Factors affecting Learning and Memory: Implications for Intervention

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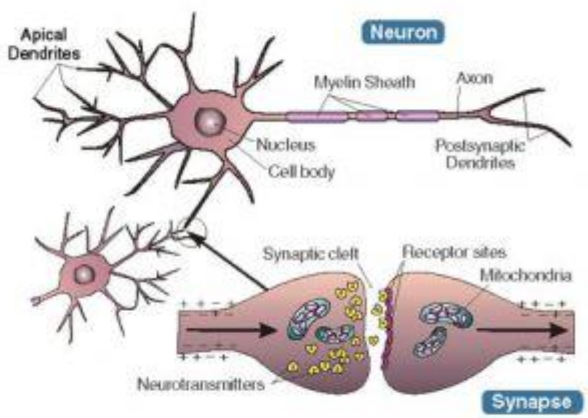
Outline

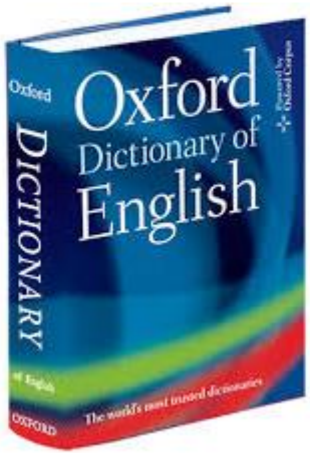
- Introduction
- The Learning Process
- Memory Model
- Factors Affecting Learning and Memory
- Long-term Memory Assessment
- Experimental Evidences of use of 3D Technology
- Neurofeedback Research
- References

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



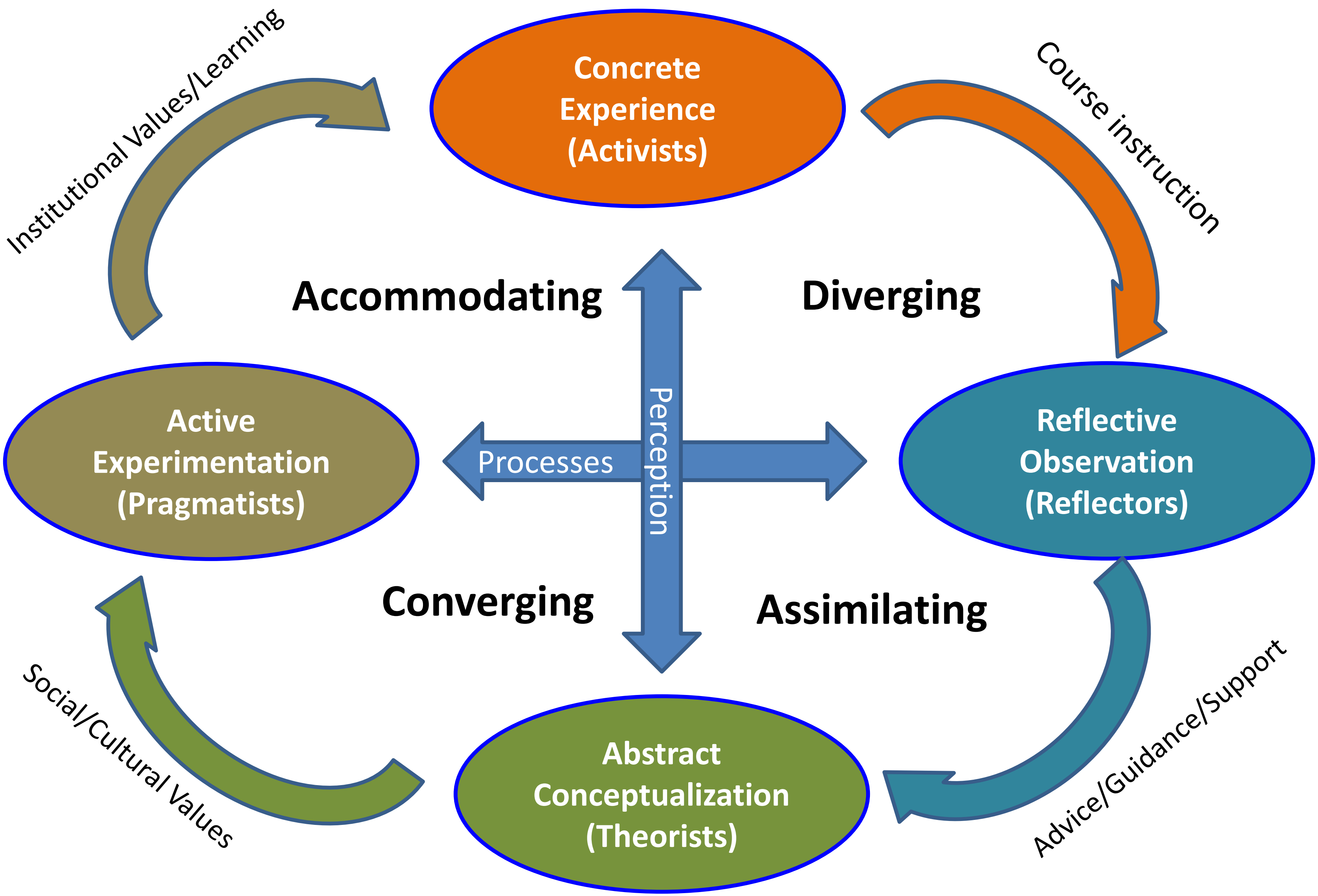
Learning



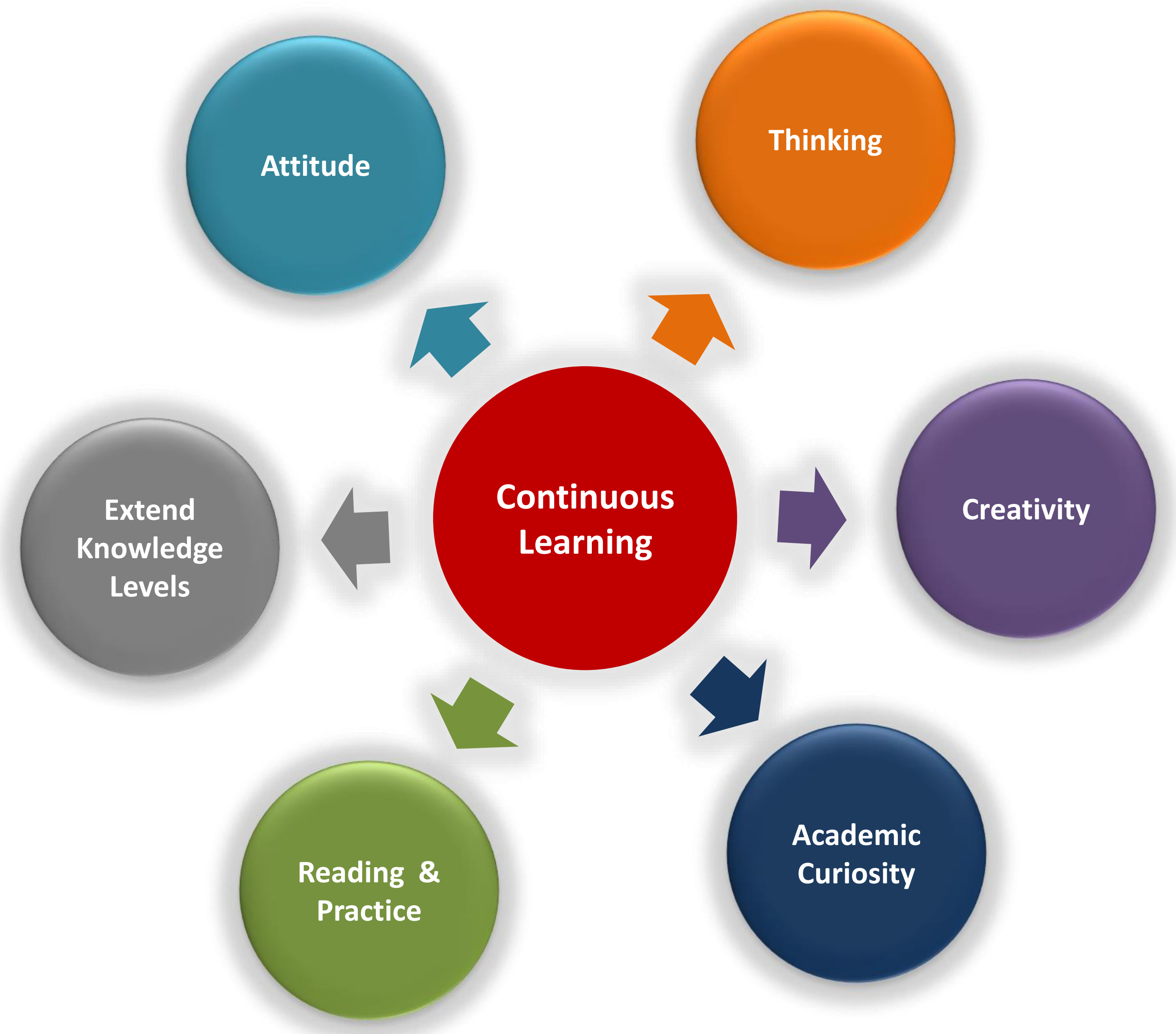
"The acquisition of knowledge or skills through study, experience, or being taught."

