Factors affecting Learning and Memory: Implications for Intervention

Aamir Malik
Assoc. Prof., Univ. Tech. PETRONAS
Outline

- Introduction
- The Learning Process
- Memory Model
- Factors Affecting Learning and Memory
- Long-term Memory Assessment
- Experimental Evidences of use of 3D Technology
- Neurofeedback Research
- References
Introduction

• Learning and memory are two interrelated but different cognitive processes.

• Learning is a process to get new skills, knowledge and experience; while memory is the ability to retain the learned experience and reuse later
Learning

“The acquisition of knowledge or skills through study, experience, or being taught.”

“any relatively permanent change in behaviour that occurs as a result of practice and experience”
The Learning Process

Concrete Experience (Activists)

Abstract Conceptualization (Theorists)

Reflective Observation (Reflectors)

Active Experimentation (Pragmatists)

Accommodating

Diverging

Converging

Assimilating

Perception

Processes

Institutional Values/Learning

Course instruction

Social/Cultural Values

Advice/Guidance/Support
Why Learning is the continuous Process

- Continuous Learning
- Thinking
- Creativity
- Academic Curiosity
- Extend Knowledge Levels
- Reading & Practice
- Attitude

Academic Curiosity

Reading & Practice

Extend Knowledge Levels

Attitude

Thinking

Creativity

Continuous Learning
How Does Learning Occur?

• To explain how and when learning occurs, a number of different psychological theories have been proposed.
Learning through Classical conditioning

Before Classical Conditioning

Food → Salivation

Bell → NO Salivation

(ding ding!)

During Classical Conditioning

Bell followed by Food → Salivation

(ding ding!)

After Classical Conditioning

Bell → Salivation

(ding ding!)
Operand Conditioning

Operant Conditioning
Specific consequences are associated with a voluntary behavior

Rewards introduced to increase a behavior

Punishment introduced to decrease a behavior

• For example, when a lab rat presses a green button, it receives a food pellet as a reward, but when he presses the red button he receives a mild electric shock.

• As a result, he learns to press the green button but avoid the red button.
Social Learning

- Albert Bandura (1961)
- Four requirements for learning:
  - observation (environmental),
  - retention (cognitive),
  - reproduction (cognitive), and
  - motivation (both).
Memory
Memory Types

Sensory Memory
(< 1 sec)

Short-term
(working Memory)
(20-30 sec)

Long-term
Memory
(life time)

Explicit Memory
(conscious)

Declarative Memory
(facts, events)

Episodic Memory
(events, experiences)

Implicit Memory
(unconscious)

Procedural Memory
(skills, tasks)

How to do things, like running, swimming

Semantic Memory
(facts, concepts)
Memory Processes

The three main processes involved in human memory are therefore encoding, storage and recall (retrieval).
Additionally, the process of memory consolidation (which can be considered to be either part of the encoding process or the storage process).

Memory Encoding: It allows the perceived information of interest to be converted into construct that can be stored within the brain, which can later be recalled.

Memory Storage: It allows to retain the encoded information in the brain.

Memory Retrieval/Recall: It refers to recollect the stored information from memory.
MEMORY MODEL

Environmental Stimuli

- Iconic Memory
- Echoic Memory
- Gustatory Memory
- Haptic Memory

Sensory Memory

Selective Attention

Short-Term Memory

Long-term Memory

Storage

Retrieval

Information that is not encoded gets forgotten

Information is forgotten due to interference, decay or retrieval failure
Factor Affecting Learning and Memory
Factors

- Sleep
- Caffeine
- Working Memory
- Emotion
- Intelligence
- Exercise
- Recall or Testing
- Rehearsal
- Attention
- Multilingual
- Visual and Auditory Combination
Sleep

• Good night sleep and cognitive benefits:
  – Enhanced Attention
  – Learning become easy
  – Better Problem-Solving Skills
  – Improved Recall
Research studies linked Sleep with academic performance
A strong relationship is evident between good sleep quality and high academic performance.
Conclusion: Adequate sleep the night prior to an examination was positively associated with student course grades and semester GPAs.
• consumed no caffeine reported the highest grades with nearly 64 % reporting they earned mostly A’s or A-’s in high school
Outcome: Results reveal that children with sub-average school achievement showed deficits in working memory functioning, irrespective of intelligence. By contrast, children with regular school achievement did not show deficits in working memory, again irrespective of intelligence.

Improving Academic Performance and Working Memory in Health Science Graduate Students Using Progressive Muscle Relaxation Training.

Hubbard KK1, Blyler D2.

Abstract
Research involving working memory has indicated that stress and anxiety compete for attentional resources when a person engages in attention-dependent cognitive processing. The purpose of this study was to investigate the impact of perceived stress and state anxiety on working memory and academic performance among health science students and to explore whether the reduction of stress and anxiety was achieved through progressive muscle relaxation (PMR) training. A convenience sample of 128 graduate students participated in this study. Using an experimental pretest-posttest design, we randomly assigned participants to a PMR group or a control group. Results indicated that PMR reduced state anxiety, F(1, 126) = 15.58, p < .001, thereby freeing up working memory and leading to improved academic performance in the treatment group. The results of this study contribute to the literature on Attentional Control Theory by clarifying the process through which working memory and anxiety affect cognitive performance.

PMID: 27767946 DOI: 10.5014/ajot.2016.020644
Emotion

- Emotions play an important role in learning and memory.
- They drive attention, which in turn drives learning and memory.
Results indicated students' emotion regulation, general affective dispositions, and academic affect were related to each other, each of these variables also made a unique significant contribution to students' GPA.
Intelligence

• It is the ability to learn or understand or to deal with new or trying situations

• There is an established relationship between intelligence and learning performance
Outcome: The results of proper analyses are consistent with the conclusion that performance on learning tasks and on conventional tests of intelligence, or IQ, both reflect common factors, principally Spearman's $g$, or the general factor common to all cognitive abilities.
Intelligence and educational achievement

Ian J. Deary a, b, Steve Strand b, Pauline Smith c, Cres Fernandes c

Abstract

This 5-year prospective longitudinal study of 70,000 + English children examined the association between psychometric intelligence at age 11 years and educational achievement in national examinations in 25 academic subjects at age 16. The correlation between a latent intelligence trait (Spearman's g from CAT2E) and a latent trait of educational achievement (GCSE scores) was 0.81. General intelligence contributed to success on all 25 subjects. Variance accounted for ranged from 58.6% in Mathematics and 48% in English to 18.1% in
Exercise

• Exercise Improves Cognitive functions
• Regular exercise changes the brain to improve memory, thinking skills
Results demonstrate that controlled training (CT), if performed with an appropriate combination of speed and duration, improves memory performance and neurogenesis.
Recall or Testing

- Testing or retrieval practice is the process in which the studied items or stored memory are recollected.
- The testing effect was first studied by Karpicke and Roediger in comparison with rehearsal for long-term retention.

