1973; Hintzman, 1988; Shiffrin, Huber & Marirelli, 1995; McDermott, 1996; Payne et al., 1996; Reyna & Kiernan, 1994; 1995; Roediger & McDermott, 1995; McDermott, 1996; Payne et al., 1990; Roediger & McDermott, 1995; Schacter, Verfaellie & Pradere, 1996) and CA task (Hintzman, 1988; Seamon et al., 2000; Thapar and McDermott, 2001; Toglia et al., 1999; Norman & Schacter, 1997; Brainerd, Reyna & Kneer, 1995;

Strack & Bless, 1994; Koutstaal & Schacter, 1997) and have reported that both methods are capable in formation of false memory under controlled conditions of the laboratory. The false memory induction methods experimented in this research are different as one used words (semantic associate) while the other uses pictures (category associate) for inducing false memory. Precious research show that both pictures (visual stimuli) and words (language stimuli) are processed differently in brain. It has also been reported that rCBF (regional cerebral blood flow) increased in bilateral extrastriate and ventral medial temporal cortices during pictures encoding and the left hemisphere regions including left frontal, medial temporal (Nyberg et al., 1996), and parietal regions are activated during word processing (Grady et al., 1998; Perani et al., 1999; Schacter et al., 1996). These finding approved the functional neuroanatomical difference in the processing of words and pictures and hence the difference between the CA and SA method.

In this study, we compare the Deese-Rodieger-McDermott (DRM) paradigm that uses words lists for inducing false memory with the category associate method that uses simple line drawing for false memory induction. The DRM is a semantic task while the CA is a visual task and both of them form different mental representations. Hence comparing them will provide a better understanding of the false memory formation process. Results from our experiments suggest that both the semantic associates and category associates are equally effective in the generation of false memory. This trend is also true when the experiments used varied retrieval strategies i.e. recall and recognition. One interesting finding that was reported from the experiments was that time interval between encoding and retrieval has a positive effect on false memory generation. Semantic associates were found to produce higher critical lure reproductions (false memory identifier) than category associates when retrieval was done immediately following encoding (Semon et al., 2000; Semon et al., 1998). For all other retrieval intervals both the methodology produced similar false memories. This result was true irrespective of the retrieval strategy employed. Similarly, true target

(studied items / old items) were effectively remembered in CA task (picture identification) then SA task (words identification) both on recall as well as in recognition across all retrieval intervals. The high number of true target identification for CA task can be attributed to the fact that picture stimuli are more vivid and rich in sensory perceptual content (Pavio, 1971, Weldon & Roediger, 1987) which may have led to more correct hits in category associates than semantic associates. Research suggests that pictorial stimuli are rich in their sensory-perceptual codes and have direct access for their semantic processing, while the word stimuli are rich in their phonetic, orthographic codes and have lexical access only (Conway & Gathercole, 1990; Nelson, Reed, & McEvoy, 1977). The result of the present experiment concerning similar efficiency of semantic and category associates in terms of generating false memory is a departure from the prevalent research findings. The inconsistent results of this study may be due to s methodological and procedural differences (like, in present study experiments, we use stimulus formats like line drawings, words, list lengths, category list lengths, retention intervals etc). Seamon et al. (2000) reported that the reduction in false recognition in their study was not due to the pictorial stimulus, list length or category list but due to stimuli presentation rate of 2000 millisecond/stimuli used in their study. In our study, we used 3000 milliseconds/stimuli and found very comparable false recognition of pictures and words. Another possible reason for the inconsistent result could be that in the present study we used line drawings as stimuli while another group of researcher Koutstaal & Schacter (1997) used colored pictures. Also, methodologically this study current used the with-in subject design, whereas, previous studies (Israel & Schacter, 1997) was based on between subject manipulations.

The *second research question* was aimed at investigating whether different retrieval strategies differentially modulate the false memory formation across varied methodologies of false memory. Retrieval of memories plays an important role in the accessibility of memories which can in turn

influence false memories. Retrieval using recognition and recall tests use different processing mechanisms for accessing and retrieving memories which could in turn modify the content and specificity of memories reproduced.

In this present study, false memory generation was tested for the SA (semantic associate) and CA (category associate) methodologies using both recall and recognition. In semantic associate (DRM) *task*, it was found that both critical lure and intrusion words were identified more on recognition than recall, while true targets (studied words) were equally identified on recognition and recall. These current study findings are similar with previous findings of Roediger, & McDermott, 1995, where more critical lures (false memories) were reported on recognition than recall. Similarly, Monds et al., 2017, reported results similar to the present study for false memory generation by semantic associates. In category associate (line-drawing) *task* both recall and recognition retrieval strategies are almost equally inducing false memory. Interestingly, for shorter retention interval recognition out performs recall by very small margin in terms of false memory accessed. For true targets (studied pictures), recall is better than recognition in assessing false memory.

The possible reason for both retrieval strategies (recall, recognition) in SA and CA task might be explained on the basis of two-stage process theory, which stated that participants who goes through decision process used recognition, whereas recall relies on recollection of information as well as decision process *i.e.* recall process involves search of studied items and then a decision process to retrieve the information, whereas recognition involves only decision process. As recognition involves only one process which might be responsible for memory error or failure (Watkins & Gardiner, 1979) this might lead to false memory. Also during recognition, participants were getting retrieval cues that might be responsible for false memory formation (source monitoring theory;

Reyna, 2000; Johnson & Raye, 1981; Johnson, Hashroudi, & Lindsay, 1993), whereas during recall no cues are present.

The *third research question* investigated the effect of retention intervals (between encoding and retrieval) on formation of false memory. Retention interval is one of the key factor through which the performance on false memory can be modulated. This is because the active interference during time elapsed between encoding and retrieval can cause inadequate consolidation of memories leading to poor performance at retrieval time. In addition, the process of consolidation of memories is time dependent with the first eight hours responsible for maximum forgetting. Research studies suggest that it is only after 48 hours have passed after learning that memory traces are consolidated and stored for later retrieval at the neocortical sites. The present experiment was interested in evaluating the role of short and long retention interval on false memories induced using semantic associates and category associates. Additionally, the impact of retrieval strategy on such retention interval based false memory generation is also tested.

In the semantic associate *task*, it was found that across all retention interval and retention strategy, the identification of critical lure words remained constant reflecting the persistency effect of false memory. The identification of intrusion and studied words varied across short and long retention intervals for the semantic associate task. The Bonferroni post-hoc analysis reveals that both short and long retention interval significantly influenced *recognition* of **intrusion words**, whereas short and long retention interval influenced *recall* of studied (old) words. Toggia *et al.* (1999) reported findings similar with present study across retrievals which are longer than the present study intervals. The present study additionally evaluated the effects of short retention intervals between learning and retrieval on false memory formation (McDermott, 1996; Payne et al., 1996; Reyna & Kiernan, 1994; 1995; Roediger & McDermott, 1995). This present study results thus provide

additional support for the *persistence effect of false memory* (Toglia *et al.*, 1999; McDermott, 1996; Payne *et al.*, 1990; Roediger & McDermott, 1995; Schacter, Verfaellie & Pradere, 1996). These outcomes of the present study can be explained with the predictions of the fuzzy trace theory (FTT), which stated that repetition over retention intervals enhances the *gist memories* that lead to the illusory recollection and this strengthening of gist traces and in the process making participants very confident to their memory decision based on gist (Toglia *et al.*, 1999). Few studies (Payne *et al.*, 1996) showed that, on repeated testing across retention intervals the gist traces remain highly accessible which helps in retrieving of critical intrusion. It was also found that gist representations are more durable and dominant than verbatim traces (Keenan & Kintsch, 1974; Reyna, 1996). So it would be expected that gist-consistent intrusions occurs with high frequency for semantic processing than non-semantic.

In *category associate task*, false memory is affected by both the short and long retention intervals on recognition test while false memories remain consistent over short and long retrieval on recall test. In recognition test from immediate to 24 hours of delay the false recognition of CL (critical lure) increases and then became constant from 24 hours to 48 hours of delay. Across retention intervals, the true targets decreased as time progresses on recall test but remained constant on recognition test.

The ***fourth research question***, investigates the effect of sleep nights on the generation of false memory. For achieving this target, we introduced experimental nights filled with sleep and sleep deprivation between learning and retrieval of false memory task. Research on sleep and memory clearly tilts towards a beneficial role of sleep on memory. We reasoned that if sleep helps in benefitting memories in terms of better retrieval following learning the generation and maintenance of false memories should also be effected by nocturnal sleep. Additionally, the

available literature of sleep and false memory is the best unclear and we wanted to address this issue through this present research. Previous research on sleep and various types of memories suggest that whereas sleep help in stabilization and reconsolidation of memory, the deprivation of sleep can hinder both the stabilization and consolidation of memories. Another interest we had in this study was in terms of determining whether words stimuli (semantic) or line-drawing pictures (category) stimuli are processed in similar ways in terms of false memories across experimental sleep nights.

In *semantic associates task* (words) on recall test, there is no differences on the number of critical lures, intrusions and true target words which were retrieved across sleep and deprivation nights. Similarly, on recognition test, critical lure and true target words are equally remembered across both sleep and sleep deprivation nights. Although, the mean number of critical lures retrieval was more in sleep deprivation than sleep but this effect did not reach significance (Sleep deprivation = 0.74; Sleep = 0.70). Previous studies on sleep and false memories (McKeon et al., 2012; Payne et al., 2009) support the idea that sleep helps in formation of both false memory and true memory which is in direct opposition to the result of the present study. The present study results are however supported by research done by Pardilla & Payne, (2017). The inconsistency in the results of the present study and previous studies (McKeon et al., 2012; Payne et al., 2009) and also be partly attributed to the lack of statistical power of the critical lure words (Pardilla & Payne, 2017). In the present study we used total 10 word lists which is in between the range of 8 lists (Payne et al., 2009) and 16 lists (Pardilla & Payne, 2017). Also, in this study, the retention delay was only 48 hours whereas 12 hours (Payne et al., 2009), 24 hours, and 48 hours (Pardilla & Payne, 2017) was used in previous study. Previous studies on sleep and false memory used both sleep and wake group (sleep group, day time wakefulness group, nap group) while the present study avoided the wake and nap group. This could also be a reason of different results of the present study from

previous studies. The present study required same volunteer (with-in subject) to complete both the recall and recognition retrievals. The sequence we used for retrieval was recognition followed by recall. We believe using recall before recognition could be one of the reasons for non-significant results obtained in the present experiment because after recalling the list items, participants might rely on the retrieval of recalled items which might influence the recognition also. Pardilla & Payne, (2017) performed a similar study with recognition following recall and found significant differences between sleep and deprivation on false memories. Since recall includes recognition as part of retrieval process this could lead to near similar results on recall and recognition of false memories following sleep.

In recognition test, one of the important parameter known as *response bias* was also investigated. In this study, the response biases for critical lures are liberal for both sleep and sleep deprivation nights (Pardilla & Payne, 2017), whereas for true target words the response bias are conservative for both sleep and sleep deprivation nights. A number of studies have pointed out that sleep can increase (Hu et al., 2006; Sterpenich et al., 2007), decrease (Atienza & Cantero, 2008) or have no effect on recognition memory response biases (Baran, Pace-Schott, Ericson, & Spencer, 2012, Sterpenich et al., 2009; Wagner, Kashyap, Diekelmann, & Born, 2007). These findings support the idea that response bias are independent of sensitivity. There is no any direct relationship of response bias.

In *category associates (simple line drawings)*, we have found different pattern of results as compared to semantic associates in the induction of false memory. In category associates we used simple line drawings pictures as stimuli where the list items are grouped according to their category. For example, *reading material* is category for *booklet, pamphlet, comic book, broacher* (possible exemplars) etc. On sleep experiments it was reported that volunteers identified higher critical lures on both recall and recognition retrieval session following sleep nights as compared

to sleep deprivation nights. These findings can be supported by fuzzy trace theory as previous findings are also supported by this explanation that sleep might generally benefit the memory performances which are depend on the gist processing.

The experimental nights (sleep, sleep deprivation) in the induction of category associated false memory is first study in our knowledge. Few studies have been conducted previously (Diekelmann et al., 2008; Diekelmann, Born, & Wagner, 2010; Payne et al., 2009; Verma & Kashyap, 2019) to investigate the sleep effect on semantic task. These studies have reported that for semantic task, false recall of critical lures was increased after full night sleep (Diekelmann, Born, & Wagner, 2010; Payne et al., 2009) and 90-minute nap (Payne et al., 2009) in comparison to daytime wake. In contrast few studies (Fenn et al., 2009; Lo, Sim & Chee, 2014) support the idea that sleep reduces the formation of false memory because sleep can consolidate information which is supported by recollection (Drosopoulos et al., 2005), in older adults, the reduction of false memory after sleep is related to duration of Slow wave sleep (SWS) (Lo, Sim & Chee, 2014). Verma & Kashyap (2019) also found that sleep deprivation helps in formation of false memory. They argued that sleep deprived participants show poor source monitoring because executive function in frontal lobe decline/ hinders due to sleep deprivation which in turn leads to higher false memories.

Results similar to the present experiment was reported in earlier studies evaluating sleep and false memory where they found the sleep enhances false memory generation (Diekelmann et al., 2008; Diekelmann, Born, & Wagner, 2010; Payne et al., 2009). The present study reported the increase in false memory recollections following sleep in category associate task. We believe that sleep might have benefited the gist processing of information for categorical picture items and at the time of retrieval the gist items were retrieved with higher probability leading to high levels of false memories. Smith et al. (2002) found that false memory in categorical repetitions are formed due to their *meaning/gist* traces at the time of testing. The current study findings can also be supported

with the help of fuzzy trace theory (Reyna & Brainerd, 1995; Reyna & Kiernan, 1994) which states that, memory is composed of *verbatim traces* (specific contextual details) and *gist traces* (General meaning of information), where true memories are based on both verbatim as well as gist traces and critical lures are based on only gist traces.