"any relatively permanent **change** in behaviour that occurs as a result of **practice** and **experience**"

The Learning Process



Why Learning is the continuous Process



How Does Learning Occur?

- To explain how and when learning occurs, a number of different psychological theories have been proposed.

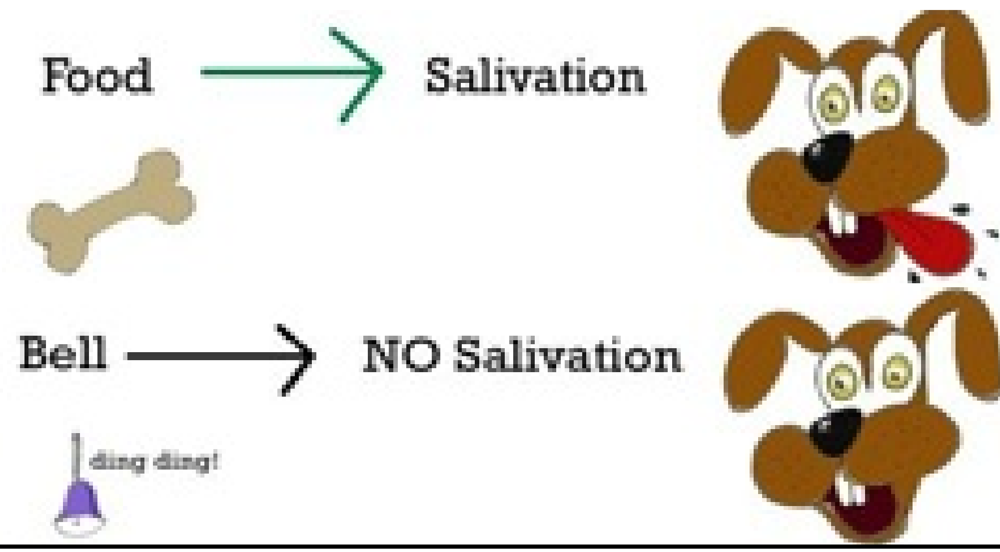
Classical Conditioning

Operant Conditioning

Social learning

Learning through Classical conditioning

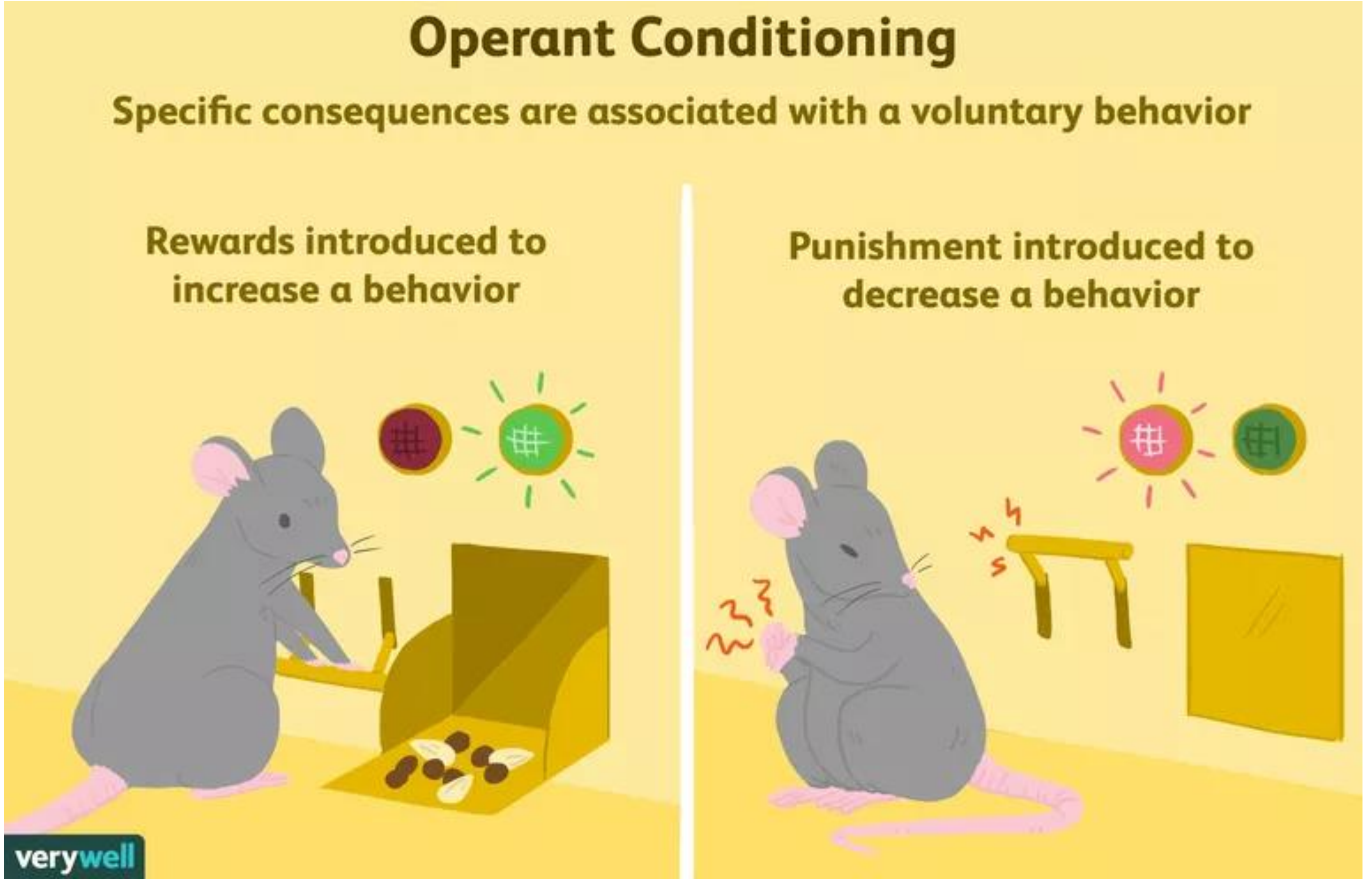
Before Classical Conditioning



During Classical Conditioning

After Classical Conditioning

Operand Conditioning



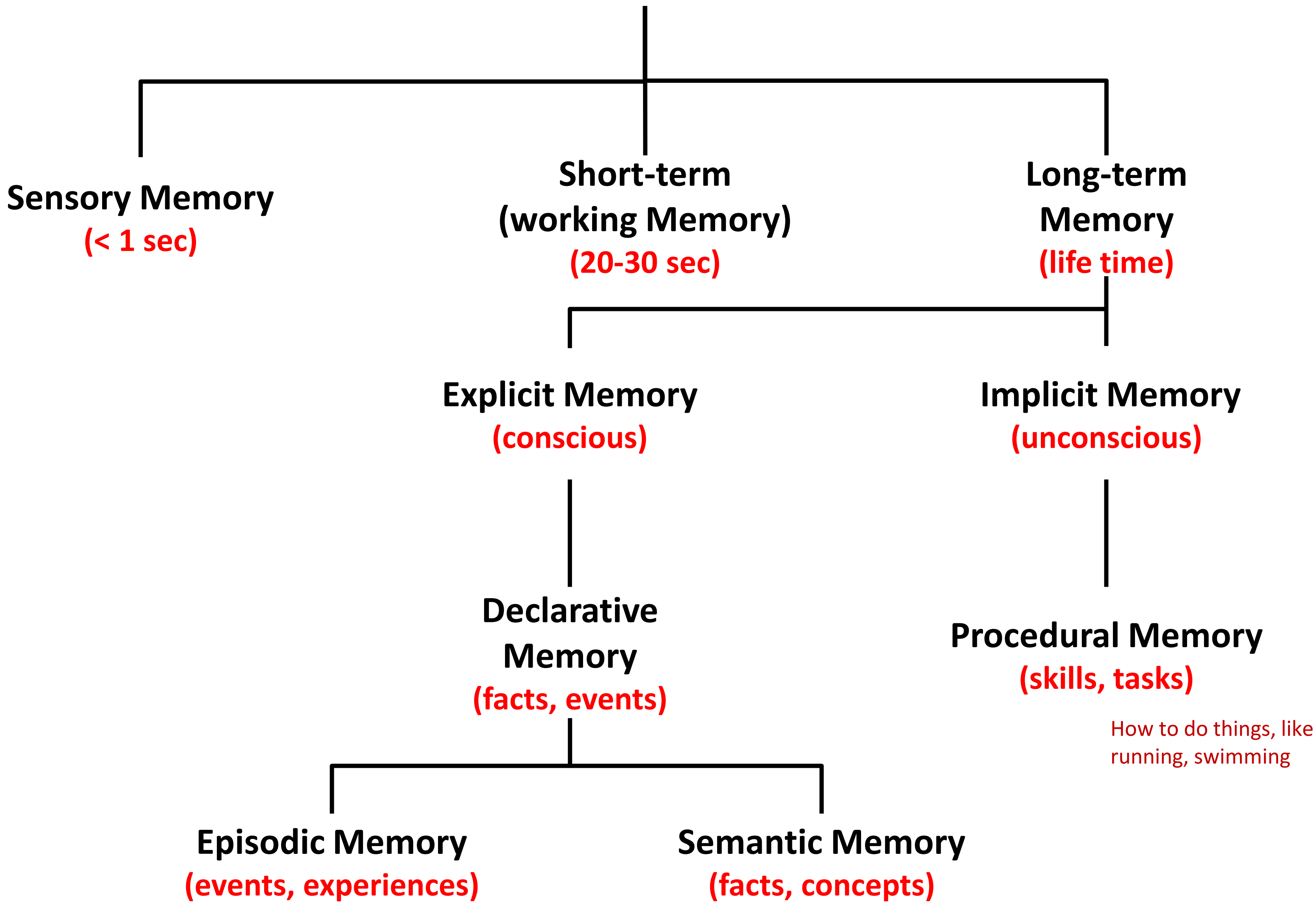