![Proportion of memory recall in three different retention durations for rehearsal and testing effects](chart.png)
Recall or Testing

- In short-term retention, ‘SSSS’ condition recalled more than the rest of two conditions ‘SSST’ and ‘STTT’. However, the recalled performance was reversed for long-term retention
- The work of Karpicke and Roediger

Comparison of three experimental conditions for memory retrieval with two types of retention intervals (S=Study; T=Test)
Attention

• Working Memory capacity is limited
• Attending to (focusing on) a fact/event will increase the likelihood of memorization.
• The acceptable view among the memory experts of this relation between attention and memory is that focusing on or attending to a fact or event means allocation of processing resources of the brain for certain task
The functions of rehearsal are to maintain information active in the working memory and to create new memory traces for long-term retention.
Multi-lingual

• We use language to communicate our thoughts and feelings, to connect with others
• Learners who are multi-lingual can better understand and learn as compared to mono-lingual
The Impact of Bilingualism on Working Memory: A Null Effect on the Whole May Not Be So on the Parts

Noelia Calvo 1, 2, Agustín Ibáñez 3, 4, 5, 6, 7 and Adolfo M. García 3, 4, 8, 9*

1 Institute of Philosophy, School of Philosophy, Humanities and Arts, National University of San Juan, San Juan, Argentina, 2 Faculty of Psychology, National University of Córdoba, Córdoba, Argentina, 3 Laboratory of Experimental Psychology and Neuroscience, Institute of Translational and Cognitive Neuroscience, INECO Foundation, Favaloro University, Buenos Aires, Argentina, 4 National Scientific and Technical Research Council, Buenos Aires, Argentina, 5 Universidad Autónoma del Caribe, Barranquilla, Colombia, 6 Department of Psychology, Universidad Adolfo Ibáñez, Santiago, Chile, 7 ARC Centre of Excellence in Cognition and its Disorders, Sydney, NSW, Australia, 8 UDP-INECO Foundation Core on Neuroscience, Diego Portales University, Santiago, Chile, 9 Faculty of Elementary and Special Education, National University of Cuyo, Mendoza, Argentina

Keywords: bilingualism, bilingual advantage, executive functions, working memory, L2 proficiency, simultaneous interpreting
Multimedia (Visual and Auditory Combination)

• Brain process auditory and visual info in different pathways

• Instructions in visual and auditory combination improves learning performance
Abstract

According to the modality effect in multimedia, a text accompanying a picture should be auditorily presented instead of visually in order to avoid split of attention. In two experimental studies (34 and 78 participants, respectively), the impact and possible compensatory effects of two aptitude variables, that is, memory strategy skills and working memory capacity, on multimedia learning were tested. Aptitude–treatment–interaction effects were found with respect to comprehension (Study 1) and transfer (Study 2). The modality effect was confirmed for less-skilled learners in memory strategy use but not for highly skilled ones.
Use of Technology

• Multimedia Tools
• 3D & VR Technology
• Mobile Apps
• Web based learning
• Online Forums and chats
Factors

- Sleep
- Caffeine
- Working Memory
- Emotion
- Intelligence
- Exercise
- Recall or Testing
- Rehearsal
- Attention
- Multi-lingual
- Visual and Auditory Combination
3D Multimedia in Education
Since 2009: Entertainment

In 2009, James Cameron’s Avatar: A Stereoscopic 3D movie
Such as education & research, architecture design (3D CAD), health & medicine (training, imaging, therapy, and surgery).
The impact of 3D on academic results (Anne Bamford, 2011)

- The experimental results of the research indicated a positive effect of the use of 3D animations on learning and memory recall.
- 86% of students improved from the pre-test to the post-test in the 3D classes, compared to only 52% who improved in the 2D classes.
- Individuals improved test scores by an average of 17% in the 3D classes, compared to only an 8% improvement in the 2D classes between pre-test and post-test.

The research study involved 740 students as a sample, 47 teachers and 15 schools across France, Germany, Italy, Netherlands, Turkey, United Kingdom and Sweden.
3D in Education (1)

• **Objectives:**
  – to identify the most effective way of 3D presentation in classrooms
  – to measure the effect and benefit of this experience to learning and achievement of the pupils.
3D in Education (2)

• The research took place between October 2010 and May 2011 across seven countries in Europe.
• The study focused on pupils between the ages of 10-13 years learning science-related content.
• The research project involved 740 students, 47 teachers and 15 schools across France, Germany, Italy, Netherlands, Turkey, United Kingdom and Sweden.
3D in Education (3)

• The study involved:
  – Private and public schools;
  – single sex schools; city schools and rural schools; high and low academic achieving schools;
  – technology-rich and technology-poor schools; large schools and small schools; primary, middle and secondary schools;
  – experienced and less experienced teachers.
  – In each school there was a ‘control’ class and a 3D class.
  – Both classes had the same instruction, but the 3D class also had the 3D resources.
3D in Education (4)

• During study, several tests were undertaken
  – Teachers were asked to note the pupils’ retention (memory) after one month, between 3D and 2D classes
  – Open-ended tasks were given to determine the impact both on retention and on recall.
  – The teachers noted changes in the manner in which the 3D and 2D pupils recalled the learning.
  – For Example
    • *The 3D learners had better ordering (sequence) of concepts*
The impact of 3D on academic results

- The experimental results of the research indicate a marked positive effect of the use of 3D animations on learning, recall and performance in tests.
- 86% of pupils improved from the pre-test to the post-test in the 3D classes, compared to only 52% who improved in the 2D classes.
- The rate of improvement was also much greater in the classes with the 3D.
- Individuals improved test scores by an average of 17% in the 3D classes, compared to only an 8% improvement in the 2D classes between pre-test and post-test.
3D in Education (6)

• The marked improvement in test scores was also supported by qualitative data i.e.,
  – 100% of teachers agreed or strongly agreed that 3D animations in the classroom made the children understand things better,
  – 100% of teachers agreed or strongly agreed that the pupils discovered new things in 3D learning that they did not know before.
  – The teachers commented that the pupils in the 3D groups had deeper understanding, increased attention span, more motivation and higher engagement.
3D in Education (7)

• The findings from the teachers was also evident in the findings from the pupils, with a higher level of reported self-efficacy in the pupils within the 3D cohort compared to the 2D control groups.
  – The pupils felt strongly (84% agreed or strongly agreed) that 3D had improved their learning.
  – High levels of pupil satisfaction with 3D learning were also evident with an 83% approval rating.
  – The pupils in the 3D class were more likely to recall detail and sequence of processes in recall testing than the 2D group.
• Teachers and Pupils Comments:
  – Both pupils and teachers stated that 3D made learning more “real” and that these concrete, “real” examples aided understanding and improved results.
  – The pupils in the 3D classes could remember more than the 2D classes after four weeks.
  – Not only were there differences in the quantity of material recalled, but the pupils who studied with 3D remembered in a more connected ‘systems’ manner.
3D in Education (9)

• Teachers and Pupils Comments:

“When the teacher shows a model if it is small you can't see it, but with 3D even if the teacher moves around or a big kid is in front of you the 3D will always move in front so you can always see things clearly.” – Pupil comment

“It gives the pupils a better chance to visualize various parts of the lesson. The children can easily imagine and it makes these imaginings visual.” – Teacher comment
3D in Education (10)

• **Principal Comment:**

  “In this school we find that theoretical retention is a problem. As I see it, the 3D increases visual retention and this boosts learning.” – *Principal comment*

  “We are sure that the system should be in every school and be available for every teacher.” – *Principal comment*
Strategies for implementing 3D in the classroom

• To begin teaching with 3D, a teacher would need access to:
  – 3D-enabled projector
  – A laptop or PC with good graphic capability
  – 3D content
  – 3D glasses
WHY?

• There are many other studies which followed this main study proving the same results

• The question is WHY 3D is producing such good results?