In the current study, it was found that the response bias also shifted across experimental nights. Subjects after sleep nights reported conservative bias on false recognition task whereas after sleep deprivation they reported liberal bias. Interestingly, subjects during both the sleep and deprivation nights reported liberal bias for true target (correct / old items) recognition.

Finally, we have found that experimental nights significantly modulate the false memory through category associates as DRM task in previous findings. The full night sleep in comparison to sleep deprivation, significantly benefited the false recall and false recognition memory of simple line drawing pictures through category associate task.

Limitations of Study:

- Most of the experiments of this thesis have listed low power as a major limitation. One reason for the low sample size is the unavailability of subjects as the design of the experiment requires multiple testing. A number of subjects drop out midway resulting in lower subject's ratio who complete the entire experiment.
- This thesis recruited only undergraduate male students as the experiment's participants.
- The experiments of this thesis were conducted and analyzed only in a well-equipped laboratory, rather we neglected the comparison of current findings with real-life settings outputs. This is our future plan to conduct false memory experiments in real-life settings and compare them with laboratory finds to extrapolate the results.

REFERENCES

- Alba, J. W., & Hasher, L. (1983). Is memory schematic? *Psychological Bulletin*, 93(2), 203-231.
- Anderson, J. R., & Bower, G. H. (1973). Human associative memory. Washington, DC: V. H. Winston.
- Anderson, J. R., & Pirolli, P. L. (1984). Spread of activation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 10(4), 791-798.
- Anderson, N. D., Martin, C. B., Czyzo, J., & Köhler, S. (2018). When Gist and Familiarity Collide: Evidence from False Recognition in Younger and Older Adults. *The Journals of Gerontology: Series B*.
- Anisfeld, M., & Knapp, M. (1968). Association, synonymity, and directionality in false recognition. *Journal of Experimental Psychology*, 77(2), 171-179.
- Aserinsky, E. (1996). Memories of famous neuropsychologists: The discovery of REM sleep. *Journal of The History of the Neurosciences*, 2(3), 213-227.
- Atienza, M., & Cantero, J. L. (2008). Modulatory effects of emotion and sleep on recollection and familiarity. *Journal of sleep research*, 17(3), 285-294.
- Atkinson, R. C., & Juola, J. F. (1973). Factors influencing speed and accuracy of word recognition. *Attention and performance IV*, 583-612.
- Atkinson, R. C., & Juola, J. F. (1974). *Search and decision processes in recognition memory*. WH Freeman.
- Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *Psychology of learning and motivation*, 2, 89-195.
- Atkinson, R. C., & Wescourt, K. T. (1975). Some remarks on a theory of memory. *Attention and performance*, 5.

- Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in cognitive sciences*, 4(11), 417-423.
- Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of learning and motivation*, 8, 47-89.
- Baddeley, A. Human memory: Theory and practice. Boston: Allyn and Bacon, 1990.
- Balota, D. A., Cortese, M. J., Duchek, J. M., Adams, D., Roediger III, H. L., McDermott, K. B., & Yerys, B. E. (1999). Veridical and false memories in healthy older adults and in dementia of the Alzheimer's type. *Cognitive Neuropsychology*, 16(3-5), 361-384.
- Baran, B., Pace-Schott, E. F., Ericson, C., & Spencer, R. M. (2012). Processing of emotional reactivity and emotional memory over sleep. *Journal of Neuroscience*, 32(3), 1035-1042.
- Barclay, C. R., & Wellman, H. M. (1986). Accuracies and inaccuracies in autobiographical memories. *Journal of Memory and Language*, 25(1), 93-103.
- Bartlett, F. C. (1932). Remembering: An experimental and social study. Cambridge: Cambridge University.
- Battig, W. F., & Montague, W. E. (1969). Category norms of verbal items in 56 categories A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology*, 80(3p2), 1-46.
- Beato, M. S., & Arndt, J. (2017). The role of backward associative strength in false recognition of DRM lists with multiple critical words. *Psicothema*, 29(3), 358-363.
- Beauchamp, H. M. (2002). Aural, visual, and pictorial stimulus formats in false recall. *Psychological reports*, 91(3), 941-951.
- Bellezza, F.S. (2003). Evaluation of five multinomial model of conscious and unconscious process in the recall-recognition paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29, 779-796.

- Benmergui, S. R., McKelvie, S. J., & Standing, L. G. (2017). Beneficial Effect of Pictures on False Memory in the DRMRS Procedure. *Current Psychology*, 36(1), 136-146.
- Berliner, L., & Williams, L. M. (1994). Memories of child sexual abuse: A response to Lindsay and Read. *Applied Cognitive Psychology*, 8(4), 379-387.
- Bottoms, B. L., Shaver, P. R. & Goodman, G. S. (1991, August). *Profile of ritualistic and religion-related abuse allegation reported to clinical psychologists in the United States*. (Paper presented at the 99th Annual Convention of the American Psychological Association, San Francisco)
- Bousfield, W. A., Esterson, J., & Whitmarsh, G. A. (1957). The effects of concomitant colored and uncolored pictorial representations on the learning of stimulus words. *Journal of Applied Psychology*, 41(3), 165-168.
- Brainerd, C. J., & Reyna, V. F. (1996). Mere memory testing creates false memories in children. *Developmental Psychology*, 32(3), 467-478.
- Brainerd, C. J., & Reyna, V. F. (1998). When things that were never experienced are easier to “remember” than things that were. *Psychological Science*, 9(6), 484-489.
- Brainerd, C. J., & Reyna, V. F. (2001). Fuzzy-trace theory: Dual processes in memory, reasoning, and cognitive neuroscience. *Advances in child development and behavior*, 28, 42-100.
- Brainerd, C. J., & Reyna, V. F. (2002). Fuzzy-trace theory and false memory. *Current Directions in Psychological Science*, 11(5), 164-169.
- Brainerd, C. J., & Reyna, V. F. (2005). *The science of false memory*. Oxford University Press.
- Brainerd, C. J., Reyna, V. F., & Brandse, E. (1995). Are children's false memories more persistent than their true memories? *Psychological Science*, 6(6), 359-364.
- Brainerd, C. J., Reyna, V. F., & Kneer, R. (1995). False-recognition reversal: When similarity is distinctive. *Journal of Memory and Language*, 34(2), 157-185.

- Brainerd, C. J., Reyna, V. F., & Mojardin, A. H. (1999). Conjoint recognition. *Psychological review*, 106(1), 160-179.
- Bransford, J. D., & Franks, J. J. (1971). The abstraction of linguistic ideas. *Cognitive psychology*, 2(4), 331-350.
- Bransford, J. D., & Johnson, M. K. (1973). Considerations of some problems of comprehension. In W. Chase (Ed.), *Visual information processing* (pp. 383-438). New York: Academic.
- Bransford, J. D., Barclay, J. R., & Franks, J. J. (1972). Sentence memory: A constructive versus interpretive approach. *Cognitive psychology*, 3(2), 193-209.
- Brewer, W. F. (1977). Memory for the pragmatic implications of sentences. *Memory & Cognition*, 5(6), 673-678.
- Brewer, W. F., & Treyens, J. C. (1981). Role of schemata in memory for places. *Cognitive psychology*, 13(2), 207-230.
- Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, 5(1), 73-99.
- Buzsaki G. (1998). Memory consolidation during sleep: a neurophysiological perspective. *Journal of sleep research*, 7(S1), 17-23.
- Cabeza, R., Rao, S. M., Wagner, A. D., Mayer, A. R., & Schacter, D. L. (2001). Can medial temporal lobe regions distinguish true from false? An event-related functional MRI study of veridical and illusory recognition memory. *Proceedings of the National Academy of Sciences*, 98(8), 4805-4810.
- Carmichael, L., Hogan, H. P., & Walter, A. A. (1932). An experimental study of the effect of language on the reproduction of visually perceived form. *Journal of Experimental Psychology*, 15(1), 73-86.
- Caton, R. (1875). Electrical currents of the brain. *The Journal of Nervous and Mental Disease*, 2(4), 610.

- Ceci, S. J., Huffman, M. L. C., Smith, E., & Loftus, E. F. (1994). Repeatedly thinking about a non-event: Source misattributions among preschoolers. *Consciousness and Cognition*, 3(3), 388-407.
- Cofer, C. N. (1967). Does conceptual organization influence the amount retained in immediate free recall? In B. Kleinmuntz (Ed.) *concepts and the structure of memory* (pp. 181-214). New York: Wiley.
- Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological review*, 82(6), 407-428.
- Convay, M. A., & Gathercole, S. E. (1990). The effects of writing upon memory: Evidence for a translational hypothesis. *Quarterly Journal of Experimental Psychology*, 42A, 513-527.
- Cramer, P. (1970). Semantic generalization: Demonstration of an associative gradient. *Journal of Experimental Psychology*, 84(1), 164-172.
- Curran, T., Schacter, D. L., Johnson, M. K., & Spinks, R. (2001). Brain potentials reflect behavioral differences in true and false recognition. *Journal of Cognitive Neuroscience*, 13(2), 201-216.
- Darnton, N. (1991, October 7). The pain of the last taboo. *Newsweek*, , pp. 70-72.
- Deese, J. (1959a). Influence of inter-item associative strength upon immediate free recall. *Psychological Reports*, 5(3), 305-312.
- Deese, J. (1959b). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of experimental psychology*, 58(1), 17-22.
- Dewhurst, S. A., & Conway, M. A. (1994). Pictures, images, and recollective experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20(5), 1088-1098.
- Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience*, 11(2), 114-126.

- Diekelmann, S., Born, J., & Wagner, U. (2010). Sleep enhances false memories depending on general memory performance. *Behavioural brain research*, 208(2), 425-429.
- Diekelmann, S., Landolt, H. P., Lahl, O., Born, J., & Wagner, U. (2008). Sleep loss produces false memories. *PloS one*, 3(10), e3512.
- Donaldson, W. (1992). Measuring recognition memory. *Journal of Experimental Psychology: General*, 121(3), 275.
- Drosopoulos, S., Wagner, U., & Born, J. (2005). Sleep enhances explicit recollection in recognition memory. *Learning & Memory*, 12(1), 44-51.
- Edmiston, S. (1990, November). Daddy's girl. (*Glamour*, pp. 228—231, 280—285.)
- Fenn, K. M., Gallo, D. A., Margoliash, D., Roediger, H. L., & Nusbaum, H. C. (2009). Reduced false memory after sleep. *Learning & Memory*, 16(9), 509-513.
- Frenda, S. J., Berkowitz, S. R., Loftus, E. F., & Fenn, K. M. (2016). Sleep deprivation and false confessions. *Proceedings of the National Academy of Sciences*, 113(8), 2047-2050.
- Frenda, S. J., Patihis, L., Loftus, E. F., Lewis, H. C., & Fenn, K. M. (2014). Sleep deprivation and false memories. *Psychological Science*, 25(9), 1674-1681.
- Fuld, P. A., Katzman, R., Davies, P., & Terry, R. D. (1982). Intrusions as a sign of Alzheimer dementia chemical and pathological verification. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, 11(2), 155-159.
- Gais, S., & Born, J. (2004). Declarative memory consolidation: mechanisms acting during human sleep. *Learning & Memory*, 11(6), 679-685.
- Gallo, D. A. (2006). Associative illusions of memory. *False memory research in DRM and related tasks*. New York, NY, USA: Psychology Press.

- Gallo, D. A., & Roediger III, H. L. (2002). Variability among word lists in eliciting memory illusions: Evidence for associative activation and monitoring. *Journal of Memory and Language*, 47(3), 469-497.
- Ganaway, G. K. (1989). Historical versus narrative truth: Clarifying the role of exogenous trauma in the etiology of MPD and its variants. *Dissociation*, 2, 205-220.
- Gaskell, M. G., & Dumay, N. (2003). Lexical competition and the acquisition of novel words. *Cognition*, 89(2), 105-132.
- Golier, J.A., Yehuda, R. and Southwick, S. (1997) "Memory and Posttraumatic Stress Disorder", in Appelbaum, P.S., Uyehara, L.A. and Elin, M.R. (eds.), *Trauma and Memory: Clinical and Legal Controversies*. New York: Oxford University Press, pp. 225–260.
- Gosselin, A., De Koninck, J., & Campbell, K. B. (2005). Total sleep deprivation and novelty processing: implications for frontal lobe functioning. *Clinical neurophysiology*, 116(1), 211-222.
- Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior*, 23(5), 553-568.
- Hall, J. W., & Kozloff, E. E. (1973). False recognitions of associates of converging versus repeated words. *The American Journal of Psychology*, 86(1), 133-139.
- Harsch, N. & Neisser, U. (1989). *Substantial and irreversible errors in flashbulb memories of the Challenger explosion*. (Poster presented at the annual meeting of the Psychonomic Society, Atlanta, GA)
- Hasher, L., & Griffin, M. (1978). Reconstructive and reproductive processes in memory. *Journal of Experimental Psychology: Human Learning and Memory*, 4(4), 318-330.
- Hebb, D. O. (1949). *The organization of behavior: A neuropsychological approach*. John Wiley & Sons.