- For example, when a lab rat presses a green button, it receives a food pellet as a reward, but when he presses the red button he receives a mild electric shock.
- As a result, he learns to press the green button but avoid the red button.

Social Learning

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

Memory

Memory Types



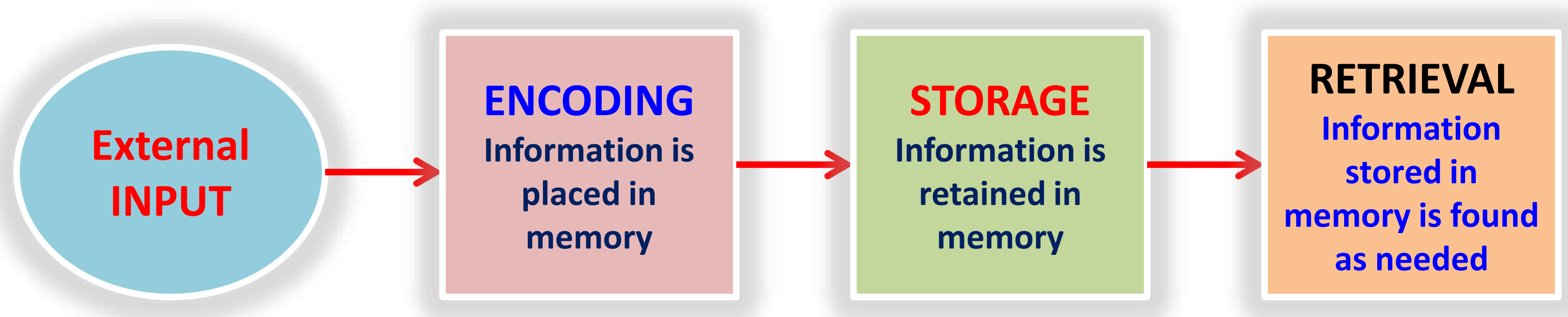
Memory Processes

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**).

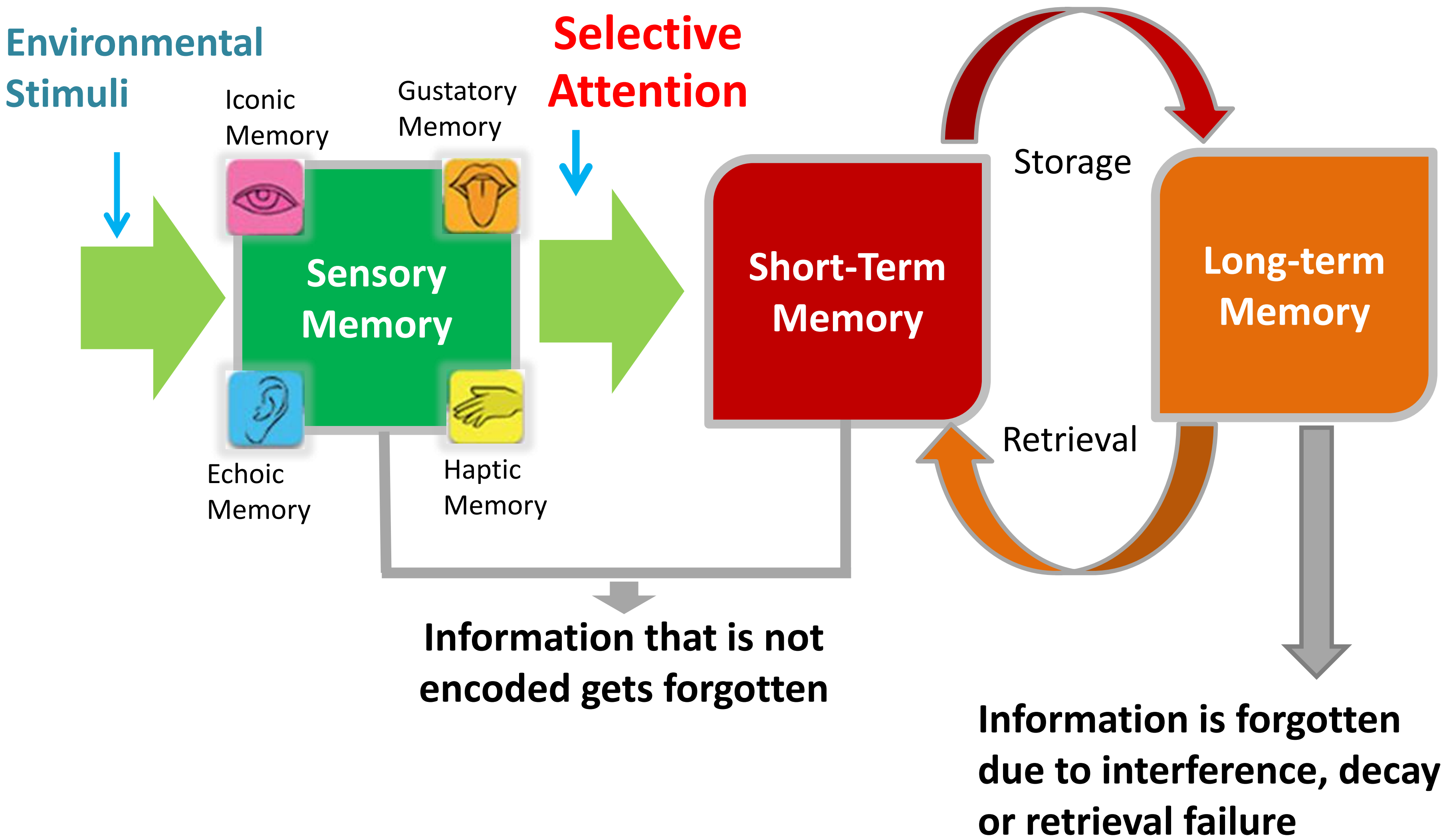
Memory Encoding: It allows the perceived information of interest to be converted into construct that can be stored within the brain, which can later be recalled.