• Another question is WHICH 3D technology is the best?
3D Perception

- Left image
- Right image
- 3D objects
- Binocular disparity
The imitation of 3D vision

Left image  Right image

Left eye    Right eye
Anaglyph Glasses

Left images    Right images

Left eye    Right eye
3D Passive Polarized Glasses

- Linear polarization
3D Passive Polarized Glasses

- Circular polarization
3D Active Shutter Glasses

Left eye
Right eye

L
R

1920
1080

Left eye
Right eye
Methodology
Experimental Design

- **Data acquisition computer**
- **Amplifier**
- **EEG & ECG electrodes**
- **Subject**
- **PS3**
- **TV**

Timeline:
- 0 min: Eyes Closed
- 5 min: Eyes Open
- 10 min: 2D Eyes Open
- 30 min: 3D Active Eyes Open
- 35 min: 3D Passive Eyes Open

Distance: 2.0 m
**EEG Power Difference**

<table>
<thead>
<tr>
<th></th>
<th>Delta</th>
<th>Theta</th>
<th>Alpha</th>
<th>Beta</th>
<th>High Beta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D A – 2D</td>
<td><img src="image1" alt="Delta" /></td>
<td><img src="image2" alt="Theta" /></td>
<td><img src="image3" alt="Alpha" /></td>
<td><img src="image4" alt="Beta" /></td>
<td><img src="image5" alt="High Beta" /></td>
<td><img src="image6" alt="Gamma" /></td>
</tr>
<tr>
<td>3D P – 2D</td>
<td><img src="image7" alt="Delta" /></td>
<td><img src="image8" alt="Theta" /></td>
<td><img src="image9" alt="Alpha" /></td>
<td><img src="image10" alt="Beta" /></td>
<td><img src="image11" alt="High Beta" /></td>
<td><img src="image12" alt="Gamma" /></td>
</tr>
<tr>
<td>3D A – 3D P</td>
<td><img src="image13" alt="Delta" /></td>
<td><img src="image14" alt="Theta" /></td>
<td><img src="image15" alt="Alpha" /></td>
<td><img src="image16" alt="Beta" /></td>
<td><img src="image17" alt="High Beta" /></td>
<td><img src="image18" alt="Gamma" /></td>
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</tbody>
</table>

- Brain is implicated with global processing under 3DP viewing at lower frequencies
- 2D viewing results in high engagement in local processing at higher frequencies
Absolute Power (P<0.05)

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<td><strong>3D A – 2D</strong></td>
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<td></td>
</tr>
</tbody>
</table>
| 2D > 3DA | | | Lower bands (\(\theta - \alpha\)):
global & distributed processing
i.e. working memory, attention |
| **3D P – 2D** |       |       |       |
| 2D > 3DA | | | |
| C3, P4, O1, T3, T5, CZ, *T4, *T6, *O2 | O1, FZ | C4, FZ |
| | | |
| **3D P – 3D** |       |       |       |
| 3DP > 2D | | | |
| | | |
| **3DA – 3DP** |       |       |       |
| 3DP > 3DA | | | |
| | | |

*P* – Values in **blue** indicate that activation in **2D** are greater than **3D active/passive**

*P* – Values in **red** indicate that activation in **3D active** are greater than **3D passive**

*P* – Values in **green** indicate that activation in **3D passive** are greater than **2D/3D active**
## EEG Coherence Difference

<table>
<thead>
<tr>
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<tr>
<td>3DA - 2D</td>
<td><img src="image" alt="Delta 3DA - 2D" /></td>
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*Significant group differences with $P < 0.0167$ are marked in an asterisk*

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<tr>
<th>3DA - Hyper (anterior)</th>
<th>3DA - Hypo (anterior)</th>
<th>3DA - Hyper (posterior)</th>
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<tr>
<td>3DP - Hyper (anterior)</td>
<td>3DP - Hypo (posterior)</td>
<td>3DP - Hyper</td>
</tr>
<tr>
<td>3DP - hypo</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hyper – coherence**

- Delta: ![Red line](image)
- Theta: ![Red line](image)
- Alpha: ![Red line](image)
- Beta: ![Red line](image)

**Hypo – coherence**

- Delta: ![Blue line](image)
- Theta: ![Blue line](image)
- Alpha: ![Blue line](image)
- Beta: ![Blue line](image)

**P – Value**

- $< 0.05$
- $< 0.025$
- $< 0.001$
I. Hjorth - Complexity

- **Lower complexity:** Signal is closer to sinusoidal behavior (more regular)
- **Higher complexity:** More sudden frequent changes in the signal over time

II. CPEI
Subjective Feedback

3D Active or 3D Passive?

- Passive: 75%
- Active: 25%
- No: 20%
- Slight: 20%

Do you like 3D movies better than 2D movies?

Yes

No
Results summary

**3D Active Failures**

- EEG absolute power is lower than 2D (in all bands)
- Majority subjects preferred 3DP viewing mode
- EEG power is significantly lower than 3DP (in occipital lobe)
- Signal complexity is comparable or lower to 2D
Why 3D Active results in lower brain activation than 2D?

PROBLEMS WITH 3D ACTIVE

(1) Discontinuous 3D visualization
(a) Sequential images
(b) Eye blinks

(2) Glasses weight
Why 3D Active results in lower brain activation than 2D? (a)
Sequential 2D images presentation

1st image at time ‘t’ ms

2nd image at time ‘t + 4’ ms

Left eye

Right eye

3DTV
Why 3D Active results in lower brain activation than 2D? (b) Eye blinks
References


References


Long-term Memory: Assessment and Effects of Stereoscopic 3D Educational Contents using EEG Signals
# Summary of EEG Theta, Alpha and Gamma Frequency bands in LTM recall

<table>
<thead>
<tr>
<th>Freq. Bands</th>
<th>Location and reported changes</th>
<th>Role in Memory</th>
<th>Critics</th>
</tr>
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<tbody>
<tr>
<td>Theta Power</td>
<td>Medial Temporal (rhinal cortex and hippocampus) Theta Power increased before stimulus presentation reflects preparation for stimulus-triggered memory processing</td>
<td>Prediction of LTM formation</td>
<td>Patients of temporal lobe epilepsy were used for experimentation and the memory material was word recognition</td>
</tr>
<tr>
<td>Theta Coherence</td>
<td>High coherence left frontal (Fp1,F7), anterior and posterior temporal sites (T4,T6) and right posterior parietal-occipital regions (P4, O2).</td>
<td>LTM retrieval, high information processing</td>
<td>The material of memory was abstract and concrete nouns</td>
</tr>
<tr>
<td>Theta Phase</td>
<td>Theta phase of single neurons at hippocampus (bilateral) is associated with the performance in memory task</td>
<td>Prediction of successful LTM formation</td>
<td>The experiment was performed in patients of epilepsy and the memory task was old-new paradigm (recognition memory)</td>
</tr>
<tr>
<td>Alpha Power</td>
<td>Medial Temporal Alpha Power increased before stimulus presentation indicates activation of contextual information</td>
<td>Prediction of successful LTM formation</td>
<td>Patients of temporal lobe epilepsy were used for experimentation and the memory material was word recognition</td>
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### Summary of EEG Theta, Alpha and Gamma Frequency bands in LTM recall …