- Hintzman, D. L. (1988). Judgments of frequency and recognition memory in a multiple-trace memory model. *Psychological review*, 95(4), 528-551.
- Hollingworth, H. L. (1913). Characteristic differences between recall and recognition. *The American Journal of Psychology*, 24, 532-544.
- Holmes, D. (1990). The evidence for repression: An examination of sixty years of research. (In J. Singer (Ed.), *Repression and dissociation: Implications for personality, theory, psychopathology, and health* (pp. 85—102). Chicago: University of Chicago Press.)
- Hu, P., Stylos-Allan, M., & Walker, M. P. (2006). Sleep facilitates consolidation of emotional declarative memory. *Psychological science*, 17(10), 891-898.
- Hunt, R. R., & Einstein, G. O. (1981). Relational and item-specific information in memory. *Journal of Verbal Learning and Verbal Behavior*, 20(5), 497-514.
- Hunt, R. R., & McDaniel, M. A. (1993). The enigma of organization and distinctiveness. *Journal of Memory and Language*, 32(4), 421-445.
- Hyman, I. E., Husband, T. H., & Billings, F. J. (1995). False memories of childhood experiences. *Applied cognitive psychology*, 9(3), 181-197.
- Israel, L., & Schacter, D. L. (1997). Pictorial encoding reduces false recognition of semantic associates. *Psychonomic Bulletin & Review*, 4(4), 577-581.
- Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of memory and language*, 30(5), 513-541.
- James, W. (1890). The principles of. *Psychology*, 2, 94.
- Jenkins, J. G., & Dallenbach, K. M. (1924). Obliviscence during sleep and waking. *The American Journal of Psychology*, 35(4), 605-612.
- Johnson, M. K. (1988). Reality monitoring: An experimental phenomenological approach. *Journal of Experimental Psychology: General*, 117(4), 390-394.

- Johnson, M. K., & Raye, C. L. (1981). Reality monitoring. *Psychological review*, 88(1), 67-85.
- Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological bulletin*, 114(1), 3-28.
- Johnson, M. K., Nolde, S. F., & De Leonardis, D. M. (1996). Emotional focus and source monitoring. *Journal of Memory and Language*, 35(2), 135-156.
- Jones, K., & Harrison, Y. (2001). Frontal lobe function, sleep loss and fragmented sleep. *Sleep medicine reviews*, 5(6), 463-475.
- Juola, J. F., Fischler, I., Wood, C. T., & Atkinson, R. C. (1971). Recognition time for information stored in long-term memory. *Attention, Perception, & Psychophysics*, 10(1), 8-14.
- Kales, A., & Rechtschaffen, A. (1968). *A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects*. US Department of Health, Education and Welfare, Public Health Service, National Institutes of Health, National Institute of Neurological Diseases and Blindness, Neurological Information Network.
- Keenan, J. M., & Kintsch, W. (1974). The identification of explicitly and implicitly presented information. *The representation of meaning in memory*, 153-176.
- Kensinger, E. A. (2009). Remembering the details: Effects of emotion. *Emotion review*, 1(2), 99-113.
- Kim, H., & Cabeza, R. (2007). Trusting our memories: dissociating the neural correlates of confidence in veridical versus illusory memories. *Journal of Neuroscience*, 27(45), 12190-12197.
- King, D. B., Viney, W., & Woody, W. D. (2009). *A history of psychology: Ideas and context*.
- Kintsch, W. (1974). *The representation of meaning in memory*. Oxford, England: Lawrence Erlbaum.

- Kluft, R. P. (1997). The argument for the reality of delayed recall of trauma. *Trauma and memory: Clinical and legal controversies*, 25-57.
- Koriat, A., Goldsmith, M., & Pansky, A. (2000). Toward a psychology of memory accuracy. *Annual review of psychology*, 51(1), 481-537.
- Koutstaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language*, 37(4), 555-583.
- Kucera, H., & Francis, W. N. (1967). Computational analysis of present-day American English. *Providence, RI: Brown University Press*.
- Lampinen, J. M., Copeland, S. M., & Neuschatz, J. S. (2001). Recollections of things schematic: Room schemas revisited. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 27(5), 1211-1222.
- Leicht, K. L. (1968). Recall and judged frequency of implicitly occurring words. *Journal of Verbal Learning and Verbal Behavior*, 7(5), 918-923.
- Leichtman, M. D., & Ceci, S. J. (1995). The effects of stereotypes and suggestions on preschoolers' reports. *Developmental Psychology*, 31(4), 568-578.
- Linton, M. (1982). Transformations of memory in everyday life. In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 77-91).
- Lo, J. C., Sim, S. K., & Chee, M. W. (2014). Sleep reduces false memory in healthy older adults. *Sleep*, 37(4), 665-671.
- Lofft, K. v. Lofft, D. (1989). Complaint for Damages. (Case No. 617151, Superior Court of the State of California for County of San Diego)
- Loftus, E. F. (1975). Leading questions and the eyewitness report. *Cognitive psychology*, 7(4), 560-572.

- Loftus, E. F. (1980). Impact of expert psychological testimony on the unreliability of eyewitness identification. *Journal of Applied Psychology*, 65(1), 9-15.
- Loftus, E. F. (1993). The reality of repressed memories. *American psychologist*, 48(5), 518-537.
- Loftus, E. F. (2003). Make-believe memories. *American Psychologist*, 58(11), 867-873.
- Loftus, E. F., & Palmer, J. C. (1974). Reconstruction of automobile destruction: An example of the interaction between language and memory. *Journal of verbal learning and verbal behavior*, 13(5), 585-589.
- Loftus, E. F., & Pickrell, J. E. (1995). The formation of false memories. *Psychiatric annals*, 25(12), 720-725.
- Loftus, E. F., Feldman, J., & Dashiell, R. (1995). The reality of illusory memories. *Memory distortion: How minds, brains, and societies reconstruct the past*, 47-68.
- Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of experimental psychology: Human learning and memory*, 4(1), 19-31.
- Loftus, E. F., Weingardt, K., & Hoffman, H. (1993). Sleeping memories on trial: Reactions to memories that were previously repressed. *Expert Evidence*, 2(2), 51-59.
- Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and hearing*, 19(1), 1-36.
- MacDougall, R. (1904). Recognition and recall. *The Journal of Philosophy, Psychology and Scientific Methods*, 1(9), 229-233.
- Macnish, R. (1834). *The philosophy of sleep*. D. Appleton & Company.
- Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological review*, 87(3), 252-271.

- Marshall, L., Helgadóttir, H., Mölle, M., & Born, J. (2006). Boosting slow oscillations during sleep potentiates memory. *Nature*, *444*(7119), 610-613.
- Mather, M., Henkel, L. A., & Johnson, M. K. (1997). Evaluating characteristics of false memories: Remember/know judgments and memory characteristics questionnaire compared. *Memory & Cognition*, *25*(6), 826-837.
- Maylor, E. A., & Mo, A. (1999). Effects of study-test modality on false recognition. *British Journal of Psychology*, *90*(4), 477-493.
- McCloskey, M., & Zaragoza, M. (1985). Misleading postevent information and memory for events: Arguments and evidence against memory impairment hypotheses. *Journal of Experimental Psychology: General*, *114*(1), 1-16.
- McDermott, K. B. (1996). The persistence of false memories in list recall. *Journal of Memory and Language*, *35*(2), 212-230.
- McDermott, K. B. (1997). Priming on perceptual implicit memory tests can be achieved through presentation of associates. *Psychonomic Bulletin & Review*, *4*(4), 582-586.
- McDermott, K. B., & Watson, J. M. (2001). The rise and fall of false recall: The impact of presentation duration. *Journal of Memory and Language*, *45*(1), 160-176.
- McEvoy, C. L., Nelson, D. L., & Komatsu, T. (1999). What is the connection between true and false memories? The differential roles of interitem associations in recall and recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*(5), 1177-1194.
- McKeon, S., Pace-Schott, E. F., & Spencer, R. M. (2012). Interaction of sleep and emotional content on the production of false memories. *PloS one*, *7*(11), e49353.

- Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of experimental psychology*, 90(2), 227-234.
- Miller, G. (1956). Human memory and the storage of information. *IRE Transactions on Information Theory*, 2(3), 129-137.
- Monds, L. A., Paterson, H. M., & Kemp, R. I. (2017). Do emotional stimuli enhance or impede recall relative to neutral stimuli? An investigation of two “false memory” tasks. *Memory*, 25(8), 945-952.
- Neisser, U. (1982). Snapshots or benchmarks. *Memory observed: Remembering in natural contexts*, 43-48.
- Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. *Behavior Research Methods, Instruments, & Computers*, 36(3), 402-407.
- Nelson, D. L., Reed, V. S., & McEvoy, C. L. (1977). Learning to order pictures and words: A model of sensory and semantic encoding. *Journal of Experimental Psychology: human learning and memory*, 3(5), 485-497.
- Neuschatz, J. S., Benoit, G. E., & Payne, D. G. (2003). Effective warnings in the Deese-Roediger-McDermott false-memory paradigm: The role of identifiability. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29(1), 35.
- Nicole D. Anderson, et al. (2018). When Gist and Familiarity Collide: Evidence from False Recognition in Younger and Older Adults. *Journals of Gerontology: Psychological Sciences*, 00(0), 1-6.
- Norman, K. A., & Schacter, D. L. (1997). False recognition in younger and older adults: Exploring the characteristics of illusory memories. *Memory & Cognition*, 25(6), 838-848.

- Oldenberg, D. (1991). Dark memories: Adults confront their childhood abuse. *Washington Post*.
- Paivio, A. (1967). Paired-associate learning and free recall of nouns as a function of concreteness, specificity, imagery, and meaningfulness. *Psychological Reports*, 20(1), 239-245.
- Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of experimental psychology*, 76(1p2), 1.
- Pardilla-Delgado, E., & Payne, J. D. (2017). The impact of sleep on true and false memory across long delays. *Neurobiology of learning and memory*, 137, 123-133.
- Pavio, A. (1971). Imagery and verbal processes. New York: Holt, Rinehart, & Winston.
- Payne, D. G., Elie, C. J., Blackwell, J. M., & Neuschatz, J. S. (1996). Memory illusions: Recalling, recognizing, and recollecting events that never occurred. *Journal of Memory and Language*, 35(2), 261-285.
- Payne, D. G., Tolia, M. P., & Anastasi, J. S. (1994). Recognition performance level and the magnitude of the misinformation effect in eyewitness memory. *Psychonomic Bulletin & Review*, 1(3), 376-382.
- Payne, J. D. (2011). Sleep on it! stabilizing and transforming memories during sleep. *Nature Neuroscience*, 14(3), 272.
- Payne, J. D., Schacter, D. L., Propper, R. E., Huang, L. W., Wamsley, E. J., Tucker, M. A., ... & Stickgold, R. (2009). The role of sleep in false memory formation. *Neurobiology of learning and memory*, 92(3), 327-334.
- Payne, J. D., Stickgold, R., Swanberg, K., & Kensinger, E. A. (2008). Sleep preferentially enhances memory for emotional components of scenes. *Psychological Science*, 19(8), 781-788.
- Payne, J.D., Ellenbogen, J.M., Walker, & Stickgold, R. (2008). The role of sleep in memory consolidation. In *Learning and memory: A comprehensive reference*. New York: Elsevier.

- Percer, J. M., & Roediger III, H. L. (2001). Modality effects in false recall and false recognition. *Learning, Memory, 27*(2), 339-353.
- Pezdek, K., & Lam, S. (2007). What research paradigms have cognitive psychologists used to study “false memory,” and what are the implications of these choices? *Consciousness and cognition, 16*(1), 2-17.
- Plihal, Werner, and Jan Born. (1997). Effects of early and late nocturnal sleep on declarative and procedural memory. *Journal of cognitive neuroscience, 9*,4 534-547.
- Pope, H. G., Hudson, J. I., Bodkin, J. A., & Oliva, P. (1998). Questionable validity of dissociative amnesia in trauma victims. Evidence from prospective studies. *The British Journal of Psychiatry, 172*(3), 210-215.
- Porter, S., Yuille, J. C., & Lehman, D. R. (1999). The nature of real, implanted, and fabricated memories for emotional childhood events: implications for the recovered memory debate. *Law and human behavior, 23*(5), 517-537.
- Posner, M. I., Snyder, C. R. (1975). Attention and cognitive control. In R.L. Soloso (Ed.) *Information processing and cognition: The Loyola Symposium*. Hillsdale, NJ: Erlbaum.
- Postman, L. (1963). One-trial learning. In *Conference on Verbal Learning and Verbal Behavior, 2nd, Jun, 1961, Ardsley-On-Hudson, NY, US*. McGraw-Hill Book Company.
- Reyna, V. F. (1995). Interference effects in memory and reasoning. *Interference and inhibition in cognition, 29-59*.
- Reyna, V. F. (1996). Repetition dissociates verbatim and gist memory for narratives. In *37th Annual Meeting of the Psychonomic Society, Chicago*.
- Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: An interim synthesis. *Learning and individual Differences, 7*(1), 1-75.

- Reyna, V. F., & Brainerd, C. J. (1998). Fuzzy-trace theory and false memory: New frontiers. *Journal of experimental child psychology*, 71(2), 194-209.
- Reyna, V. F., & Kiernan, B. (1994). Development of gist versus verbatim memory in sentence recognition: Effects of lexical familiarity, semantic content, encoding instructions, and retention interval. *Developmental Psychology*, 30(2), 178-191.
- Rhodes, M. G., & Anastasi, J. S. (2000). The effects of a levels-of-processing manipulation on false recall. *Psychonomic Bulletin & Review*, 7(1), 158-162.
- Ritter, M. (1991, June 30). Sudden recall of forgotten crimes is a puzzler for juries, experts say. *Los Angeles Times*, -p. A10.
- Roediger III, H. L. (1996). Memory illusions. *Journal of memory and Language*, 35(2), 76-100.
- Roediger III, H. L., & McDermott, K. B. (2000). Tricks of memory. *Current Directions in Psychological Science*, 9(4), 123-127.
- Roediger III, H. L., Balota, D. A., & Watson, J. M. (2001). Spreading activation and arousal of false memories. *The nature of remembering: Essays in honor of Robert G. Crowder*, 95-115.
- Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American psychologist*, 45(9), 1043-1056.
- Roediger, H. L. III, Balota, D. A., & Watson, J. M. (2001). Spreading activation and arousal of false memories. In H. L. Roediger III, J. S. Nairne, I. Neath, & A. M. Surprenant (Eds.), *Science conference series. The nature of remembering: Essays in honor of Robert G. Crowder* (p. 95–115). American Psychological Association.
- Roediger, H. L., & Gallo, D. A. (2003). Processes affecting accuracy and distortion in memory: An overview. *Memory and suggestibility in the forensic interview*, 3-28.