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



Factor Affecting Learning and Memory

Factors

- Sleep
- Caffeine
- Working Memory
- Emotion
- Intelligence
- Exercise
- Recall or Testing
- Rehearsal
- Attention
- Multi-lingual
- 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

BMC Res Notes. 2015; 8: 706. PMCID: PMC4657259
Published online 2015 Nov 23. doi: 10.1186/s13104-015-1712-9 PMID: 26597849

Good sleep quality is associated with better academic performance among Sudanese medical students

Hyder Osman Mirghani,[✉] Osama Salih Mohammed, Yahia Mohamed Almurtadha, and Moneir Siddig Ahmed

Abstract

Go to:

Background

Go to:

There is increasing awareness about the association of sleep quality and academic achievement among university students. However, the relationship between sleep quality and academic performance has not been examined in Sudan; this study assessed the relationship between sleep quality and academic performance among Sudanese medical students.

- A strong relationship is evident between good sleep quality and high academic performance.

AMERICAN JOURNAL OF
PHARMACEUTICAL
EDUCATION

Am J Pharm Educ. 2015 Jun 25; 79(5): 63.
doi: 10.5688/ajpe79563

PMCID: PMC4571043
PMID: 26396272

Sleep Duration and Academic Performance Among Student Pharmacists

Megan L. Zeek, PharmD, Matthew J. Savoie, PharmD, Matthew Song, PharmD, Leanna M. Kennemur, PharmD, Jingjing Qian, PhD, MS, Paul W. Jungnickel, PhD, MS, and Salisa C. Westrick, PhD, MS[☒]

Abstract

Go to:

Objective. To identify sleep patterns and frequency of daytime sleepiness and to assess the association between sleep duration and academic performance among student pharmacists.

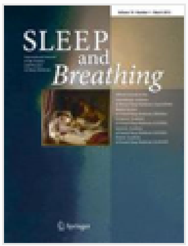
Methods. A cross-sectional design was used. An anonymous self-administered paper questionnaire was administered to first-year through third-year students at a pharmacy school.

Results. Questionnaires were completed by 364 student pharmacists (79.4% response rate and 93.8% cooperation rate). More than half of student pharmacists obtained less than 7 hours of sleep at night during a typical school week (54.7%) and a large majority on the night prior to an examination (81.7%). Almost half (47.8%) felt daytime sleepiness almost every day. Longer sleep duration the night prior to an examination was associated with higher course grades and semester grade point averages (GPAs).

Conclusion: Adequate sleep the night prior to an examination was positively associated with student course grades and semester GPAs.

Caffeine

SpringerLink Search



Sleep and Breathing
March 2015, Volume 19, Issue 1, pp 123–127 | Cite as

A survey of college-bound high school graduates regarding circadian preference, caffeine use, and academic performance

Authors Authors and affiliations

James S. Cole

Original Article
First Online: 01 May 2014

- consumed no caffeine reported the highest grades with nearly 64 % reporting they earned mostly A’s or A-’s in high school

Working Memory

ELSEVIER

Research in Developmental Disabilities

Volume 58, November 2016, Pages 1-8

The importance of working memory for school achievement in primary school children with intellectual or learning disabilities

Claudia Maehler (Prof., Dr.), Kirsten Schuchardt (Dr.)

⊞ Show more

https://doi.org/10.1016/j.ridd.2016.08.007

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.

Working Memory

Format: Abstract ▾ Send to ▾

Am J Occup Ther. 2016 Nov/Dec;70(6):7006230010p1-7006230010p8.

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

Hubbard KK[1], Blyler D[2].

⊕ Author information

Abstract

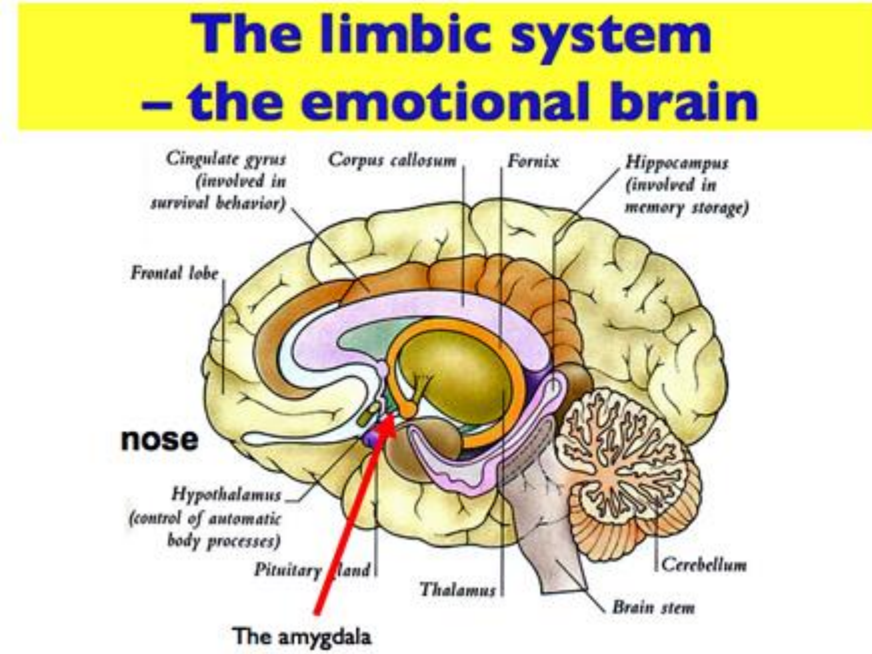
Research involving working memory has indicated that stress and anxiety compete for attentional resources when a person engages in attention-dependent cognitive processing. The purpose of this study was to investigate the impact of perceived stress and state anxiety on working memory and academic performance 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

LinkOut - more resources

Emotion

- Emotions Plays important role in learning and memory
- Its drive attention, which in turn drives learning and memory



Journal of School Psychology

Volume 40, Issue 5, September–October 2002, Pages 395-413

Emotionality, Emotion Regulation, and School Performance in Middle School Children

Gail Gumora, William F Arsenio

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https://doi.org/10.1016/S0022-4405(02)00108-5

Get rights and content

Abstract

This research investigated the connections of middle school students' emotional dispositions and academic-related affect with their school performance. One hundred three 6th–8th grade students completed three self-rated assessments regarding: (a) their academic

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

ELSEVIER

Learning and Individual Differences

Volume 1, Issue 1, 1989, Pages 37-62

The relationship between learning and intelligence

Arthur R. Jensen

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https://doi.org/10.1016/1041-6080(89)90009-5

Abstract

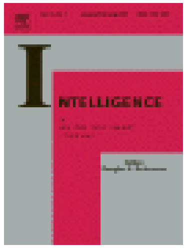
The historical separation of the study of learning and of intelligence is seen as an anomaly in the development of scientific psychology. Although learning and intelligence can be

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.

ELSEVIER

Intelligence

Volume 35, Issue 1, January–February 2007, Pages 13-21



Intelligence and educational achievement

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

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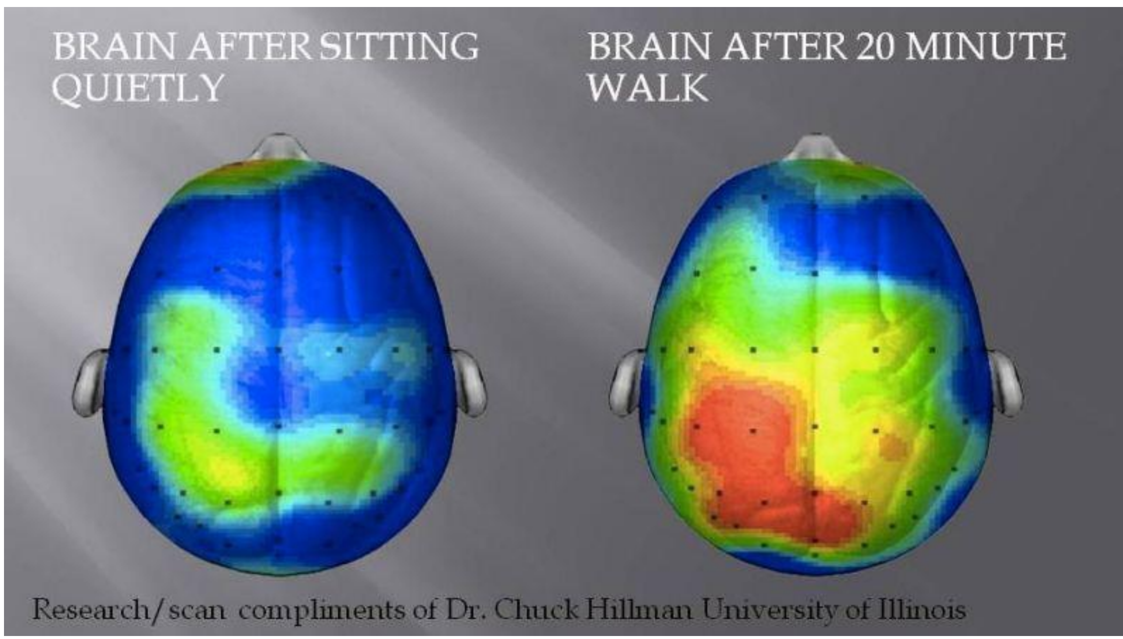
https://doi.org/10.1016/j.intell.2006.02.001