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<tr>
<td><strong>Alpha Power</strong> <em>(Klimesch et al., 1997)</em></td>
<td>Variations in alpha power as a function of memory performance</td>
<td>LTM retrieval</td>
<td>The variations in alpha are not so clear with respect to attentional demands, memory load, and level of intelligence of the participants.</td>
</tr>
<tr>
<td><strong>Theta and Alpha</strong> <em>(Khader et al., 2010)</em></td>
<td>High alpha power at parietal-occipital cortex (P4, Pz, O2) and high theta power at mid-frontal cortex (Fz, Cz) were observed for subsequently remembered stimuli</td>
<td>LTM encoding and retrieval</td>
<td>The retention duration was only 5 to 7 seconds in the delayed matching-to-sample task</td>
</tr>
<tr>
<td><strong>Gamma power</strong> <em>(Sederberg et al., 2007)</em></td>
<td>Increased gamma power left temporal lobe, hippocampus, inferior PFC and occipital lobe during encoding of nouns</td>
<td>Prediction of LTM correct retrieval</td>
<td>The results obtained from epileptic patients and the study material was common nouns. There may be effect of background knowledge during encoding the nouns.</td>
</tr>
<tr>
<td><strong>Theta and Gamma power</strong> <em>(Sederberg et al., 2003)</em></td>
<td>Theta activity in tight temporal and frontal cortex was high; while gamma was high over widespread cortical sites</td>
<td>LTM retrieval</td>
<td>The sample size was only 10 and the age range was 8 to 17 years</td>
</tr>
<tr>
<td><strong>Theta and Gamma power</strong> <em>(Osipova et al., 2006)</em></td>
<td>High theta at right temporal and high gamma power over occipital regions</td>
<td>Predicts encoding and retrieval of LTM</td>
<td>The experiment was based on recognition memory and used old/new paradigm, which is ERP experiment</td>
</tr>
</tbody>
</table>
## Summary of P300 Studies related to LTM recall

<table>
<thead>
<tr>
<th>Study</th>
<th>Feature</th>
<th>Role in Memory</th>
<th>Critics</th>
</tr>
</thead>
<tbody>
<tr>
<td>P300 and face recognition (Meijer et al., 2007)</td>
<td>P300 Amplitude</td>
<td>Large P300 amplitude for recognized faces at Pz site <em>(semantic recognition memory)</em></td>
<td>The stimuli were acquired through the participants themselves, there may effect of picture recognition on P300 amplitude instead of face recognition.</td>
</tr>
<tr>
<td>P300 and memory recall (Jongsma et al., 2012)</td>
<td>P300 Amplitude</td>
<td>Increase in the amplitude of P300 at Pz site during <em>semantic memory</em> (recalling digits)</td>
<td>The non-significant effect of the rehearsal of stimuli on Fz and Cz amplitude is not well clear, either lack of attention or any other reason inhibit the amplitude at these sites.</td>
</tr>
<tr>
<td>P300 and visual recognition (Vianin et al., 2002)</td>
<td>P300 Amplitude</td>
<td>Large P300 amplitude at posterior sites (P3, P4, Pz, O1, O2, Oz) for <em>semantic recognition memory</em> between healthy and schizophrenic patients</td>
<td>The sample size used in this study was small, i.e., 10 participants in patient group and 14 participant in control group.</td>
</tr>
<tr>
<td>P300 and LTM scanning (Singhal and Fowler, 2004)</td>
<td>P300 Amplitude</td>
<td>Amplitude of Visual P300 at Pz was marginally high in LTM</td>
<td>The sample size was only 16 participants and the retention time was 24 hours.</td>
</tr>
<tr>
<td>P300 and cognitive impairment (Parra et al., 2012)</td>
<td>P300 Amplitude</td>
<td>Reduced P300 amplitude at Fz and Pz sites in mild cognitive impairment (MCI)</td>
<td>The sample size n=30 is relative small with three groups, control, MCI and Alzheimer’s disease (AD).</td>
</tr>
<tr>
<td>P300 and Alzheimer’s (Parra et al., 2012)</td>
<td>P300 Amplitude</td>
<td>Smaller P300 amplitude in Alzheimer’s patients at Fz, Cz, Pz sites</td>
<td>The variations in the P300 amplitude may be occurred in sites (left or right hemisphere) other than the midline sites, which is not discussed in this study.</td>
</tr>
</tbody>
</table>

*(semantic recognition memory)*
Problem Formulation

- Problem Formulation
  - The existing memory assessment tools are subjective in nature and lacking in automatic and quantitative assessment.

- Further, the existing techniques require an expert psychologist/clinician to interpret the tests results and compare with the population norm.

- The assessment score is always relative with respect to the population norm.

- Therefore, the existing memory assessment techniques are unable to directly measure an individual’s LTM ability.
Further, the factors which influence the LTM, such as attention, rehearsal, and testing are well studied in behavioral research.

However, the use of S3D educational tools for learning & memory is quite new; the effects of S3D display technology on LTM performance and the brain behavior during LTM recall is unknown.

Only a behavioral study on S3D reported by Anne Bamford in 2011, where she found 86% of the students in 3D class improved memory retention than 52% in 2D class.

However, the reasons of why 3D class show better performance in recall tests are unknown, because the study did not use neuroimaging techniques.

Therefore, the brain responses will be interesting to explore for LTM using neuroimaging technique, such as EEG signals.
To summarize limitations of existing studies related to Long Term Memory (LTM) in Education, following two points are found to be most significant:

1. There is no quantitative assessment of LTM (currently subjective assessments are available only)

2. Out of the various factors affecting LTM in education, S3D multimedia is least studied and understood (attention, rehearsal & testing are well studied)
Hypothesis

To address the two most significant limitations for LTM in education (as discussed in previous slide), following two hypotheses are proposed.

- **H₁**: Connectivity of brain regions using EEG frequency bands (theta, alpha and gamma) may provide basis to propose a quantitative assessment tool for LTM.

- **H₂**: The use of stereoscopic 3D multimedia educational tools may provide good effects on the brain in LTM recall.
Based on the hypotheses to address the two most significant limitations for LTM in education (as discussed in previous two slides), following are the two objectives of this study.

To develop a method for semantic long-term memory (LTM) assessment based on resting state EEG signals,

To investigate the effects of Stereoscopic 3D educational contents on long-term memory (LTM) recall process using EEG signals.
Experimental Design
&
Proposed Methodology
**Experiment Design & Flow Chart**

**Control Variables**
- General Intelligence
- Age (18-30 Years)
- Contents of Learning

**Experimental Tasks**
- RAPM Test
- Learning Task
- Oddball Task
- Memory Recall Task

**Learning Contents**
- Human Anatomy & Physiology animated contents (2D and S3D)
- Duration of Contents 10 min (presented 3 times)

**3D Technology**
- Passive Polarized
- Screen 42 inch
- Distance 1.5 meter

**EEG Recording**
- Sample Size 68
- EGI EEG 128 Channels
- Sampling rate 250
- EEG Reference Cz

---

### Structure of Experiment

1. **1st Session**
   - RAPM Test (45 min)
   - EO, EC EEG (5 min)
   - Study Contents (30 min)
   - Oddball Task (3 min)
   - Recall Test (10 min)

2. **2nd Session**
   - EO, EC EEG (5 min)
   - Recall Test (10 min)
   - Study Contents (10 min)

3. **3rd Session**
   - EO, EC EEG (5 min)
   - Recall Test (10 min)
   - Study Contents (10 min)

4. **4th Session**
   - EO, EC EEG (5 min)
   - Recall Test (10 min)