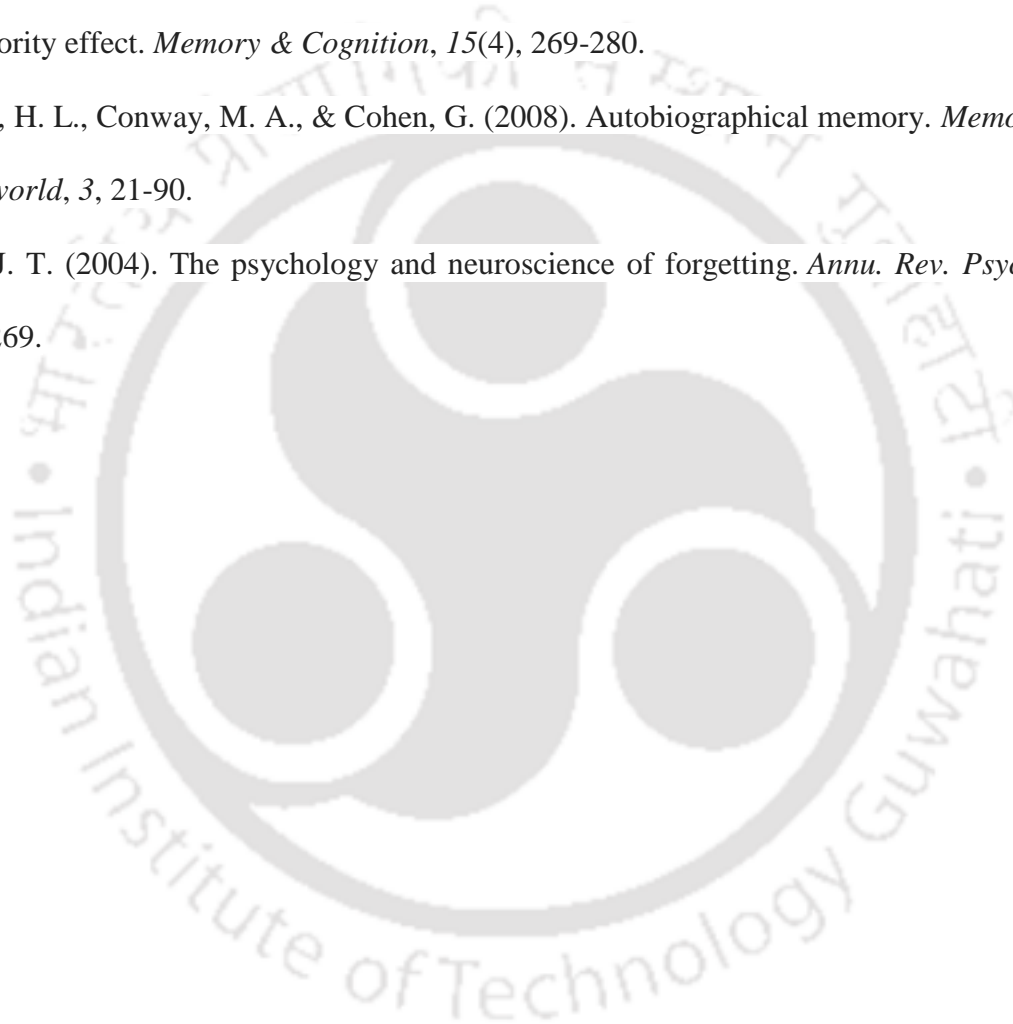
- Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of experimental psychology: Learning, Memory, and Cognition*, 21(4), 803-814.
- Roediger, H. L., & Payne, D. G. (1985). Recall criterion does not affect recall level or hypermnesia: A puzzle for generate/recognize theories. *Memory & Cognition*, 13(1), 1-7.
- Roediger, H. L., Watson, J. M., McDermott, K. B., & Gallo, D. A. (2001). Factors that determine false recall: A multiple regression analysis. *Psychonomic Bulletin & Review*, 8(3), 385-407.
- Sachs, J. S. (1967). Recognition memory for syntactic and semantic aspects of connected discourse. *Attention, Perception, & Psychophysics*, 2(9), 437-442.
- Sadler, D. D., Sodmont, S. M., & Keefer, L. A. (2018). Can false memory for critical lures occur without conscious awareness of list words? *Consciousness and Cognition*, 58, 136-157.
- Saraiva, M., Albuquerque, P. B., & Arantes, J. (2017). Production of false memories in collaborative memory tasks using the DRM paradigm. *Psicológica*, 38(2), 209-229.
- Schabus, M., Gruber, G., Parapatics, S., Sauter, C., Klösch, G., Anderer, P., ... & Zeitlhofer, J. (2004). Sleep spindles and their significance for declarative memory consolidation. *Sleep*, 27(8), 1479-1485.
- Schacter, D. (1987). Implicit memory: history and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13, 501-518.
- Schacter, D. L., & Curran, T. (1995). The cognitive neuroscience of false memories. *Psychiatric Annals*, 25(12), 726-730.
- Schacter, D. L., Cendan, D. L., Dodson, C. S., & Clifford, E. R. (2001). Retrieval conditions and false recognition: Testing the distinctiveness heuristic. *Psychonomic Bulletin & Review*, 8(4), 827-833.

- Schacter, D. L., Israel, L., & Racine, C. (1999). Suppressing false recognition in younger and older adults: The distinctiveness heuristic. *Journal of Memory and Language*, 40(1), 1-24.
- Schacter, D. L., Verfaellie, M., & Pradere, D. (1996). The neuropsychology of memory illusions: False recall and recognition in amnesic patients. *Journal of Memory and Language*, 35(2), 319-334.
- Seamon, J. G., Luo, C. R., & Gallo, D. A. (1998). Creating false memories of words with or without recognition of list items: Evidence for nonconscious processes. *Psychological Science*, 9(1), 20-26.
- Seamon, J. G., Luo, C. R., Schlegel, S. E., Greene, S. E., & Goldenberg, A. B. (2000). False memory for categorized pictures and words: The category associates procedure for studying memory errors in children and adults. *Journal of Memory and Language*, 42(1), 120-146.
- Shiffrin, R. M., Huber, D. E., & Marinelli, K. (1995). Effects of category length and strength on familiarity in recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21(2), 267-287.
- Smith, C. (2001). Sleep states and memory processes in humans: procedural versus declarative memory systems. *Sleep medicine reviews*, 5(6), 491-506.
- Smith, R. E., & Hunt, R. R. (1998). Presentation modality affects false memory. *Psychonomic Bulletin & Review*, 5(4), 710-715.
- Smith, S. M., Gerkens, D. R., Pierce, B. H., & Choi, H. (2002). The roles of associative responses at study and semantically guided recollection at test in false memory: The Kirkpatrick and Deese hypotheses. *Journal of Memory and Language*, 47(3), 436-447.
- Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: applications to dementia and amnesia. *Journal of Experimental Psychology: General*, 117(1), 34.

- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of experimental psychology: Human learning and memory*, 6(2), 174-215.
- Sommers, M. S., & Lewis, B. P. (1999). Who really lives next door: Creating false memories with phonological neighbors. *Journal of Memory and Language*, 40(1), 83-108.
- Squire, L. R., Knowlton, B., & Musen, G. (1993). The structure and organization of memory. *Annual review of psychology*, 44(1), 453-495.
- Stadler, M. A., Roediger, H. L., & McDermott, K. B. (1999). Norms for word lists that create false memories. *Memory & Cognition*, 27(3), 494-500.
- Sterpenich, V., Albouy, G., Boly, M., Vandewalle, G., Darsaud, A., Balteau, E., ... & Rauchs, G. (2007). Sleep-related hippocampo-cortical interplay during emotional memory recollection. *PLoS biology*, 5(11), e282.
- Sterpenich, V., Albouy, G., Darsaud, A., Schmidt, C., Vandewalle, G., Vu, T. T. D., ... & Collette, F. (2009). Sleep promotes the neural reorganization of remote emotional memory. *Journal of Neuroscience*, 29(16), 5143-5152.
- Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature*, 437(7063), 1272-1278.
- Strack, F., & Bless, H. (1994). Memory for nonoccurrences: Metacognitive and presuppositional strategies. *Journal of Memory and Language*, 33(2), 203-217.
- Sulin, R. A., & Dooling, D. J. (1974). Intrusion of a thematic idea in retention of prose. *Journal of Experimental Psychology*, 103(2), 255-262.
- Sun, R., Merrill, E., & Peterson, T. (2001). From implicit skills to explicit knowledge: A bottom-up model of skill learning. *Cognitive science*, 25(2), 203-244.

- Thapar, A., & McDermott, K. B. (2001). False recall and false recognition induced by presentation of associated words: Effects of retention interval and level of processing. *Memory & Cognition*, 29(3), 424-432.
- Toglia, M. P. (1999). Recall accuracy and illusory memories: When more is less. *Memory*, 7(2), 233-256.
- Toglia, M. P., & Battig, W. F. (1978). *Handbook of semantic word norms*. Hillsdale, NJ: Erlbaum.
- Toglia, M. P., & Neuschatz, J. S. (1996). False memories: Where does encoding opportunity fit into the equation. In *Poster presented at the 37th Annual Meeting of the Psychonomic Society, Chicago*.
- Toglia, M. P., Neuschatz, J. S., & Goodwin, K. A. (1999). Recall accuracy and illusory memories: When more is less. *Memory*, 7(2), 233-256.
- Tulving, E. (1972). Episodic and semantic memory. *Organization of memory*, 1, 381-403.
- Tulving, E. (1974). Cue-dependent forgetting: When we forget something we once knew; it does not necessarily mean that the memory trace has been lost; it may only be inaccessible. *American Scientist*, 62(1), 74-82.
- Tulving, E. (1985). Memory and consciousness. *Canadian Psychology*, 26(1), 1-12.
- Underwood, B. J. (1965). False recognition produced by implicit verbal responses. *Journal of experimental psychology*, 70(1), 122-129.
- Verma, K., & Kashyap, N. (2019). Sleep Deprivation Enhances False Memory on the Deese-Roediger-McDermott (DRM) Task. *Psychological Thought*, 12(1), 120-130.
- Wagner, U., Kashyap, N., Diekelmann, S., & Born, J. (2007). The impact of post-learning sleep vs. wakefulness on recognition memory for faces with different facial expressions. *Neurobiology of learning and memory*, 87(4), 679-687.

- Watkins, M. J., & Gardiner, J. M. (1979). An appreciation of generate-recognize theory of recall. *Journal of Verbal Learning and Verbal Behavior*, 18(6), 687-704.
- Watters, E. (1991). The devil in Mr. Ingram. *Mother Jones*, July—August, 65-68.
- Waugh, N. C., & Norman, D. A. (1965). Primary memory. *Psychological review*, 72(2), 89-104.
- Weldon, M. S., & Roediger, H. L. (1987). Altering retrieval demands reverses the picture superiority effect. *Memory & Cognition*, 15(4), 269-280.
- Williams, H. L., Conway, M. A., & Cohen, G. (2008). Autobiographical memory. *Memory in the real world*, 3, 21-90.
- Wixted, J. T. (2004). The psychology and neuroscience of forgetting. *Annu. Rev. Psychol.*, 55, 235-269.



Appendices

The logo of the Indian Institute of Technology Guwahati is a circular emblem. It features a central stylized figure with three rounded protrusions, resembling a traditional Indian motif. The text "Indian Institute of Technology Guwahati" is written in English around the bottom half of the circle, and "भारतीय प्रौद्योगिकी संस्थान गुवाहाटी" is written in Hindi around the top half. The logo is rendered in a light gray color.

Appendix A

Questionnaires used in the Study

INFORMED CONSENT FORM

We invite you to take part in a research study at the Sleep and Cognition Laboratory, IIT Guwahati. The purpose of research is to analyze the memory performance. The research will conduct by Kedarmal Verma, a Research Scholar at the Department of HSS, under the guidance of Dr. Naveen Kashyap, Associate Professor, HSS Department IITG.

Information to the Participants

The experiment is to investigating the memory functioning of the brain. In this experiment, you have to sleep or wake for whole night. During sleep, we would place few electrodes on your scalp to get your brain signals. This technique is completely non-invasive as it does not use any external stimuli like current etc. and it does not have any harmful effect on the participant's skin and brain. The entire electrode placement procedure would take approximately 30 minutes and then you have to sleep or wake for whole night. For psychological task, subject response would be acquired using a computer keyboard. Sleep would be monitored by polysmith and video EEG. The results obtained from the study would be kept confidential.

The monetary support and course credits would be provided to the participants depending on the experiment they participating in. 300 INR would be awarded per night to every participant on the completion of their participation.

Undertaking by the investigator

You are requested to participate in the above-mentioned study and your consent for the same is sought. The information you provide will be kept confidential. The data will not identify you in any way. Your taking part in the study is voluntary. You may or may not benefit from taking part in this study. You have the right to refuse consent or withdraw the same during any part of the study without giving any reason. If you have any doubts about the study, please feel free to clarify the same. You are free to contact the investigator and guide, for any further clarification or assistance if you need.

Consent

“I have been informed about the procedure used in the study. I understand that the information I provide will be kept strictly confidential, data will not identify me in any way and if needed. I have been informed that I will not receive any direct benefit for participating in this study and that I have the right to refuse my consent or withdraw it anytime during the study without giving any reason. I

am aware that by participating in this study, I will have to give time to the investigator for assessment.”