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



frontiers in Behavioral Neuroscience

Effects of Different Exercise Strategies and Intensities on Memory Performance and Neurogenesis

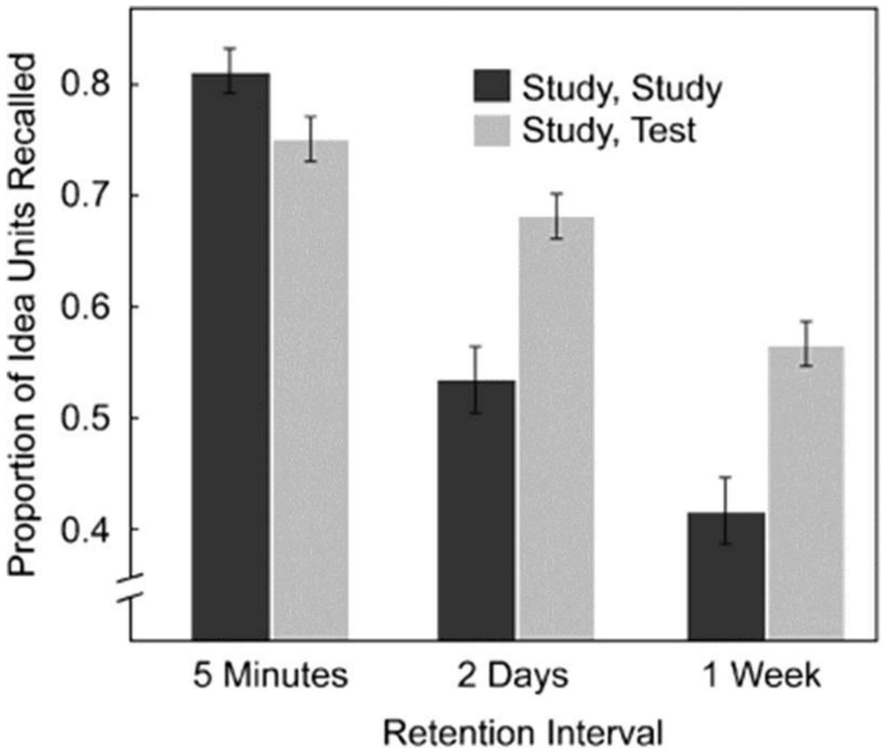
Kai Diederich[1], Anna Bastl[2], Heike Wersching[3], Anja Teuber[3], Jan-Kolja Strecker[1], Antje Schmidt[1], Jens Minnerup[1†] and Wolf-Rüdiger Schäbitz[4†]*

[1]Department of Neurology, University of Münster, Münster, Germany, [2]Department of Anesthesiology, Intensive Care, and Pain Medicine, University of Münster, Münster, Germany, [3]Institute of Epidemiology and Social Medicine, University of Münster, Münster, Germany, [4]Department of Neurology, Evangelisches Krankenhaus Bielefeld, Bielefeld, Germany

Results demonstrate that controlled training (CT), if performed with an appropriate combination of speed and duration, improves memory performance and neurogenesis.

Recall or Testing

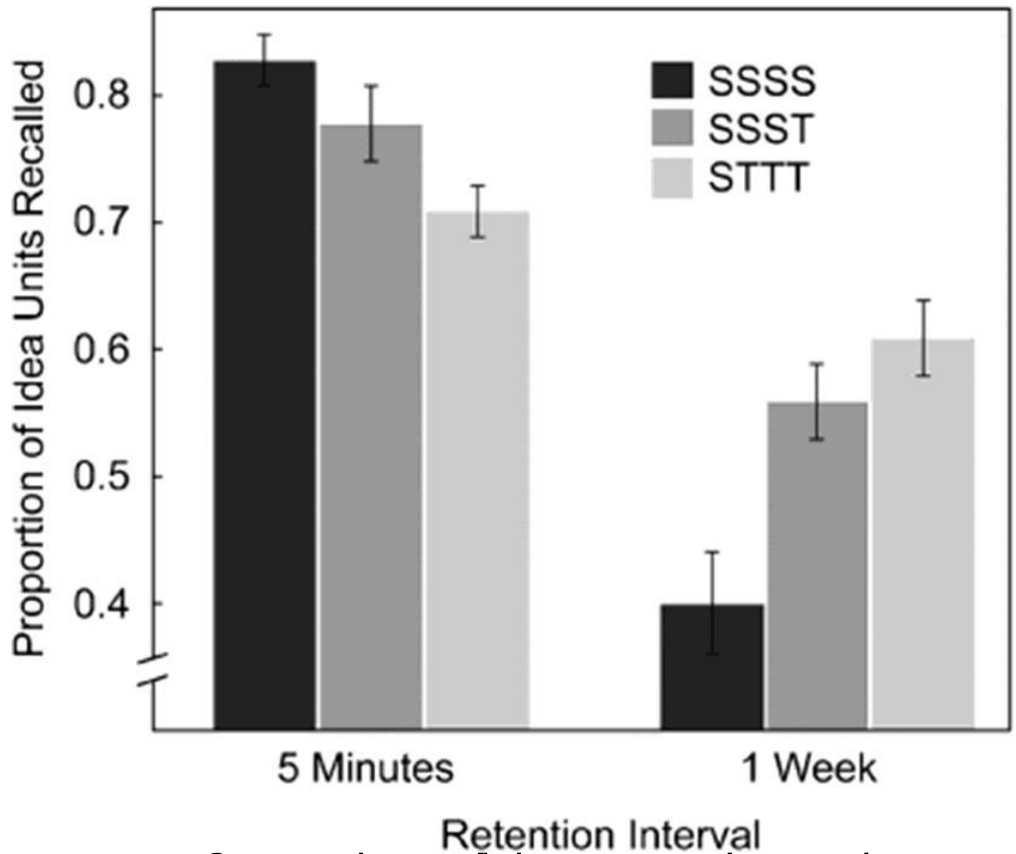
- Testing or retrieval practice is the process in which the studied items or stored memory are recollected
- The testing effect was first studied by Karpicke and Roediger in comparison with rehearsal for long-term retention



Proportion of memory recall in three different retention durations for rehearsal and testing effects

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

Rehearsal

- 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

frontiers in Psychology

OPINION
published: 25 February 2016
doi: 10.3389/fpsyg.2016.00265

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

Learning and Instruction

Volume 19, Issue 1, February 2009, Pages 28-42

Memory characteristics and modality in multimedia learning: An aptitude–treatment–interaction study