---

### Flow Chart

- **Subjects**
  - Consent?
  - Inclusion Criteria?
  - EEG Baseline Recordings (EO, EC)
  - Learning Process (watching animations)
  - Oddball Task
  - Memory Recall Test
  - EEG Raw Data
  - Statistical Analysis
  - Significance?
  - Reject H
  - Accept H

---

**Experimental Tasks**
- RAPM Test
- Learning Task
- Oddball Task
- Memory Recall Task

**Learning Contents**
- Human Anatomy & Physiology animated contents (2D and S3D)
- Duration of Contents 10 min (presented 3 times)

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- Passive Polarized
- Screen 42 inch
- Distance 1.5 meter

**EEG Recording**
- Sample Size 68
- EGI EEG 128 Channels
- Sampling rate 250
- EEG Reference Cz
Data Analysis

**Behavioral Data**
- Accuracy (ACC %)
- Reaction Time (RT)

**EEG Signals**
- Proposed LTM Assessment Scheme based on Resting State EEG Signals (eyes open)
- Proposed Feature Extraction Scheme for EEG Signal to discriminate S3D and 2D Memory Recall
- EEG Source Analysis with LORETA-Key for S3D/2D

**ERP Signals**
- Proposed LTM Assessment Scheme based on P300 component of ERP Signals
Proposed LTM Assessment Scheme based on Resting State EEG

**Steps of the Proposed Scheme**

1. **Feature Extraction**: Compute EEG absolute Phase delay of theta, alpha and gamma frequency bands of $171 \times 3 = 513$ pairs from 19 electrodes.

2. **Feature Selection**: Apply correlation to identify significant related electrodes pairs with memory score.

3. **Prediction Model**: Apply Multiple-Linear Regression (MLR) on the selected features to train the model.

4. **Proposed LTM Grading**: The output of the trained MLR model is used to grade the individual LTM ability.

**Equation**

$$r = \frac{\sum_{i=1}^{n} ((x_i - \bar{x})(y_i - \bar{y}))}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}}$$

Where $x_i$ is EEG feature and $y$ is memory score

**MLR (Score %)**

<table>
<thead>
<tr>
<th>Value Range</th>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥90% to 100%</td>
<td>A</td>
<td>Excellent long-term memory ability in retrieval of semantic concepts, facts and knowledge.</td>
</tr>
<tr>
<td>≥80% to &lt;90%</td>
<td>B</td>
<td>Very Good</td>
</tr>
<tr>
<td>≥70% to &lt;80%</td>
<td>C</td>
<td>Good</td>
</tr>
<tr>
<td>≥60% to &lt;70%</td>
<td>D</td>
<td>Average</td>
</tr>
<tr>
<td>≥50% to &lt;60%</td>
<td>E</td>
<td>Fair</td>
</tr>
<tr>
<td>49% and below</td>
<td>F</td>
<td>Unsatisfied</td>
</tr>
</tbody>
</table>

**Score (%)**

$$\text{Score} = \frac{\bar{Y} \times 100}{20}$$

**Equation**

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n + \epsilon$$

Or $Y = X\beta + \epsilon$

- $Y$ is the dependent variable
- $X_i$ is the $i^{th}$ independent variables
- $\beta_i$ is the $i^{th}$ regression weight (unknown)
- $\epsilon$ is the error between actual and predicted value

Using Ordinary Least Squares to estimate the $\beta$

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

**Reference**

Proposed LTM Assessment Based on P300 Component

Steps of the Proposed Scheme

**Step 1: Preprocessing**
- Filtering (0.3 to 30 Hz)
- Segmentation
- Artifacts Rejection
- Bad Channels Rejection
- Averaging Trials
- Re-Referencing

**Step 2: Feature Extraction**
- Amplitude
- Latency

**Step 3: Multiple Linear Regression**
\[ Y = X\beta + \varepsilon \]

**Step 4: Proposed LTM Grading**

Amplitude \( (S_{\text{max}}) \) — It is the maximum signal value at some point in time for a specified window. Time window was 276–500ms.

\[
s_{\text{max},i} = \max_t\{s(t)|w_i(t)\}
\]

where
\[
w(t) = \{ \frac{276ms}{500ms} \}
\]

Latency \( (t_{s\text{max}}) \) — The latency of an ERP component is that point in time where the maximum signal value occurs.

\[
t_{s\text{max}} = \{ t | s(t) = S_{\text{max}} \}
\]

Where \( S_{\text{max}} \) is the maximum signal value

A completely periodic signal repeats itself with a constant period and can be mathematically defined, such as sin(x) (Hayes, 1998).

However, in case of EEG signal, it is not completely periodic like sin(x), but there is some periodicity

Example of periodic sine signal and EEG signal of 3-to-6 Hz with redundant information, CR (compression ratio), R (redundancy)

Resting State ...EEG has more redundant info
Cognitive Tasks...EEG has less redundant info
Proposed EEG Feature Extraction Scheme
S3D vs. 2D

Discrete Wavelet Transform (DWT)

Threshold & Rounding-off

Arithmetic Coding

Feature Extraction

DWT Coefficients

Optimum DWT Coefficients

DWT Coefficients encoded to bit stream

Arithmetic Coding Algorithm:
\[ \Phi_k(S) = [\alpha_k, \beta_k], k = 0, 1, \ldots, N, \]

Where \( S \) is the source data sequence, \( \alpha_k \) and \( \beta_k \) are real numbers such that \( 0 \leq \alpha_k \leq \alpha_{k+1} \) and \( \beta_k \leq \beta_{k+1} \leq 1 \).

\[ \delta = \frac{\text{median}(|D_{jk}|)}{0.6745} \]

\[ E = \frac{100 \times ||X_r||^2_2}{||X||^2_2} > 99\% \]

Where:
- \( r \) is the size of the original signal \( X \)
- \( c \) is the size of the compressed signal \( X_c \)

\[ R = \frac{1}{CR} \times 100 \]

Cross Validation

K-Cross Validation:
Divide the given dataset into \( K = 10 \) subsets of equal size. A single subset is retained as the validation data for testing the model, and \( K-1 \) subsets are used as training data.

This process is repeated \( K \)-times, each time leaving out one of the subsets from training, which is used for testing.

K-NN classifier:

Input: \( D \), the set of training objects, \( z \), the test object, and \( L \), the set of classes

Output: \( c_e \in L \), the class of \( z \)

Foreach object \( y \in D \) Do

- Compute \( d(z,y) \), the distance between \( z \) and \( y \);

End

Select \( N \subseteq D \), the \( k \) closest training objects for \( z \);

\[ c_z = \arg \max \sum_{y \in L} I(v = \text{class}(c_y)) \]

Where \( I(\cdot) \) is an indicator function that returns the value 1 if its argument is true and 0 otherwise.

\( \hat{x}_i = \frac{x_i - \bar{x}}{\sigma} \)

Where, \( i = 1, 2, \ldots, N \);
\( N \) is the number of instances in a specific feature \( x \);
\( \sigma \) and \( \bar{x} \) are standard deviation and mean of \( x_i \);
and \( \hat{x}_i \) is the normalized feature value.