I,the undersigned, give my consent to be a participant in this study.”

Signature of the participant

Name: -

Hostel Address-

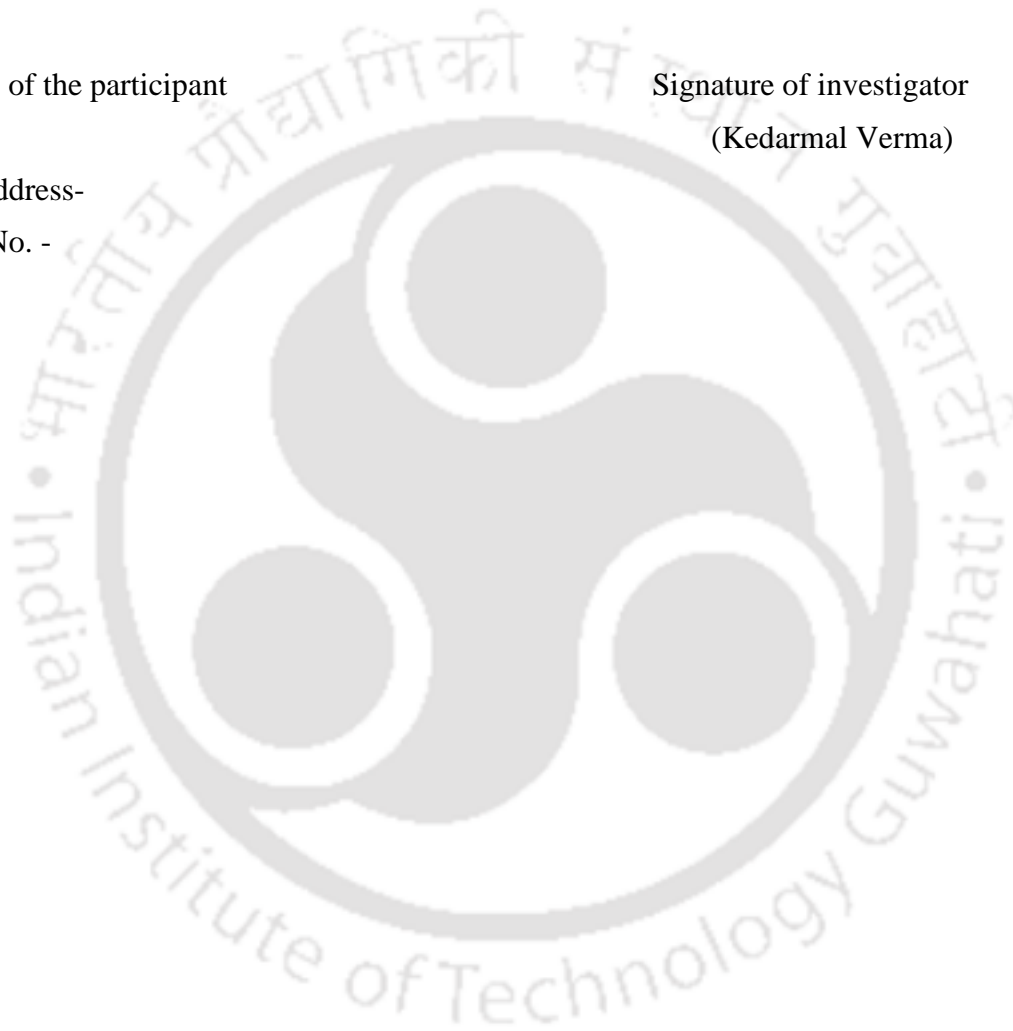
Contact No. -

Place:

Date:

Signature of investigator

(Kedarmal Verma)



GENERAL QUESTIONNAIRE

Name:

Age:

Gender:

Occupation/Academic:

Handedness: Left / Right

Spectacles: Yes / No

Non Smoker: Yes / No

At what time in the evening do you normally go to bed?

How many hours of sleep in the night do you have normally?.....

Do you sleep during the day? (If yes when, how many hours)

.....

Do you suffer from Chronic
Illness?.....

Do you suffer from Chronic
Allergies?.....

Do you suffer from any clinical sleep disorder at present or in the past?.....

Do you suffer from any endocrinological, neurological or psychiatric illness at present or in the past?.....

Have you been a subject in a sleep experiment? (If yes when and with whom).....

Do you have partial health restriction? (If yes, what).....

Do you take any medications/Drugs?.....

Have you worked during the night 6 weeks prior to this day? (If yes When and how much).....

...

Did you take cola or coffee today afternoon? (If yes when and how much).....

Have been you undergoing special stress? (If yes, which and what exact).....

What time did you awake today Morning?.....

Did you sleep today in the afternoon? (If yes when and what length).....



DRUG USE QUESTIONNAIRE (DAST-20)

Name: _____

Case _____

Number: _____

Charges: _____

Test _____

Date: _____

Score: _____

Preliminary Comments

Adapted from language provided by Dr. Harvey Skinner (January 5, 2009)

The following questions concern your potential involvement with drugs other than alcohol. When you answer the questions, remember that the term “drug abuse” does not include alcohol. Instead, it refers to your use of prescribed or over the counter drugs in excess of the recommended dosage. For example, if you were given a prescription for pain killers, but took more than you were supposed to, that would be included. The phrase “drug abuse” also includes *any* non-medical drug use, including illegal drugs. This includes substances like marijuana, valium, cocaine, amphetamines, LSD, and heroin. Remember that the term “drug abuse” does not include alcohol. If you have difficulty with a statement, then choose the response that is mostly right.

Do you understand?

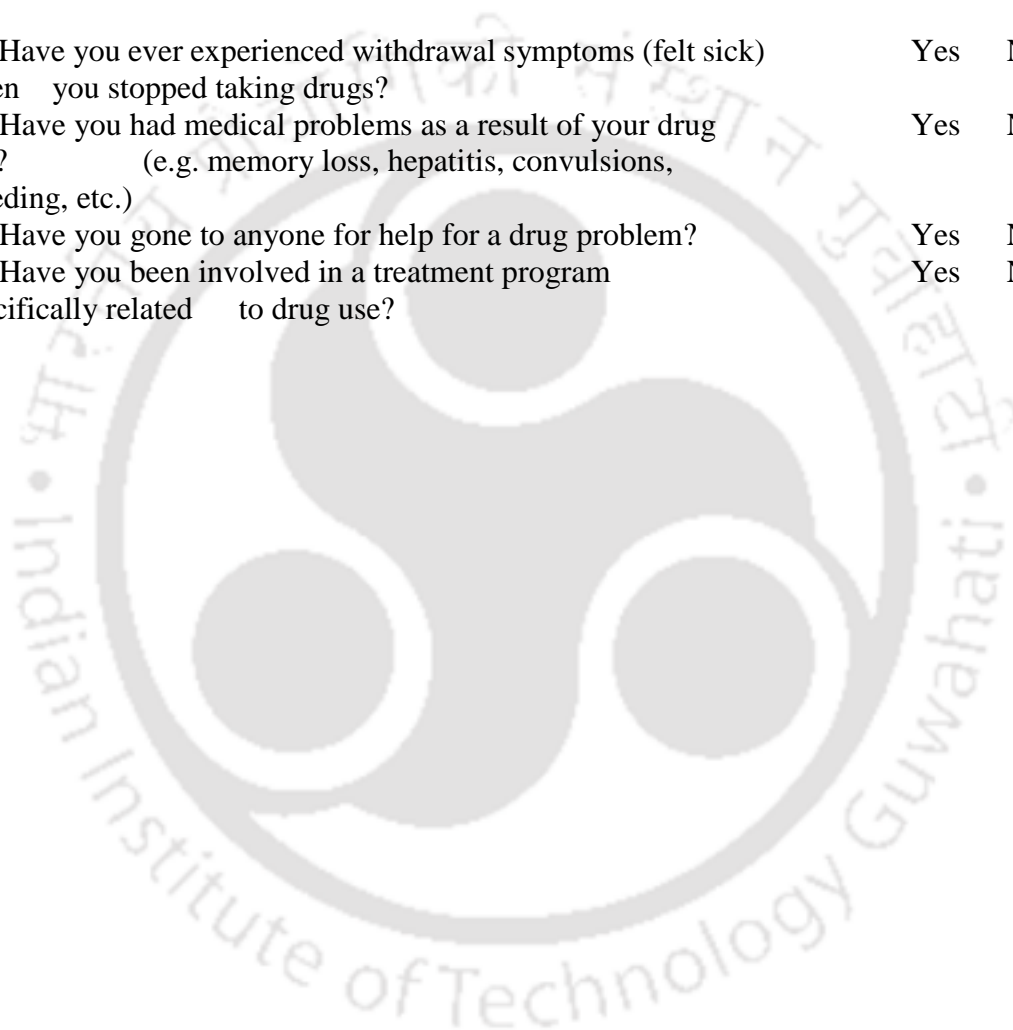
Questions

These questions refer to the past 12 months.

Circle the Response

- | | | |
|---|-----|----|
| 1. Have you used drugs other than those required for medical reasons? | Yes | No |
| 2. Have you abused prescription drugs? | Yes | No |
| 3. Do you abuse more than one drug at a time? | Yes | No |
| 4. Can you get through the week without using drugs? | Yes | No |
| 5. Are you always able to stop using drugs when you want to? | Yes | No |
| 6. Have you had “blackouts” or “flashbacks” as a result of drug use? | Yes | No |
| 7. Do you ever feel bad or guilty about your drug use? | Yes | No |
| 8. Does your spouse (or parents) ever complain about your involvement with drugs? | Yes | No |
| 9. Has drug abuse created problems between you and your spouse or your parents? | Yes | No |

- | | | |
|--|-----|----|
| 10. Have you lost friends because of your use of drugs? | Yes | No |
| 11. Have you neglected your family because of your use of drugs? | Yes | No |
| 12. Have you been in trouble at work (or school) because of drug abuse? | Yes | No |
| 13. Have you lost your job because of drug abuse? | Yes | No |
| 14. Have you gotten into fights when under the influence of drugs? | Yes | No |
| 15. Have you engaged in illegal activities in order to obtain drugs? | Yes | No |
| 16. Have you been arrested for possession of illegal drugs? | Yes | No |
| 17. Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking drugs? | Yes | No |
| 18. Have you had medical problems as a result of your drug use? (e.g. memory loss, hepatitis, convulsions, bleeding, etc.) | Yes | No |
| 19. Have you gone to anyone for help for a drug problem? | Yes | No |
| 20. Have you been involved in a treatment program specifically related to drug use? | Yes | No |



MEMORY AND ATTENTION TEST

Memory test: You have to write the name of occupations in 1 minute

Attention Test: You have to write the 10 word starts with “A” but that would not be any Name. Word should not be any compound word. (limit 1 minute)

MOOD QUESTIONNAIRE

Subject Name:

Age:

Clock Time:

Tick [✓] in appropriate box

Report as according to your present feeling I feel the following way now

	Not at all				Very much
Sleepy					
Active					
Tense					
Tired					
Bored					
Motivated					
Concentrated					

THE EPWORTH SLEEPINESS SCALE

How Sleepy Are You?

How likely are you to doze off or fall asleep in the following situations? You should rate your chances of dozing off, not just feeling tired. Even if you have not done some of these things recently try to determine how they would have affected you. For each situation, decide whether or not you would have:

- No chance of dozing =0
- Slight chance of dozing =1
- Moderate chance of dozing =2
- High chance of dozing =3

Write down the number corresponding to your choice in the right hand column. Total your score below.

Situation	Chance of Dozing
Sitting and reading	•
Watching TV	•
Sitting inactive in a public place (e.g., a theater or a meeting)	•
As a passenger in a car for an hour without a break	•
Lying down to rest in the afternoon when circumstances permit	•
Sitting and talking to someone	•
Sitting quietly after a lunch without alcohol	•
In a car, while stopped for a few minutes in traffic	•

Total Score = _____

Subject's Initials _____ ID# _____ Date _____ Time _____ AM
PM

PITTSBURGH SLEEP QUALITY INDEX

INSTRUCTIONS:

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

BED TIME _____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES _____

3. During the past month, what time have you usually gotten up in the morning?

GETTING UP TIME _____

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT _____

For each of the remaining questions, check the one best response. Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you . . .

- a) Cannot get to sleep within 30 minutes

Not during the month _____ Less than once a week _____ Once or twice a week _____ Three or more past times a week _____

- b) Wake up in the middle of the night or early morning
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- c) Have to get up to use the bathroom
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- d) Cannot breathe comfortably
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- e) Cough or snore loudly
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- f) Feel too cold
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- g) Feel too hot
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- h) Had bad dreams
- | | | | |
|------------------------------|-------------------------------|------------------------------|---|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more past
times a week_____ |
|------------------------------|-------------------------------|------------------------------|---|
- i) Have pain
- | | | | | |
|------------------------------|-------------------------------|------------------------------|------------------------------------|------|
| Not during the
month_____ | Less than
once a week_____ | Once or twice
a week_____ | Three or more
times a week_____ | past |
|------------------------------|-------------------------------|------------------------------|------------------------------------|------|
- j) Other reason(s), please
describe_____
-

How often during the past month have you had trouble sleeping because of this?

Not during the month _____
 Less than once a week _____
 Once or twice a week _____
 Three or more past times a week _____

6. During the past month, how would you rate your sleep quality overall?

Very good _____

Fairly good _____

Fairly bad _____

Very bad _____

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the month _____
 Less than once a week _____
 Once or twice a week _____
 Three or more past times a week _____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the month _____
 Less than once a week _____
 Once or twice a week _____
 Three or more past times a week _____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all _____

Only a very slight problem _____

Somewhat of a problem _____

A very big problem _____

10. Do you have a bed partner or room mate?

No bed partner or room mate _____

Partner/room mate in other room _____

Partner in same room, but not same bed _____

Partner in same bed _____

If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .

- a) Loud snoring
- | | | | |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the
past month _____ | Less than
once a week _____ | Once or twice
a week _____ | Three or more
times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
- b) Long pauses between breaths while asleep
- | | | | |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the
past month _____ | Less than
once a week _____ | Once or twice
a week _____ | Three or more
times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
- c) Legs twitching or jerking while you sleep
- | | | | |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the
past month _____ | Less than
once a week _____ | Once or twice
a week _____ | Three or more
times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
- d) Episodes of disorientation or confusion during sleep
- | | | | |
|-------------------------------|--------------------------------|-------------------------------|--|
| Not during the
month _____ | Less than
once a week _____ | Once or twice
a week _____ | Three or more past
times a week _____ |
|-------------------------------|--------------------------------|-------------------------------|--|
- e) Other restlessness while you sleep; please describe _____

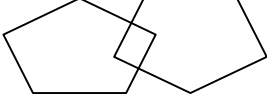
Not during the month _____	Less than once a week _____	Once or twice a week _____	Three or more past times a week _____
-------------------------------	--------------------------------	-------------------------------	--

Mini-Mental State Examination (MMSE)

Patient's Name: _____ Date: _____

Instructions: Ask the questions in the order listed. Score one point for each correct response within each question or activity.

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day of the week? Month?"
5		"Where are we now: State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: _____
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Stop after five answers. Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)

1		<p>“Please copy this picture.” (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)</p> 
30		TOTAL

(Adapted from Rovner & Folstein, 1987)





Appendix B

Equipment's Specification

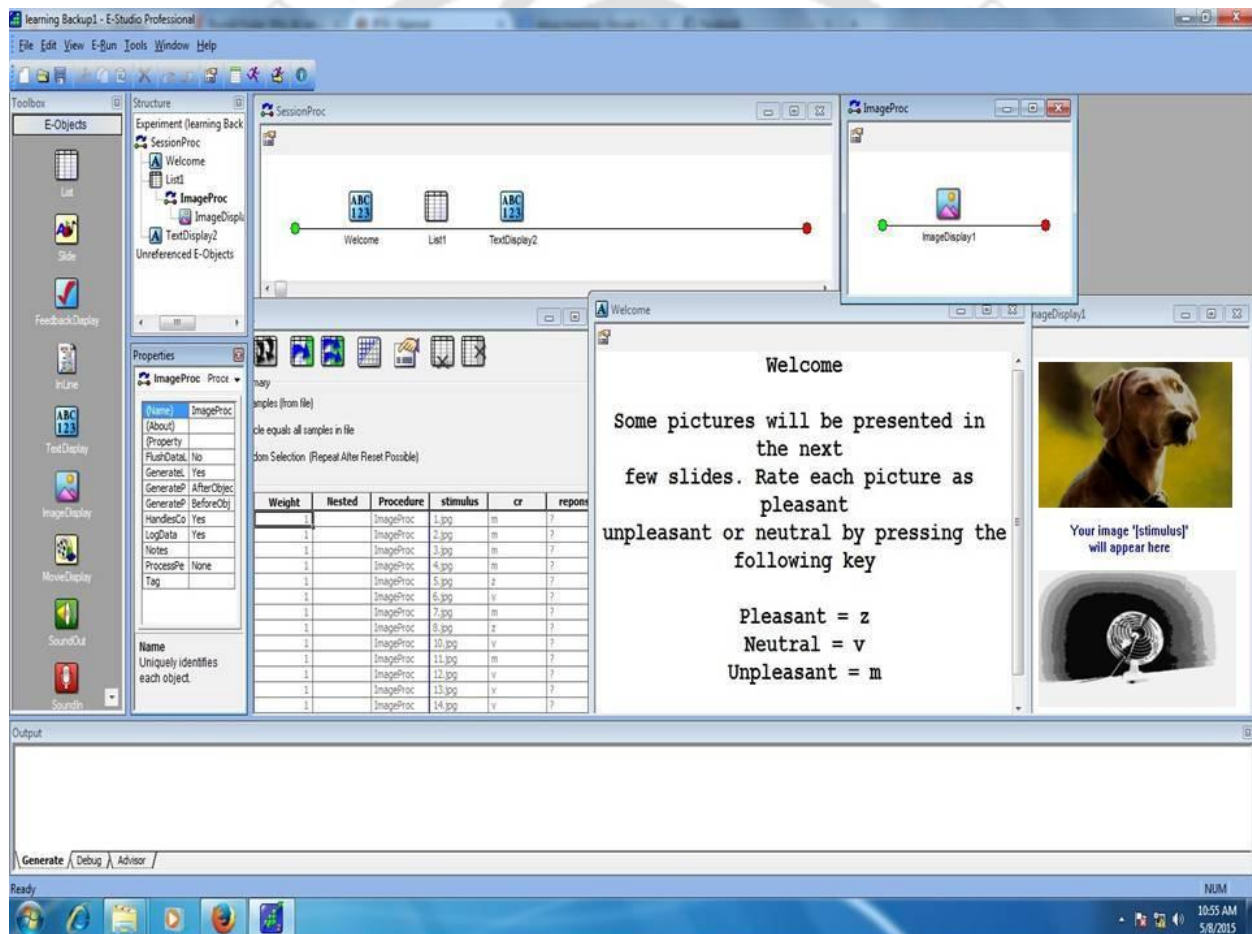
E-PRIME 2.0 PROFESSIONAL

E-Prime® is a software package which is used for the stimulus presentation in psychological and cognitive science experiments. This software system used to collect behavioral data and also helps in their analysis. It provides millisecond precision timing to ensure the accuracy of data.

E-Prime® has a good online support website: <http://www.pstnet.com/support/login.asp> , Here, you can find examples of different type of experiments, their problem solutions and frequently asked questions which helps you in resolving your query.

Following image is showing the main experimental page of E-Prime file.

Image 01:



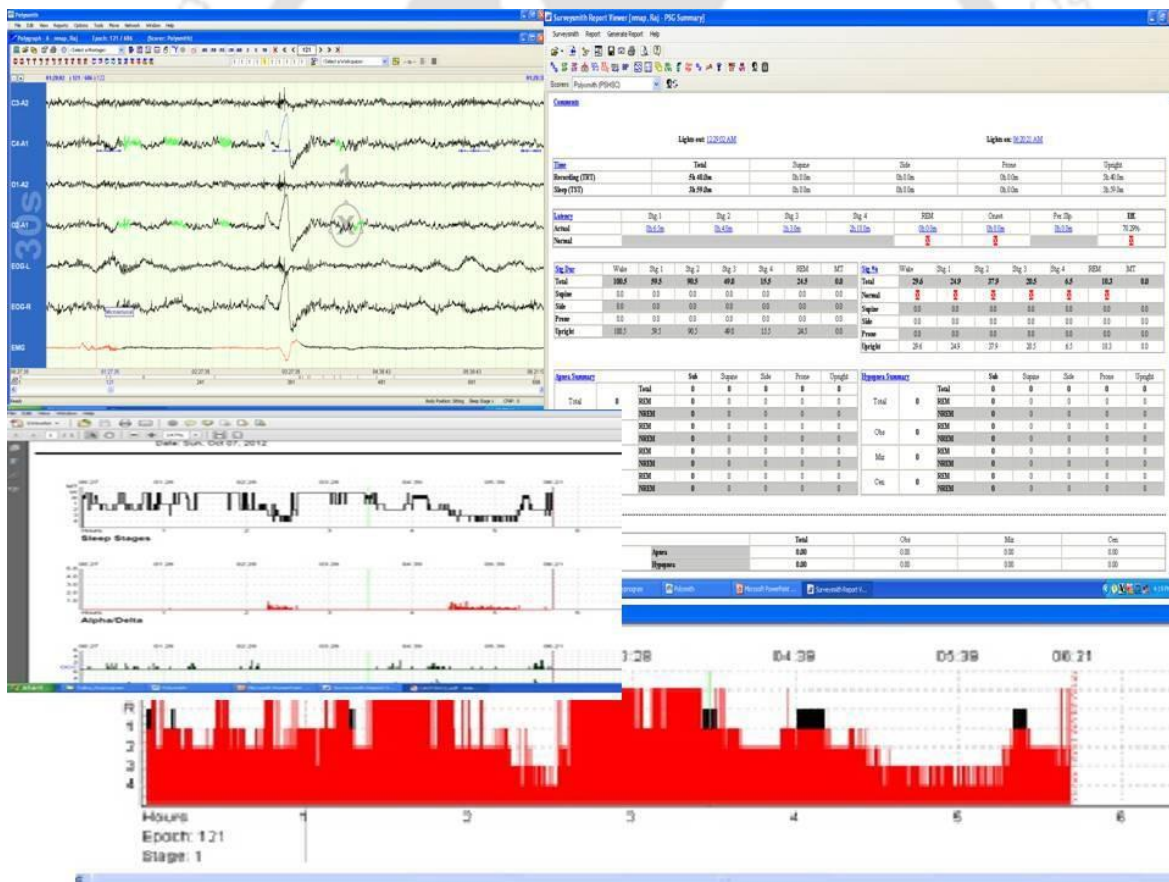
POLYSOMNOGRAPHIC TOOLS AND TECHNIQUE

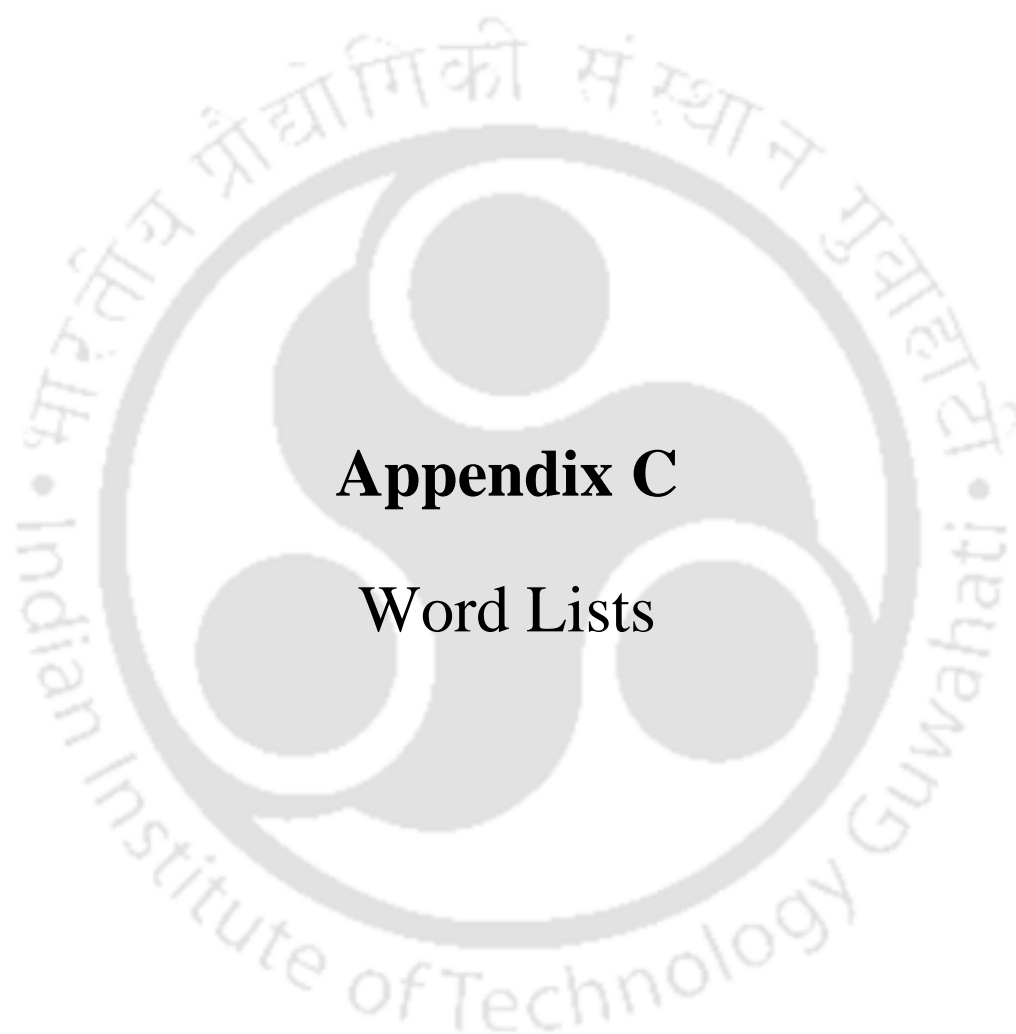
For the study of sleep, we were using *40 channel Nihon-Khoden* polysomnography system. This is sleep diagnostic system which records the sleep pattern of individuals.

This system serves as a digital electroencephalogram (EEG) and polygraph. With up to 44 channels (20 EEG/PSG inputs, 14 bipolar inputs, 10 DC inputs, and integrated SpO2 adapter connection) it is the ideal alternative for polysomnographic diagnostic recording. The scope of functions can be easily extended with optional add-ons, such as the latest generation of synchronous video recording. With integrated frequency and amplitude mapping, even the comprehensive standard software of our Neurofax series provides a range of functions which greatly exceeds the normal standard. The optional Polysmith™ software enables powerful, automated sleep analysis with report functionality.

Following image is showing the output data file of polysomnography.

Image 02:





Appendix C

Word Lists

Word Lists for DRM task

Total 10 word lists were adopted from previous literature database. All the words in each list are semantically associated to each other and arranged in their descending order of BAS (backward associative strength) value.

Group A Lists: These list items were used in *recall* group for day time experiments and in *sleep deprivation* for night experiments.