Tina Seufert, Maren Schütze, Roland Brünken

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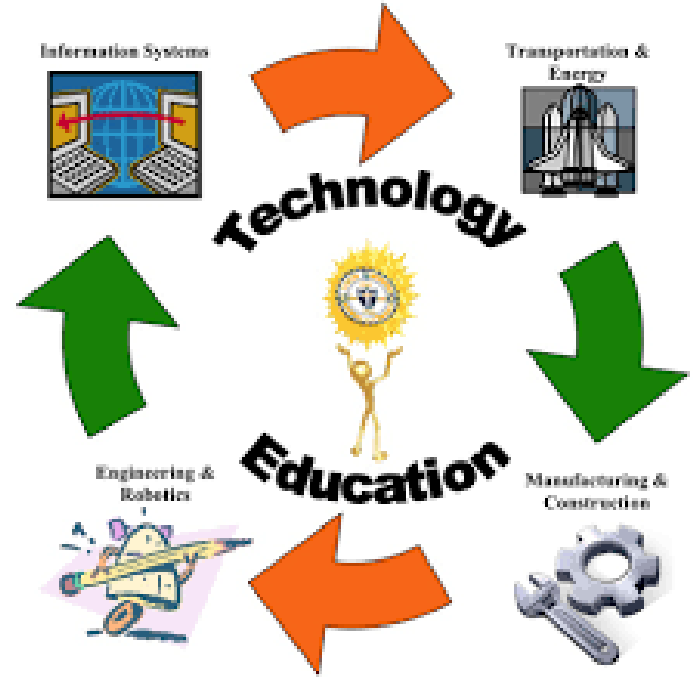
https://doi.org/10.1016/j.learninstruc.2008.01.002

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



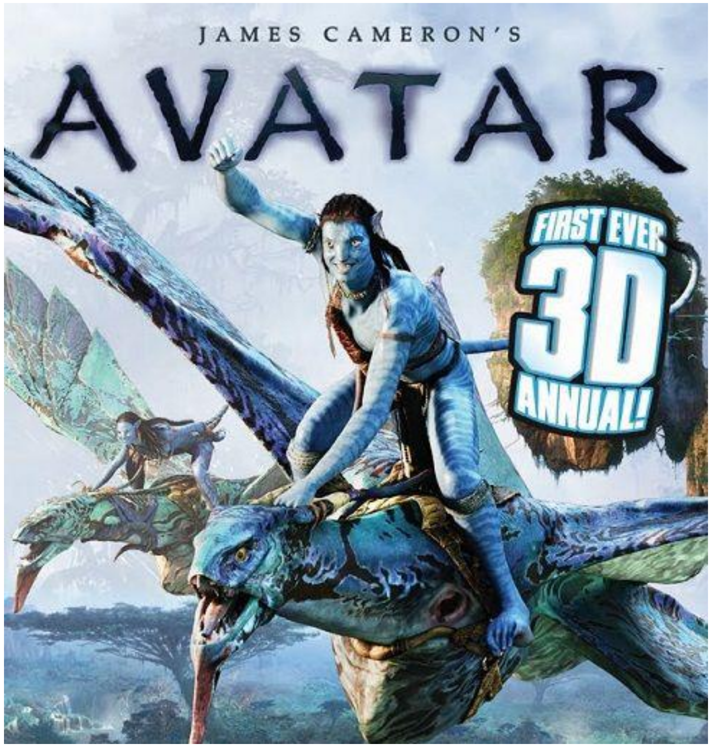
Factors

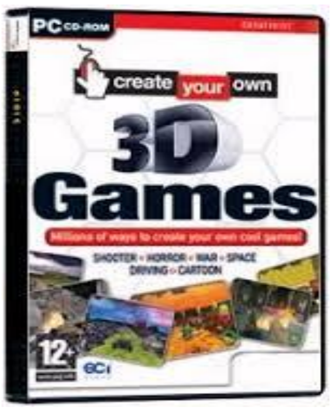
- Sleep
- Caffeine
- Working Memory
- Emotion
- Intelligence
- Exercise
- Recall or Testing
- Rehearsal
- Attention
- Multi-lingual
- Visual and Auditory Combination

3D Multimedia in Education

Since 2009: Entertainment

In 2009, James Cameron's Avatar:
A Stereoscopic 3D movie





Stereoscopic 3D in Serious Domain

Such as education & research, architecture design (3D CAD), health & medicine (training, imaging, therapy, and surgery).

Education

S3D in Education

Prof. A. Bamford
University of Arts Landon & Director of Int. Research Agency

- **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***

3D in Education (5)

- **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.

3D in Education (8)

- 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)

- <u>Teachers and Pupils Comments:</u>

"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**

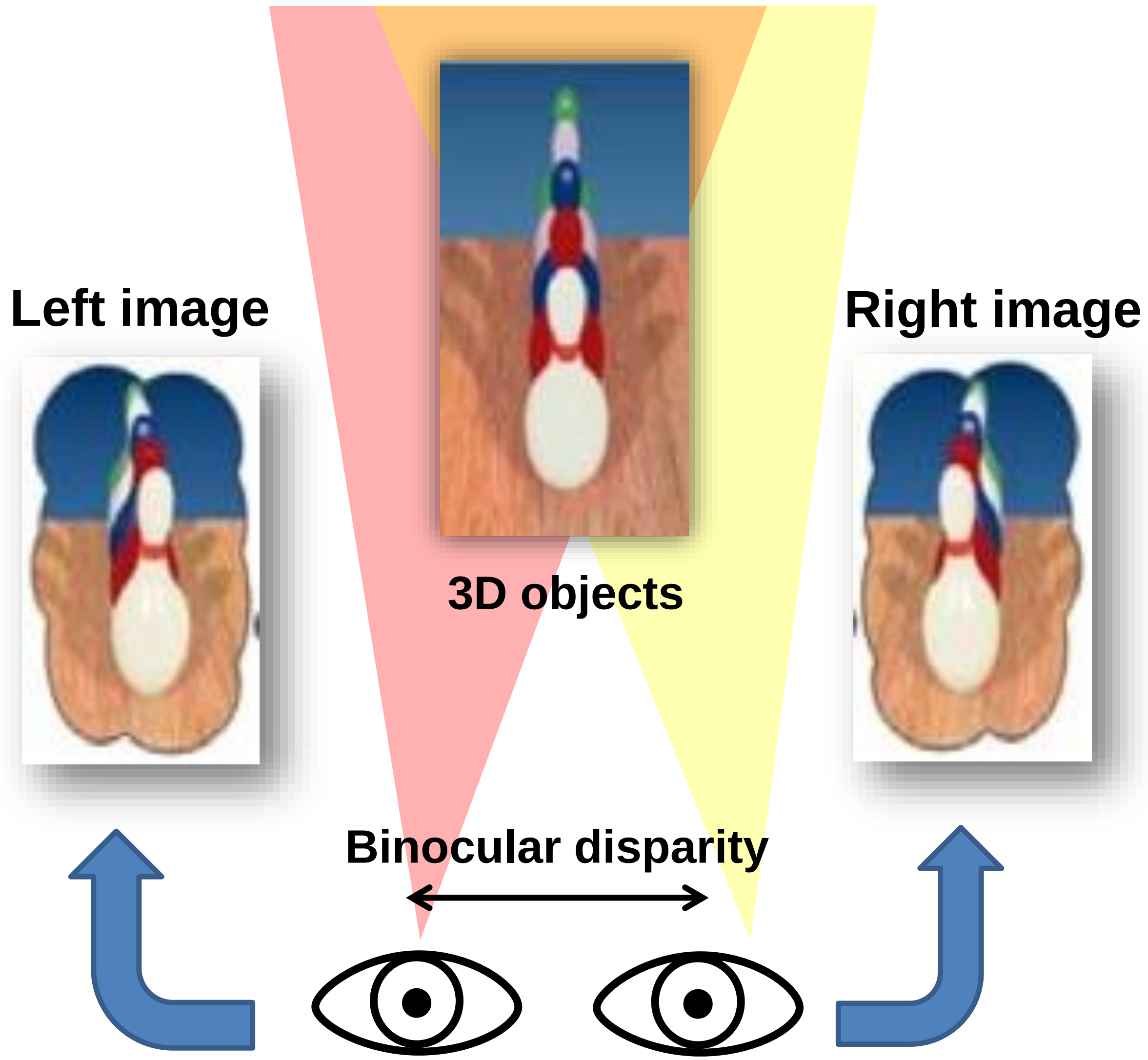
WHY?