Features Standardization

Features Selection

Reduced Feature set

Standardized Features set

Performance Evaluation

Classifier

kNN classifier:

Input: \( D \), the set of training objects, the test object, \( z \), and \( L \), the set of classes

Output: \( c_e \in L \), the class of \( z \)

Foreach object \( y \in D \) Do

- Compute \( d(z,y) \), the distance between \( z \) and \( y \);

End

Select \( N \subseteq D \), the \( k \) closest training objects for \( z \);

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\( N \) is the number of instances in a specific feature \( x \);
\( \sigma \) and \( \bar{x} \) are standard deviation and mean of \( x_i \);
and \( \hat{x}_i \) is the normalized feature value.
Experimental Results
1. To develop a method based on EEG features for long-term memory (LTM) assessment

   ▪ Proposed LTM Assessment Based on Resting State EEG Signals
   ▪ Proposed LTM Assessment Based on P300 Component
**Steps of the Proposed Scheme**

**Step 1. Feature Extraction**: Compute absolute Phase delay of theta, alpha and gamma frequency bands of $171 \times 3 = 513$ pairs from 19 electrodes.

**Step 2. Feature Selection**: Apply correlation to identify significant related electrodes pairs with memory score.

**Step 3. Prediction Model**: Apply Multiple-Linear Regression (MLR) on the selected features to train the model.

**Step 4. Proposed LTM Grading**: The output of the trained MLR model is used to grade the individual LTM ability.

---

**Results**: Proposed LTM Assessment Scheme Based on Resting State EEG

EEG Electrode Pairs (Fp2-F7, Fz-C4, T3-Pz, T5-P4, T6-T4, Fp2-P3, F7-F4, C3-O1, Fp2-P3, F3-C3, F7-C3 and T3-O2) which have strong relationship with memory recall.

**Prediction Results**: MLR model predicted the long-term memory of all 4 sessions.

- **30 min retention**: $F(12,51)=4.421, p<0.0001, R=0.714, R^2=0.560$
- **2 months retention**: $F(12,47)=4.994, p<0.0001, R=0.749, R^2=0.560$
- **4 months retention**: $F(12,44)=2.816, p=0.006, R=0.659, R^2=0.434$
- **6 months retention**: $F(12,37)=2.019, p=0.050, R=0.629, R^2=0.396$

---

**Graphs**:

- (a) Recall after 2 months
- (b) Recall after 2 months
- (c) Normal P-P Plot of Regression Standardized Residual
Here, \( y_1, y_2, y_3, \) and \( y_4 \) are percentage observed LTM scores in session 1, session 2, session 3 and session 4. The corresponding percentage predicted LTM scores are represented as \( \hat{y}_1, \hat{y}_2, \hat{y}_3, \) and \( \hat{y}_4 \), respectively.

<table>
<thead>
<tr>
<th>Subject No</th>
<th>Session 1 (30 min Retention)</th>
<th>Session 2 (2 months Retention)</th>
<th>Session 3 (4 months Retention)</th>
<th>Session 4 (6 months Retention)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( y_1 )</td>
<td>( \hat{y}_1 )</td>
<td>Grade</td>
<td>( y_2 )</td>
</tr>
<tr>
<td>1</td>
<td>90</td>
<td>83.64</td>
<td>B</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>78.22</td>
<td>C</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>75</td>
<td>82.09</td>
<td>B</td>
<td>65</td>
</tr>
<tr>
<td>4</td>
<td>70</td>
<td>66.71</td>
<td>D</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>85</td>
<td>79.93</td>
<td>C</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>95</td>
<td>85.45</td>
<td>B</td>
<td>75</td>
</tr>
<tr>
<td>7</td>
<td>85</td>
<td>89.21</td>
<td>B</td>
<td>70</td>
</tr>
<tr>
<td>8</td>
<td>90</td>
<td>76.58</td>
<td>C</td>
<td>80</td>
</tr>
<tr>
<td>9</td>
<td>80</td>
<td>80.17</td>
<td>B</td>
<td>75</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>78.92</td>
<td>B</td>
<td>60</td>
</tr>
</tbody>
</table>

### LTM Grading

- \( \geq 90\% \) to 100\%: A
- \( \geq 80\% \) to <90\%: B
- \( \geq 70\% \) to <80\%: C
- \( \geq 60\% \) to <70\%: D
- \( \geq 50\% \) to <60\%: E
- 49\% and below: F
**Results:** Comparison of Proposed LTM prediction Scheme with RAPM Test

The proposed EEG based LTM Assessment scheme was compared with Raven’s Advanced Progressive Matrices (RAPM) Test, which is an established indicator of learning and memory in educational psychology. However, the proposed scheme outperformed the RAPM.

<table>
<thead>
<tr>
<th>Session</th>
<th>F-statistic</th>
<th>p-value</th>
<th>R-value</th>
<th>R-squared</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RAPM test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>F(1,62)=10.235</td>
<td>0.002</td>
<td>0.376</td>
<td>0.142</td>
<td>0.128</td>
</tr>
<tr>
<td>02</td>
<td>F(1,58)=5.872</td>
<td>0.019</td>
<td>0.303</td>
<td>0.092</td>
<td>0.076</td>
</tr>
<tr>
<td>03</td>
<td>F(1,55)=6.422</td>
<td>0.014</td>
<td>0.323</td>
<td>0.105</td>
<td>0.088</td>
</tr>
<tr>
<td>04</td>
<td>F(1,48)=8.167</td>
<td>0.006</td>
<td>0.381</td>
<td>0.145</td>
<td>0.128</td>
</tr>
<tr>
<td><strong>Proposed EEG Scheme</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01</td>
<td>F(12,51)=4.421</td>
<td>0.001</td>
<td>0.714</td>
<td>0.510</td>
<td>0.395</td>
</tr>
<tr>
<td>02</td>
<td>F(12,47)=4.994</td>
<td>0.001</td>
<td>0.749</td>
<td>0.560</td>
<td>0.448</td>
</tr>
<tr>
<td>03</td>
<td>F(12,44)=2.816</td>
<td>0.006</td>
<td>0.659</td>
<td>0.434</td>
<td>0.280</td>
</tr>
<tr>
<td>04</td>
<td>F(12,37)=2.019</td>
<td>0.050</td>
<td>0.629</td>
<td>0.396</td>
<td>0.200</td>
</tr>
</tbody>
</table>
Results: Proposed LTM Assessment Scheme Based on P300 Component

**Steps of the Proposed Scheme**

**Step 1: Preprocessing**
- Filtering (0.3 to 30 Hz)
- Segmentation
- ……..

**Step 2: Feature Extraction**
- Amplitude
- Latency

**Step 3: Multiple Linear Regression**
\[ Y = X\beta + \varepsilon \]

**Step 4: Proposed LTM Grading**

Correlation between P300 component (Pz) and LTM Recall

<table>
<thead>
<tr>
<th>Variables</th>
<th>LTM Recall</th>
<th>RAPM</th>
<th>P3 amplitude</th>
<th>P3 latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTM Recall</td>
<td>0.653**</td>
<td>0.554**</td>
<td>-0.365*</td>
<td></td>
</tr>
<tr>
<td>RAPM</td>
<td>0.653**</td>
<td>0.540**</td>
<td>-0.495*</td>
<td></td>
</tr>
<tr>
<td>P3 amplitude</td>
<td>0.554**</td>
<td>0.540**</td>
<td>-0.328</td>
<td></td>
</tr>
<tr>
<td>P3 latency</td>
<td>-0.365*</td>
<td>-0.495*</td>
<td>-.328</td>
<td></td>
</tr>
</tbody>
</table>

Correlation is significant at the level **p < 0.005, *p < 0.025 (2-tailed). Pearson’s correlation was used, and sample size is (n=30).