Word List 01
1. stream
2. flow
3. bridge
4. lake
5. boat
6. tide
7. swim
8. run
9. fish
10. water
Critical Lure: river

Word List 02
1. smooth
2. tough
3. rugged
4. bumpy
5. jagged
6. riders
7. uneven
8. road
9. sand
10. ground
Critical Lure: rough

Word List 03
1. blouse
2. collar
3. shorts
4. button
5. pants
6. polo
7. cuffs
8. tie
9. iron
10. linen
Critical Lure: shirt

Word List 04
1. fast
2. snail
3. turtle
4. sluggish
5. speed
6. delay
7. hesitant
8. traffic
9. wait
10. stop
Critical Lure: slow

Word List 05

1. cigar
2. cigarette
3. pipe
4. chimney
5. puff
6. lungs
7. ashes
8. fire
9. stink
10. flame

Critical Lure: **smoke**

Word List 06

1. hard
2. loud
3. pillow
4. cotton
5. skin
6. furry
7. touch
8. feather
9. kitten
10. light

Critical Lure: **soft**

Word List 07

1. web
2. creepy
3. bug
4. insect
5. fright
6. crawl
7. prison
8. bite
9. ugly
10. small

Critical Lure: **spider**

Word List 08

1. honey
2. bitter
3. sugar
4. sour
5. candy
6. taste
7. cake
8. good
9. heart
10. pie

Critical Lure: **sweet**

Word List 09

1. garbage
2. dump
3. litter
4. junk
5. waste
6. sewage
7. pile
8. scrape
9. refuse
10. bag

Critical Lure: **trash**

Word List 10

1. shutter
2. curtain
3. door
4. glass
5. view
6. shade
7. open
8. frame
9. house
10. breeze

Critical Lure: **window**

Group B Lists: These list items were used in *recognition* group for day time experiments and in *sleep* for night experiments.

Word List 01

1. rage
2. mad
3. enrage
4. fury
5. happy
6. wrath
7. hate
8. fight
9. fear
10. calm

Critical Lure: **anger**

Word List 02

1. navy
2. soldier
3. marines
4. draft
5. uniform
6. march
7. captain
8. war
9. pilot
10. combat

Critical Lure: **army**

Word List 03

1. white
2. gray
3. brown
4. coal
5. dark
6. color
7. funeral
8. blue
9. ink
10. death

Critical Lure: **black**

Word List 04

1. town
2. newyork
3. urban
4. county
5. state
6. street
7. village
8. big
9. crowd
10. subway

Critical Lure: **city**

Word List 05

1. saucer
2. mug
3. goblet
4. coaster
5. plastic
6. tea
7. coffee
8. straw
9. handle
10. drink

Critical Lure: **cup**

Word List 06

1. banner
2. stripe
3. pole
4. anthem
5. emblem
6. freedom
7. symbol
8. raised
9. sign
10. wave

Critical Lure: **flag**

Word List 07

1. toe
2. inch
3. ankle
4. shoe
5. sandal
6. sock
7. hand
8. boot
9. yard
10. kick

Critical Lure: **foot**

Word List 08

1. roar
2. tiger
3. fierce
4. den
5. cub
6. cage
7. jungle
8. bears
9. pride
10. Africa

Critical Lure: **lion**

Word List 09

1. woman
2. lady
3. handsome
4. male
5. person
6. suit
7. uncle
8. beard
9. muscle
10. strong

Critical Lure: **man**

Word List 10

1. pencil
2. marker
3. write
4. fountain
5. felt
6. scribble
7. cross
8. red
9. cap
10. letter

Critical Lure: **pen**




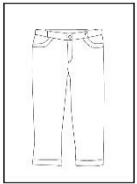

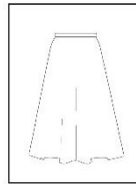



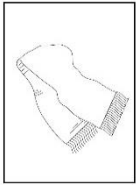





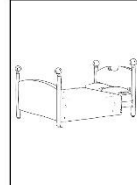






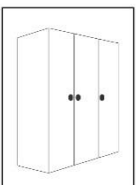



Appendix D

Category (Pictures) Lists

Picture Lists for CA task

Total 20 picture (simple line drawings) lists were adopted from previous literature database. All the pictures in each list are categorically associated with each other and arranged in the descending order of their frequency of availability.

Group A Lists: These list items were used in *recognition* group for day time experiments and in *sleep* for night experiments.

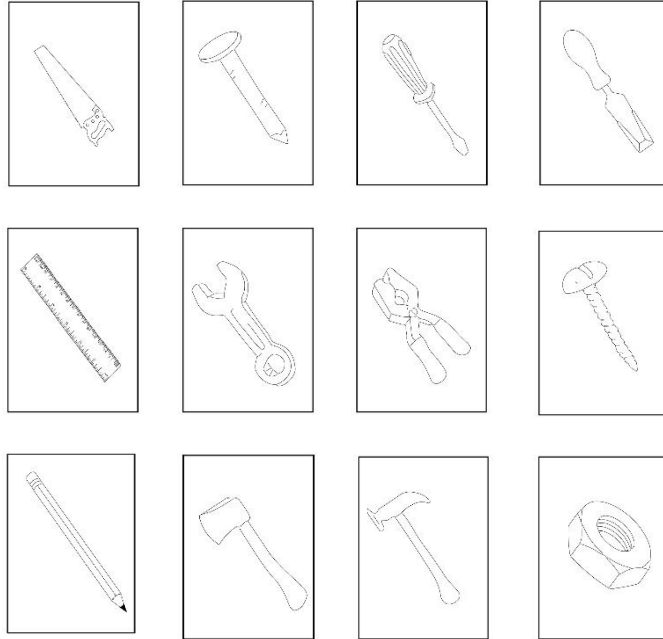
<p>Category List 01</p> <p>(Cloths)</p> <ol style="list-style-type: none"> 31. Socks 32. pant 33. shoe 34. skirt 35. sweater 36. gloves 37. belt 38. scarf 39. vest 40. bermuda <p>HF Critical Lure 01: shirt LF Critical Lure 02: raincoat</p>				
				
				
<p>Category List 02</p> <p>(Furniture)</p> <ol style="list-style-type: none"> 1. table 2. bed 3. sofa 4. desk 5. lamp 6. television 7. stool 8. bookcase 9. cupboard 10. chest <p>HF Critical Lure 01: chair LF Critical Lure 02: bench</p>				
				
				

Category List 03

(Carpenter Tool)

1. saw
2. nail
3. screwdriver
4. chisel
5. ruler
6. wrench
7. plier
8. screw
9. pencil
10. axe

HF Critical Lure 01: **hammer**
 LF Critical Lure 02: **nut**

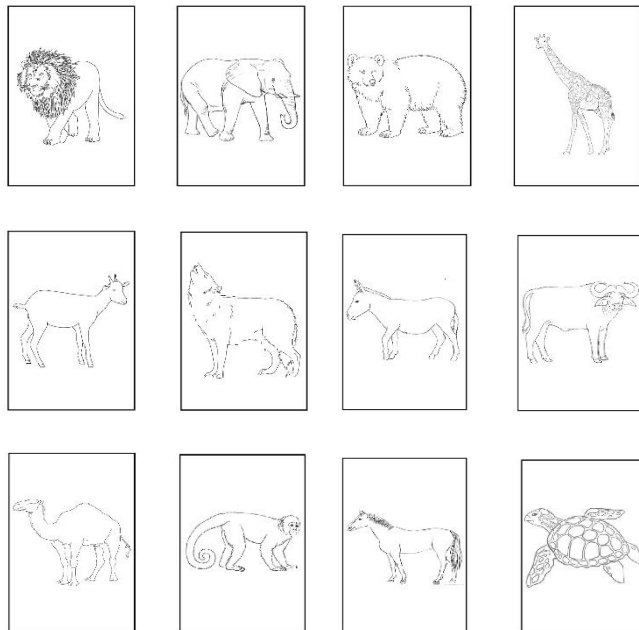


Category List 04

(Animals Four Footed)

1. lion
2. elephant
3. bear
4. giraffe
5. goat
6. wolf
7. donkey
8. buffalo
9. camel
10. monkey

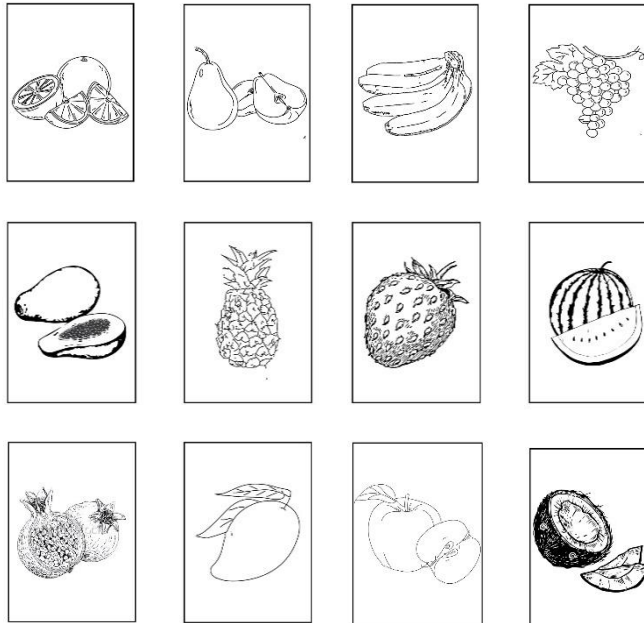
HF Critical Lure 01: **horse**
 LF Critical Lure 02: **turtle**



Category List 05**(Fruits)**

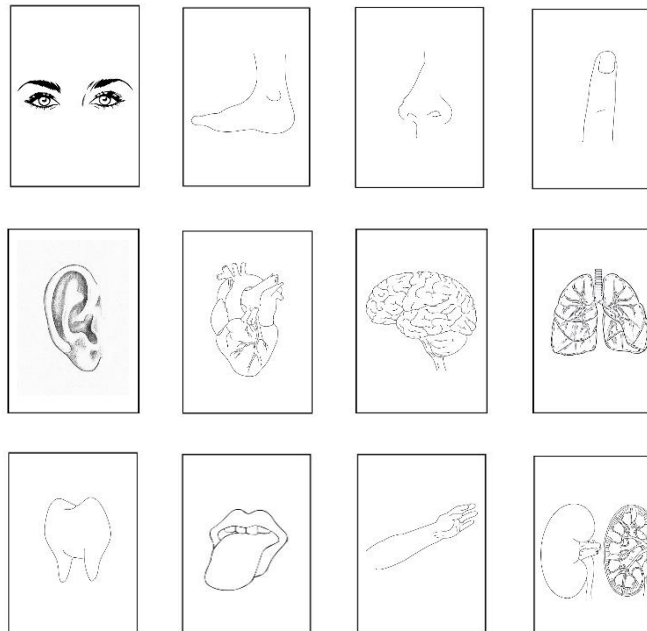
1. orange
2. pear.
3. banana
4. grapes
5. papaya
6. pineapple
7. strawberry
8. watermelon
9. pomegranate
10. mango

HF Critical Lure 01: **apple**
 LF Critical Lure 02: **coconut**

**Category List 06****(Human Body Parts)**

1. eyes
2. foot
3. nose
4. finger
5. ear
6. heart
7. brain
8. lungs
9. tooth
10. tongue

HF Critical Lure 01: **arm**
 LF Critical Lure 02: **kidney**



Category List 08

(Kitchen Utensils)

1. spoon
2. fork
3. stove
4. bowl
5. mixer
6. fryingpan
7. refrigerator
8. glass
9. oven
10. blender

HF Critical Lure 01: **knife**
 LF Critical Lure 02: **teapot**

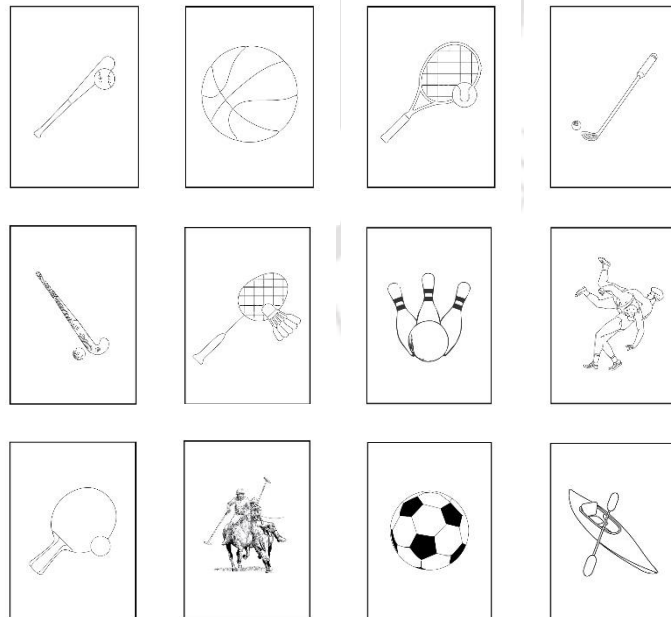


Category List 09

(Sports)

1. baseball
2. basketball
3. tennis
4. golf
5. hockey
6. badminton
7. bowling
8. wrestling
9. pingpong
10. polo

HF Critical Lure 01: **football**
 LF Critical Lure 02: **boating**

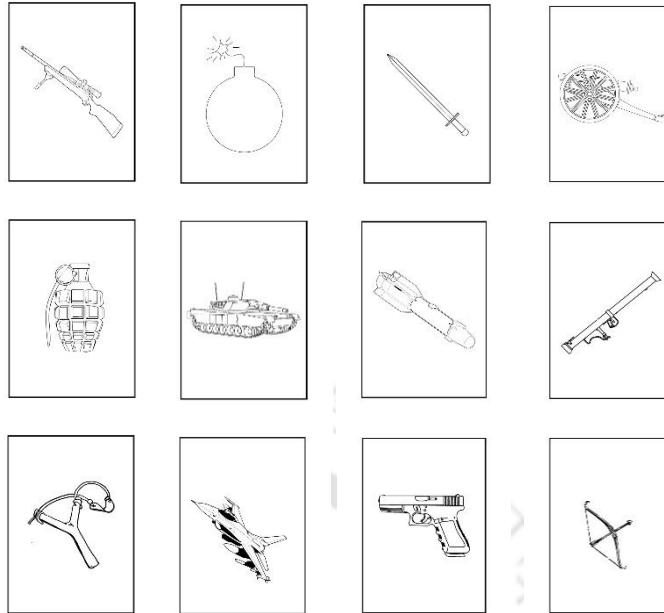


Category List 10**(Weapons)**

1. rifle
2. bomb
3. sword
4. cannon
5. grenade
6. tank
7. missile
8. bazooka
9. slingshot
10. airplane










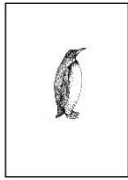


HF Critical Lure 01: **gun**

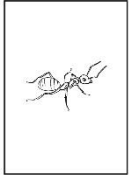

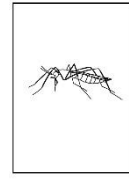


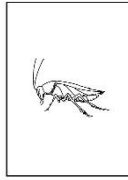
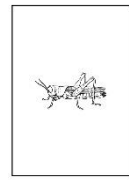


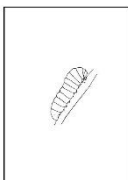
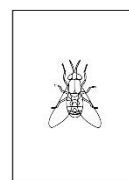

LF Critical Lure 02: **bow**

**Abbreviations:**

1. HF: High Frequency
2. LF: Low Frequency

Group B Lists: These list items were used in *recall* group for day time experiments and in *sleep deprivation* for night experiments.