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

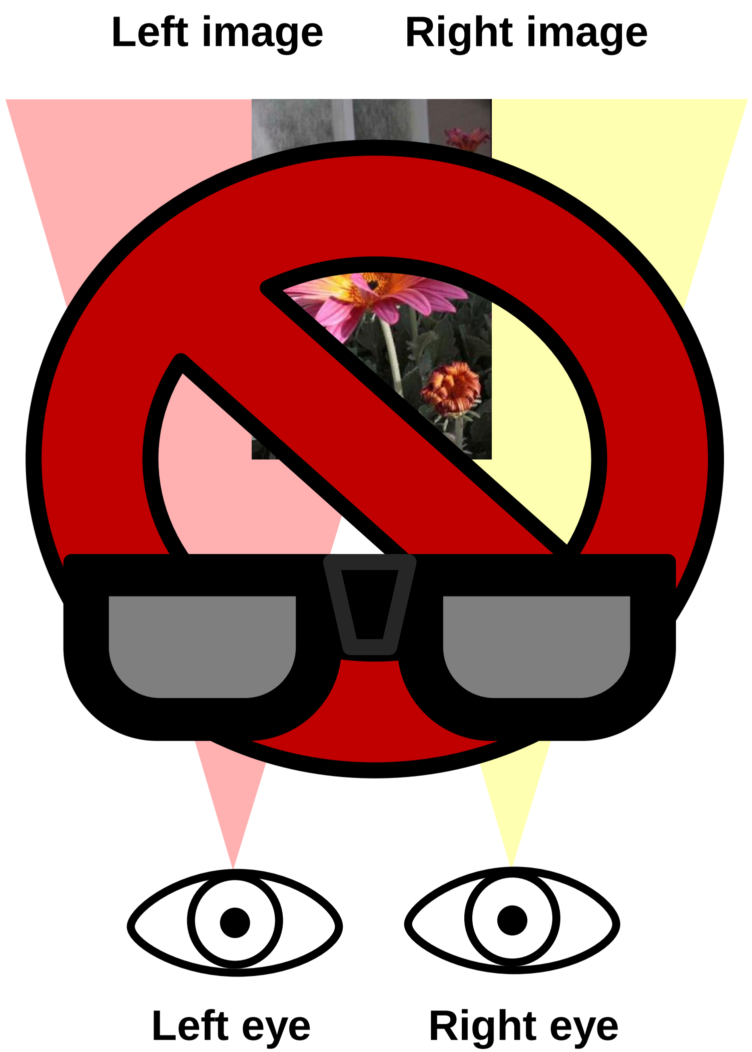
- The question is WHY 3D is producing such good results?

- Another question is WHICH 3D technology is the best?