The regression result showed that P300 amplitude successful predicted the LTM recall score of 30 min retention, \( F(1,28)=12.42, p=0.001, R=0.554 \) and \( R^2= 0.307 \). However, unable to work for long retention, i.e., \( F(1,28)=1.928, p\text{-value}=0.165, R=0.353, R^2=0.116 \), for LTM recall after 02 months, 4 months and 6 months of retention.

Published in J.NeurEng. & Rehab. Q1 Journal (IF=2.740)
2. To investigate the effects of Stereoscopic 3D educational contents on memory recall process using EEG signals.
   - Comparison of S3D vs. 2D for LTM recall
   - Proposed EEG Feature Extraction Scheme for S3D and 2D comparison
Comparison of S3D vs. 2D

2. To investigate the effects of Stereoscopic 3D educational contents on memory recall process using EEG signals.

The S3D group recalled the semantic LTM faster than the 2D group after 02 months retention duration. (p-value<0.05)

The S3D group involves widespread brain neuronal network as compared to 2D group during LTM recall.

Published in Annals of Neurology (Q1/IF 11.910) as a abstract
## Results:

Proposed EEG Feature Extraction Scheme for S3D and 2D comparison

<table>
<thead>
<tr>
<th>EEG Datasets</th>
<th>Accuracy %</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>Area Under the ROC curve (AUC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dataset-1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Memory Recall vs. EO</strong></td>
<td>96.07</td>
<td>96.96</td>
<td>95.18</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Features Matrix</strong></td>
<td>(560×64)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dataset-2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intelligence Test vs. EO</strong></td>
<td>95.58</td>
<td>100</td>
<td>91.20</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Features Matrix</strong></td>
<td>(400×64)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dataset-3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S3D vs. 2D</strong></td>
<td>90.45</td>
<td>92.35</td>
<td>88.56</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Feature Matrix</strong></td>
<td>(1320×64)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Proposed EEG Feature Extraction scheme is capable to extract redundant information, which can be used to separate two classes, such as S3D vs. 2D memory recall.

### Performance Comparison of the Proposed EEG Feature Extraction Scheme (Accuracy: k-nearest neighbor)

<table>
<thead>
<tr>
<th>Feature Methods</th>
<th>Dataset-1</th>
<th>Dataset-2</th>
<th>Dataset-3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Memory Recall vs. EO Feature Matrix (560x64)</td>
<td>Intelligence Test vs. EO Feature Matrix (400x64)</td>
<td>S3D vs. 2D Feature Matrix (1320x64)</td>
</tr>
<tr>
<td>Proposed EEG Scheme</td>
<td>96.07</td>
<td>95.58</td>
<td>90.45</td>
</tr>
<tr>
<td>Delta Power</td>
<td>94.67</td>
<td>91.17</td>
<td>69.34</td>
</tr>
<tr>
<td>Theta Power</td>
<td>92.85</td>
<td>80.88</td>
<td>71.28</td>
</tr>
<tr>
<td>Alpha Power</td>
<td>89.1</td>
<td>67.64</td>
<td>69.29</td>
</tr>
<tr>
<td>Beta Power</td>
<td>87.35</td>
<td>73.52</td>
<td>69.78</td>
</tr>
<tr>
<td>Gamma Power</td>
<td>87.48</td>
<td>67.64</td>
<td>67.35</td>
</tr>
<tr>
<td>ApEn</td>
<td>68.75</td>
<td>87.5</td>
<td>53.46</td>
</tr>
<tr>
<td>SamEn</td>
<td>86.75</td>
<td>83.82</td>
<td>53.68</td>
</tr>
<tr>
<td>CPEI</td>
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The performance of discriminating two EEG classes of the proposed EEG Feature Extraction Scheme is better than the state of the art EEG feature extraction methods as mentioned by the accuracy of k-NN classifier.
A Novel Approach Based on Data Redundancy for Feature Extraction of EEG Signals

Hafeez Ullah Amin¹ · Aamir Saeed Malik¹ · Nidal Kamel¹ · Muhammad Hussain²

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Abstract Feature extraction and classification for electroencephalogram (EEG) in medical applications is a challenging task. The EEG signals produce a huge amount of redundant data or repeating information. This redundancy causes potential hurdles in EEG analysis. Hence, we propose to use this redundant information of EEG as a feature to discriminate and classify different EEG datasets.

Keywords Data redundancy · Feature extraction · Classification · EEG signal

Introduction

Electroencephalography (EEG) is reliable technique...
P300 correlates with learning & memory abilities and fluid intelligence

Hafeez Ullah Amin¹, Aamir Saeed Malik¹*, Nidal Kamel¹, Weng-Tink Chooi² and Muhammad Hussain³

Abstract

Background: Educational psychology research has linked fluid intelligence with learning and memory abilities and neuroimaging studies have specifically associated fluid intelligence with event related potentials (ERPs). The objective of this study is to find the relationship of ERPs with learning and memory recall and predict the memory recall score using P300 (P3) component.

Method: A sample of thirty-four healthy subjects between twenty and thirty years of age was selected to perform three tasks: (1) Raven’s Advanced Progressive Matrices (RAPM) test to assess fluid intelligence, (2) learning and memory task to assess learning ability and memory recall; and (3) the visual oddball task to assess brain-evoked potentials. These subjects were divided into High Ability (HA) and Low Ability (LA) groups based on their RAPM scores. A multiple regression analysis was used to predict the learning & memory recall and fluid intelligence using P3 amplitude and latency.

Results: Behavioral results demonstrated that the HA group learned and recalled 10.89% more information than did the LA group. ERP results clearly showed that the P3 amplitude of the HA group was relatively larger than that observed in the LA group for both the central and parietal regions of the cerebrum; particularly during the 300–400 ms time window. In addition, a shorter latency for the P3 component was observed at Pz site for the HA group compared to the LA group. These findings agree with previous educational psychology and neuroimaging studies which reported an association between ERPs and fluid intelligence as well as learning performance.
Classification of EEG Signals Based on Pattern Recognition Approach

Hafeez Ullah Amin*, Wajid Mumtaz, Ahmad Rauf Subhani, Mohamad Naufal Mohamad Saad and Aamir Saeed Malik*

Centre for Intelligent Signal and Imaging Research (CISIR), Department of Electrical and Electronic Engineering, Universiti Teknologi Petronas, Seri Iskandar, Malaysia

Feature extraction is an important step in the process of electroencephalogram (EEG) signal classification. The authors propose a “pattern recognition” approach that discriminates EEG signals recorded during different cognitive conditions. Wavelet based feature extraction such as, multi-resolution decompositions into detailed and approximate coefficients as well as relative wavelet energy were computed. Extracted relative wavelet energy features were normalized to zero mean and unit variance and then optimized using Fisher’s discriminant ratio (FDR) and principal component analysis (PCA). A high density EEG dataset validated the proposed method (128-channels)
# Introducing Memory Grading Scale for semantic long-term retention using resting state EEG functional connectivity

---Manuscript Draft---

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How Neurofeedback can be used?
Factors

- Sleep
- Caffeine
- Working Memory
- Emotion
- Intelligence
- Exercise
- Recall or Testing
- Rehearsal
- Attention
- Multilingual
- Visual and Auditory Combination
3D Stimuli

• 3D Stimuli can be used in neurofeedback to use wide spread neuronal network for training
• Virtual Reality environment
Neurofeedback (NFB) enables the voluntary regulation of brain activity, with promising applications to enhance and recover emotion and cognitive processes, and their underlying neurobiology. It remains unclear whether NFB can be used to aid and sustain complex emotions, with ecological validity implications. We provide a technical proof of concept of a novel real-time functional magnetic resonance imaging (rtfMRI) NFB procedure. Using rtfMRI-NFB, we enabled participants to voluntarily enhance their own neural activity while they experienced complex emotions. The rtfMRI-NFB software (FRIEND Engine) was adapted to provide a virtual environment as brain computer interface (BCI) and musical excerpts to induce two emotions (tenderness and anguish), aided by participants' preferred personalized strategies to maximize the intensity of these emotions. Eight participants from two experimental sites performed rtfMRI-NFB on two consecutive days in a counterbalanced design. On one day,
Improving visual perception through neurofeedback

Frank Scharnowski, 1,2,3,4 Chloe Hutton, 1 Oliver Josephs, 1 Nikolaus Weiskopf, 1,5 and Geraint Rees 1,2,5

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The publisher’s final edited version of this article is available free at J Neurosci
See other articles in PMC that cite the published article.