<p style="text-align: center;">Category List 01</p> <p style="text-align: center;">(Birds)</p> <ol style="list-style-type: none"> 1. eagle 2. crow 3. parrot 4. pigeon 5. chicken 6. duck 7. owl 8. ostrich 9. peacock 10. penguin <p>HF Critical Lure 01: sparrow LF Critical Lure 02: swan</p>				
				
				

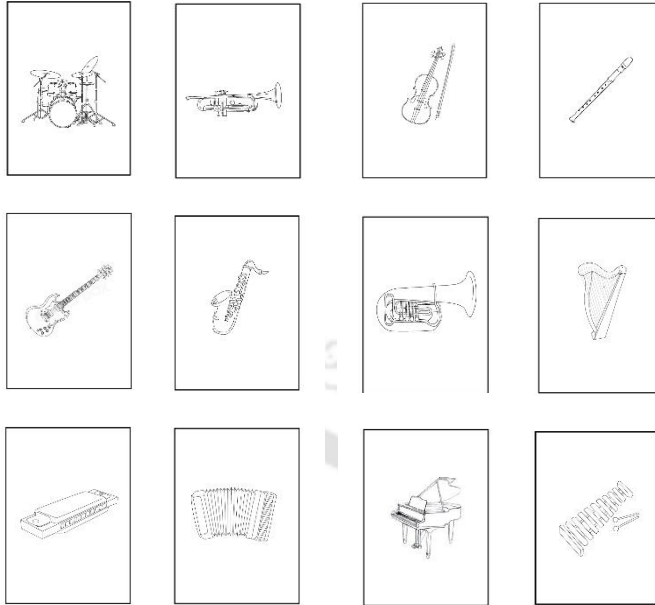
<p style="text-align: center;">Category List 02</p> <p style="text-align: center;">(Insects)</p> <ol style="list-style-type: none"> 1. ant 2. bee 3. mosquito 4. spider 5. beetle 6. cockroach 7. grasshopper 8. butterfly 9. termite 10. caterpillar <p>HF Critical Lure 01: housefly LF Critical Lure 02: centipede</p>				
				
				

Category List 03

(Musical Instruments)

1. drum
2. trumpet
3. violin
4. flute
5. guitar
6. saxophone
7. tuba
8. harp
9. harmonica
10. accordion

HF Critical Lure 01: **piano**
 LF Critical Lure 02: **xylophone**

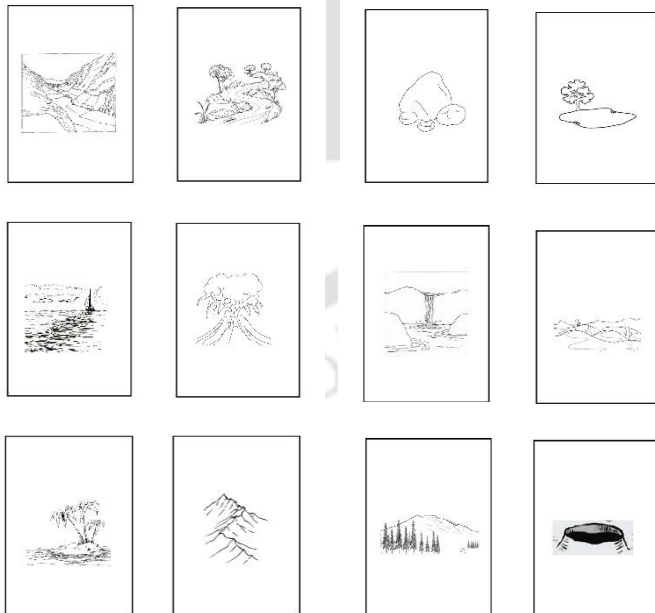


Category List 04

(Natural Earth Formation)

1. valley
2. river
3. rock
4. lake
5. ocean
6. volcano
7. waterfall
8. desert
9. island
10. ridge

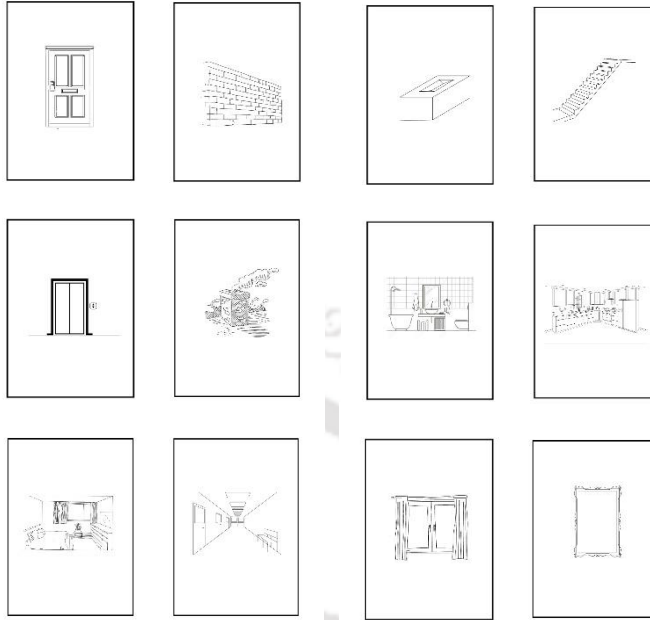
HF Critical Lure 01: **mountain**
 LF Critical Lure 02: **crater**



Category List 05
(Parts of Building)

1. door
2. wall
3. brick
4. stairs
5. elevator
6. chimney
7. bathroom
8. kitchen
9. bedroom
10. corridor

HF Critical Lure 01: **window**
LF Critical Lure 02: **frame**



Category List 06
(Profession)

1. lawyer
2. teacher
3. engineer
4. carpenter
5. plumber
6. scientist
7. farmer
8. policeman
9. fireman
10. electrician

HF Critical Lure 01: **doctor**
LF Critical Lure 02: **mailman**

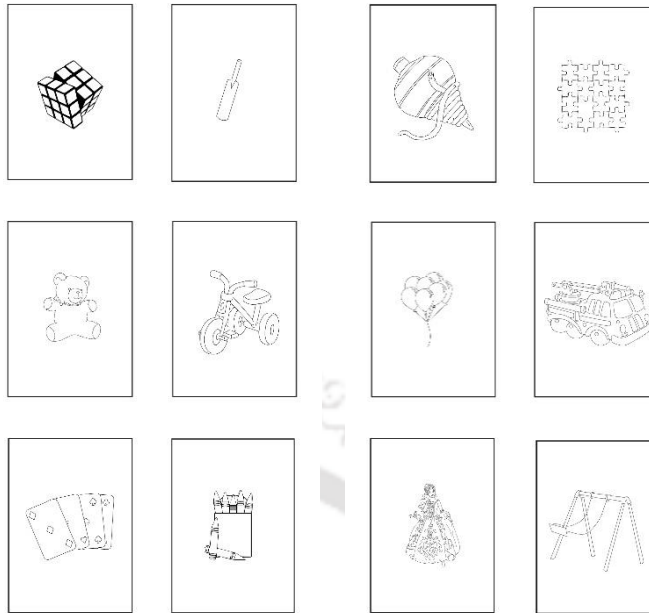


Category List 07

(Toys)

1. cube
2. bat
3. top
4. puzzle
5. teddybear
6. tricycle
7. balloon
8. fireengine
9. cards
10. crayons

HF Critical Lure 01: **doll**
 LF Critical Lure 02: **swing**

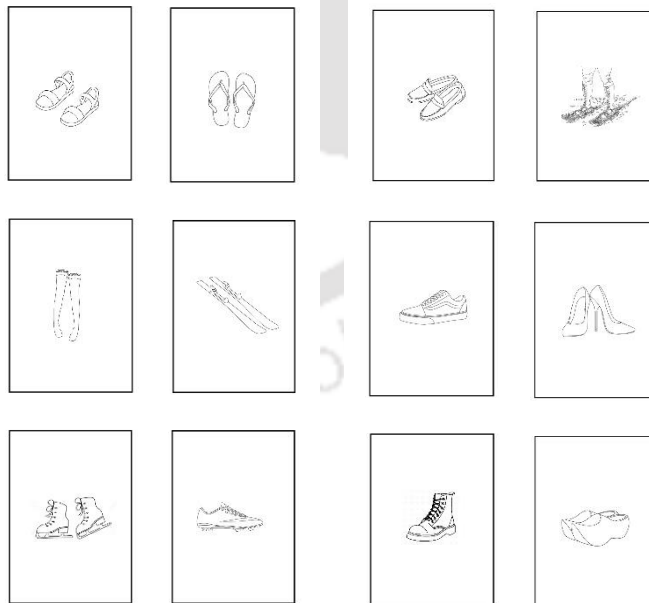


Category List 08

(Footwear Types)

1. sandals
2. slippers
3. loafers
4. snowshoes
5. stockings
6. skis
7. sneakers
8. heels
9. iceskates
10. cleats

HF Critical Lure 01: **boots**
 LF Critical Lure 02: **clogs**



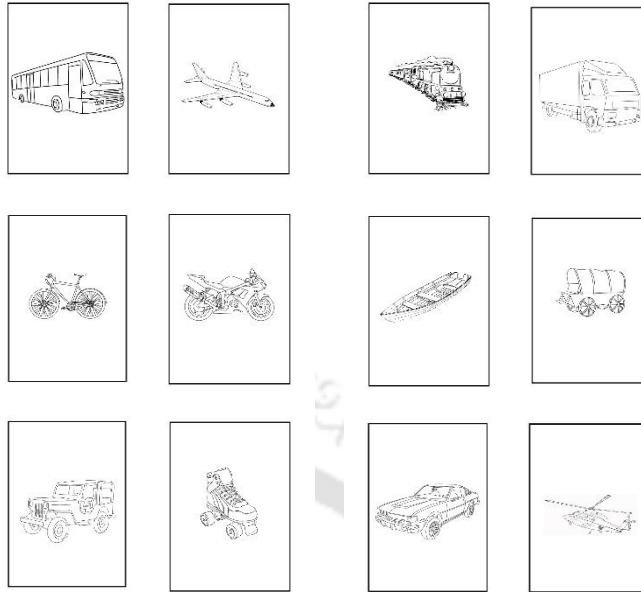
Category List 09

(Vehicle Types)

1. bus
2. airplane
3. train
4. truck
5. bicycle
6. motorcycle
7. boat
8. wagon
9. jeep
10. skate

HF Critical Lure 01: **car**

LF Critical Lure 02: **helicopter**



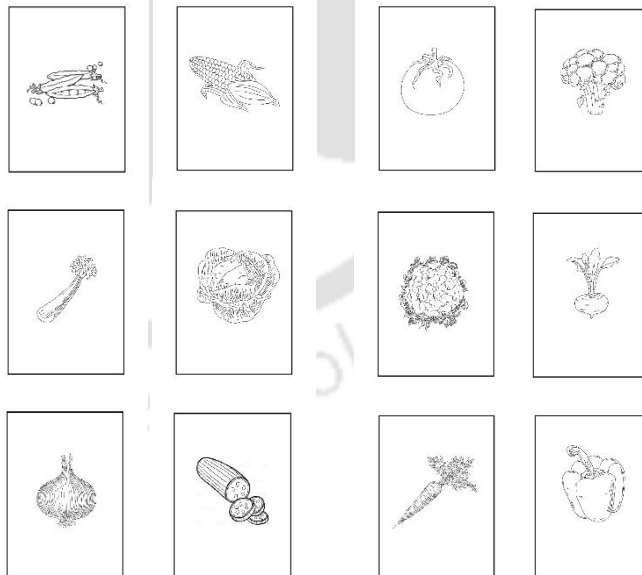
Category List 10

(Vegetables)

1. pea
2. corn
3. tomato
4. broccoli
5. celery
6. cabbage
7. cauliflower
8. beet
9. onion
10. cucumber

HF Critical Lure 01: **carrot**

LF Critical Lure 02: **pepper**



Abbreviations:

1. HF: High Frequency
2. LF: Low Frequency