Abstract

Perception depends on the interplay of ongoing spontaneous activity and stimulus-evoked activity in sensory cortices. This raises the possibility that training ongoing spontaneous activity alone might be sufficient for enhancing perceptual sensitivity. To test this, we trained human participants to control ongoing spontaneous activity in circumscribed regions of retinotopic visual cortex using real-time functional MRI based neurofeedback. After training, we tested participants using a new and previously
Neurofeedback training aimed to improve focused attention and alertness in children with ADHD: a study of relative power of EEG rhythms using custom-made software application.

Hillard B, El-Baz AS, Sears L, Tasman A, Sokhadze EM.

Abstract

Neurofeedback is a nonpharmacological treatment for attention-deficit hyperactivity disorder (ADHD). We propose that operant conditioning of electroencephalogram (EEG) in neurofeedback training aimed to mitigate inattention and low arousal in ADHD, will be accompanied by changes in EEG bands' relative power. Patients were 18 children diagnosed with ADHD. The neurofeedback protocol ("Focus/Alertness" by Peak Achievement Trainer) has a focused attention and alertness training mode. The neurofeedback protocol provides one for Focus and one for Alertness. This does not allow for collecting information regarding changes in specific EEG bands (delta, theta, alpha, low and high beta, and gamma) power within the 2 to 45 Hz range. Quantitative EEG analysis was completed on each of twelve 25-minute-long sessions using a custom-made MatLab application to determine the relative power of each of the aforementioned EEG bands throughout each session, and from the first session to the last session. Additional statistical analysis determined significant changes in relative power within sessions (from minute 1 to minute 25) and between sessions (from session 1 to session 12). Analysis was of relative power of theta, alpha,
Neurofeedback Training to Enhance Learning and Memory in Patients with Cognitive Impairment

Parvaneh Haddadi, Reza Rostami, Afsaneh Moradi, Farzaneh Pouladi

Abstract

The brain tumors can make cognitive impairment especially when they involve the limbic.
Neurofeedback training improves attention and working memory performance.

Wang JR¹, Hsieh S.

Abstract

OBJECTIVES: The present study aimed to investigate the effectiveness of the frontal-midline theta (fmθ) activity uptraining protocol on attention and working memory performance of older and younger participants.

METHODS: Thirty-two participants were recruited. Participants within each age group were randomly assigned to either the neurofeedback training (fmθ uptraining) group or the sham-neurofeedback training group.

RESULTS: There was a significant improvement in orienting scores in the older neurofeedback training group. In addition, there was a significant improvement in conflict scores in both the older and young neurofeedback training groups. However, alerting scores failed to increase. In addition, the fmθ training was found to improve working memory function in the older participants. The results further showed that fmθ training can modulate resting EEG for both neurofeedback groups.

CONCLUSIONS: Our study demonstrated that fmθ uptraining improved attention and working memory performance and theta activity in the resting state for normal aging adults. In addition, younger participants also benefited from the present protocol in terms of improving their executive function.

SIGNIFICANCE: The current findings contribute to a better understanding of the mechanisms underlying neurofeedback training in cognitive function, and suggest that the fmθ uptraining protocol is an effective intervention program for cognitive aging.

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KEYWORDS: Attention; Frontal-midline theta; Neurofeedback; Sham-neurofeedback; Working memory

PMID: 23827814 DOI: 10.1016/j.clinph.2013.05.020
Working memory training using EEG neurofeedback in normal young adults.

Xiong S¹, Cheng C¹, Wu X¹, Guo X¹, Yao L², Zhang J¹.

Abstract
Recent studies have shown that working memory (WM) performance can be improved by intensive and adaptive computerized training. Here, we explored the WM training effect using Electroencephalography (EEG) neurofeedback (NF) in normal young adults. In the first study, we identified the EEG features related to WM in normal young adults. The receiver operating characteristic (ROC) curve showed that the power ratio of the theta-to-alpha rhythms in the anterior-parietal region, accurately classified a high percentage of the EEG trials recorded during WM and fixation control (FC) tasks. Based on these results, a second study aimed to assess the training effects of the theta-to-alpha ratio and tested the hypothesis that up-regulating the power ratio can improve working memory behavior. Our results demonstrated that these normal young adults succeeded in improving their WM performance with EEG NF, and the pre- and post-test evaluations also indicated that WM performance increase in experimental group was significantly greater than control groups. In summary, our findings provided preliminarily evidence that WM performance can be improved through learned regulation of the EEG power ratio using EEG NF.

KEYWORDS: Electroencephalography; neurofeedback; power spectrum; self-regulation; working memory

PMID: 25227076 DOI: 10.3233/BME-141191
[Indexed for MEDLINE]
The effect of gamma enhancing neurofeedback on the control of feature bindings and intelligence measures

André W. Keizer a, Maurice Verschoor b, Roland S. Verment b, Bernhard Hommel a

https://doi.org/10.1016/j.ijpsycho.2009.10.011
Self-Regulation of Amygdala using NFB

Self-Regulation of Amygdala Activation Using Real-Time fMRI Neurofeedback


Published: September 8, 2011 • https://doi.org/10.1371/journal.pone.0024522

Abstract

Real-time functional magnetic resonance imaging (rtfMRI) with neurofeedback allows investigation of human brain neuroplastic changes that arise as subjects learn to modulate neurophysiological function using real-time feedback regarding their own hemodynamic responses to stimuli. We investigated the feasibility of training healthy humans to self-regulate the hemodynamic activity of the amygdala, which plays major roles in emotional processing. Participants in the experimental group were provided with ongoing information about the blood oxygen level dependent (BOLD) activity in the left amygdala (LA) and were instructed to raise the BOLD rtfMRI signal by contemplating positive autobiographical memories. A control group provided with the same information but without instruction showed no change in BOLD activity. These results suggest that it might be possible to train healthy humans to self-regulate the amygdala.
References


Improve Learning & Memory

- Improve Sleep
- Learn New Language
- Incorporate Testing & Rehearsal
- Improve Attention
- Increase Exercise & Reduce Toxins
- Use 3D and VR Content

Learn New Language

Improve Sleep

Incorporate Testing & Rehearsal

Improve Attention

Use 3D and VR Content

Increase Exercise & Reduce Toxins
Thank You

Email: aamir_saeed@utp.edu.my

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Wajid Mumtaz
Raja Nur hamizah