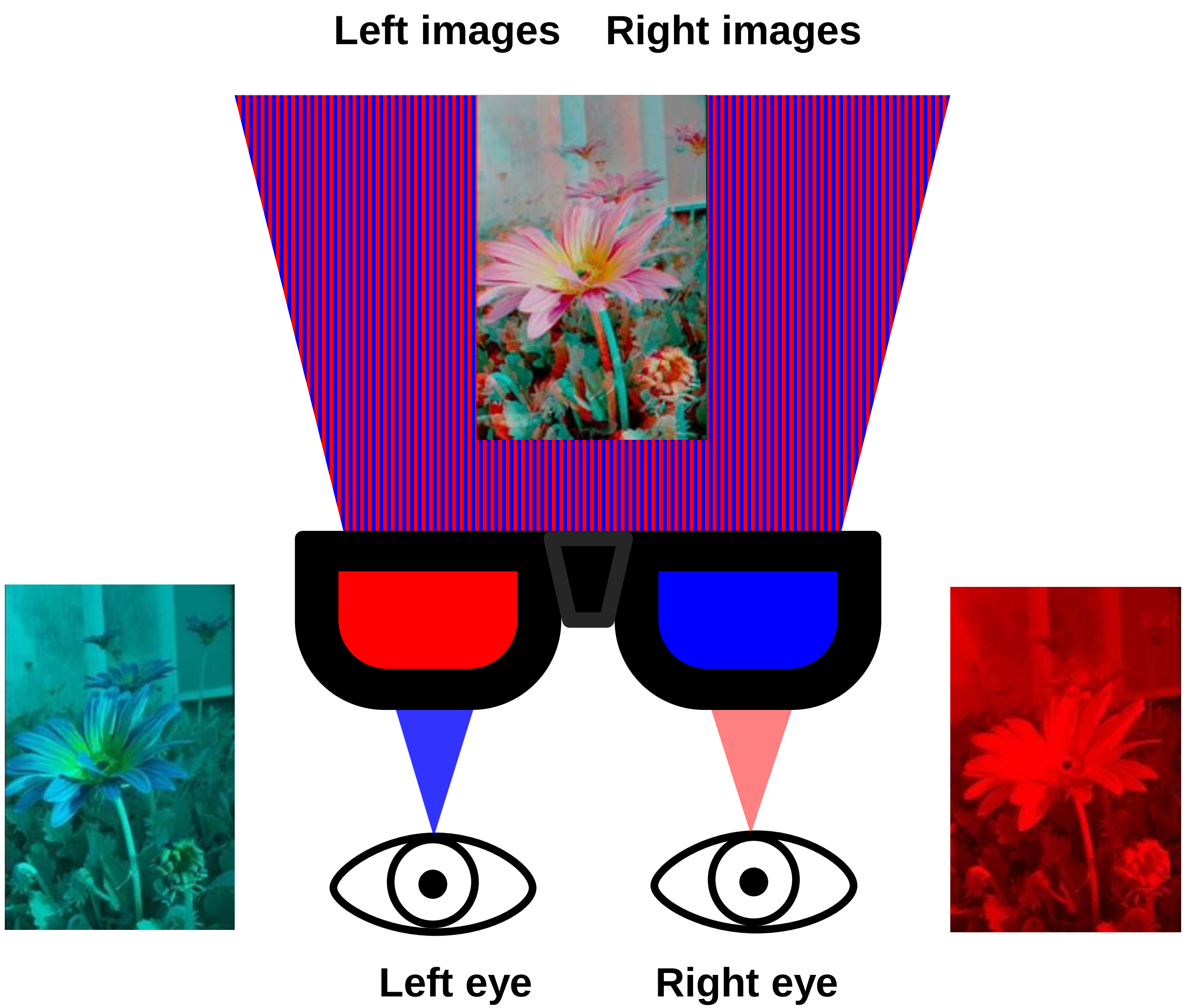
3D Perception



The imitation of 3D vision

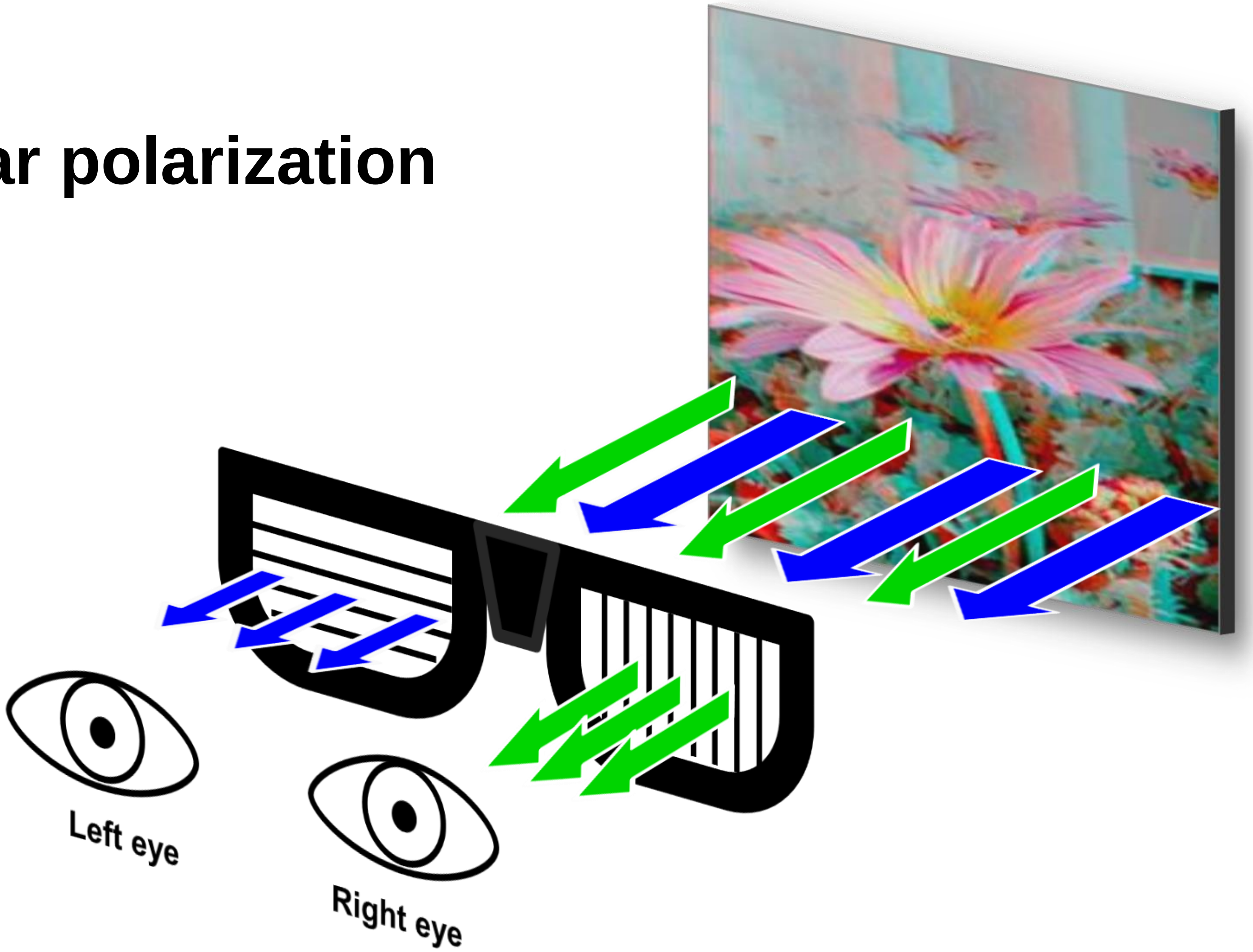


Anaglyph Glasses



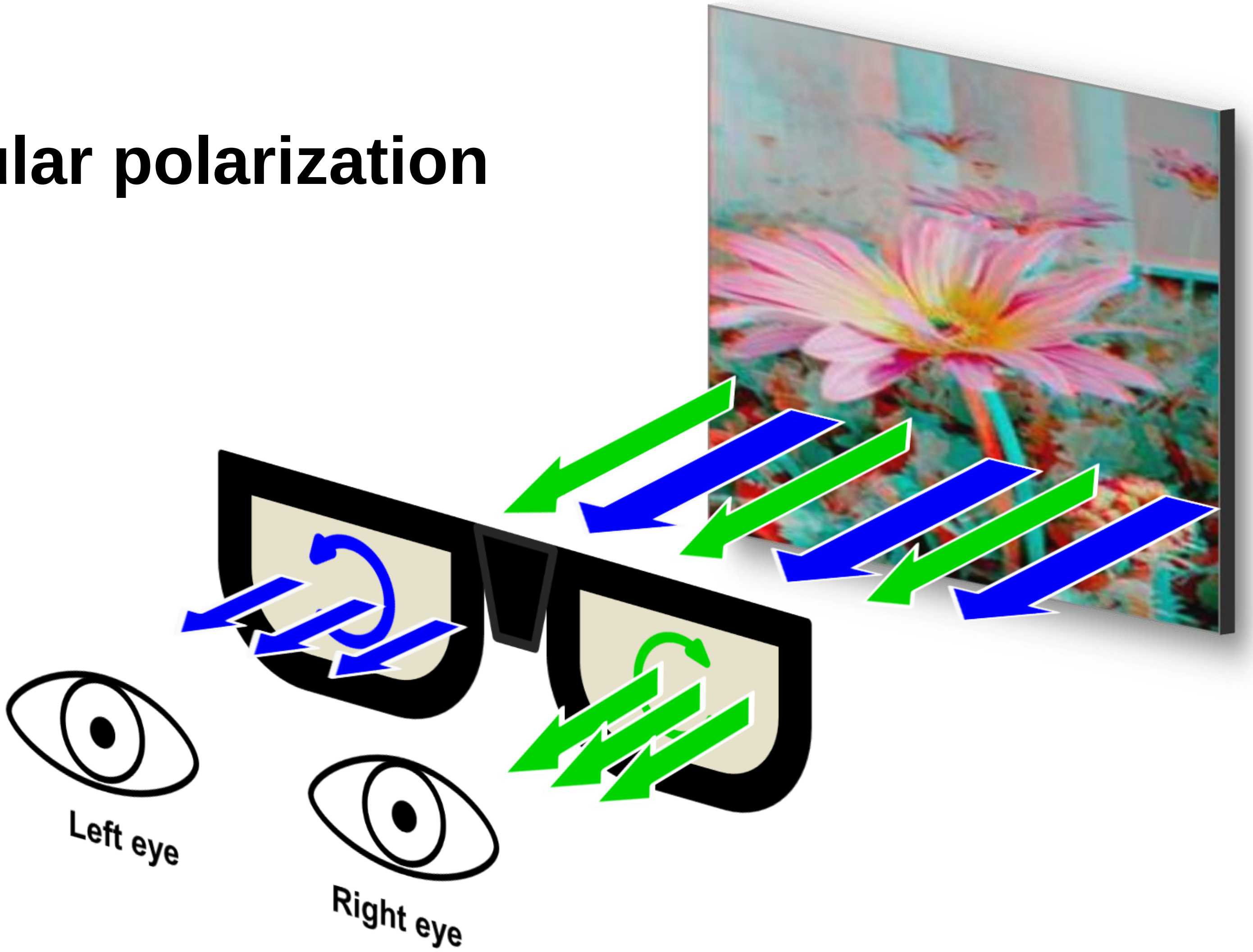
3D Passive Polarized Glasses

- Linear polarization

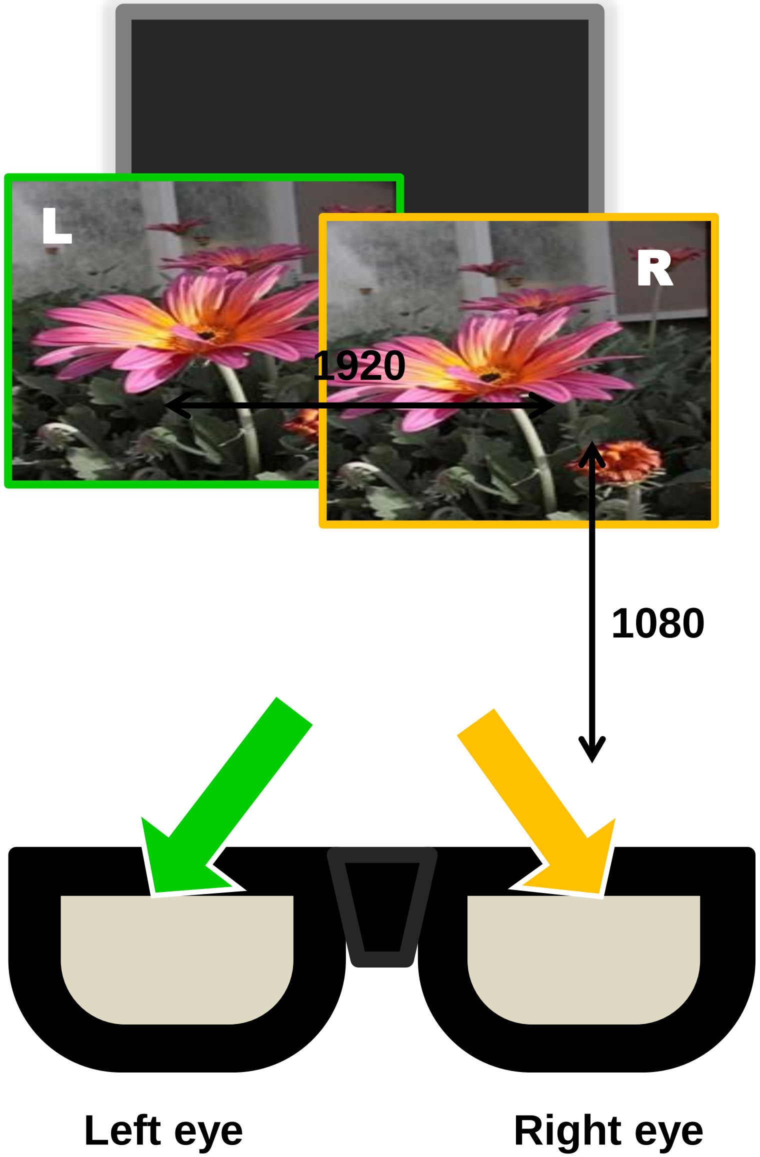


3D Passive Polarized Glasses

- Circular polarization

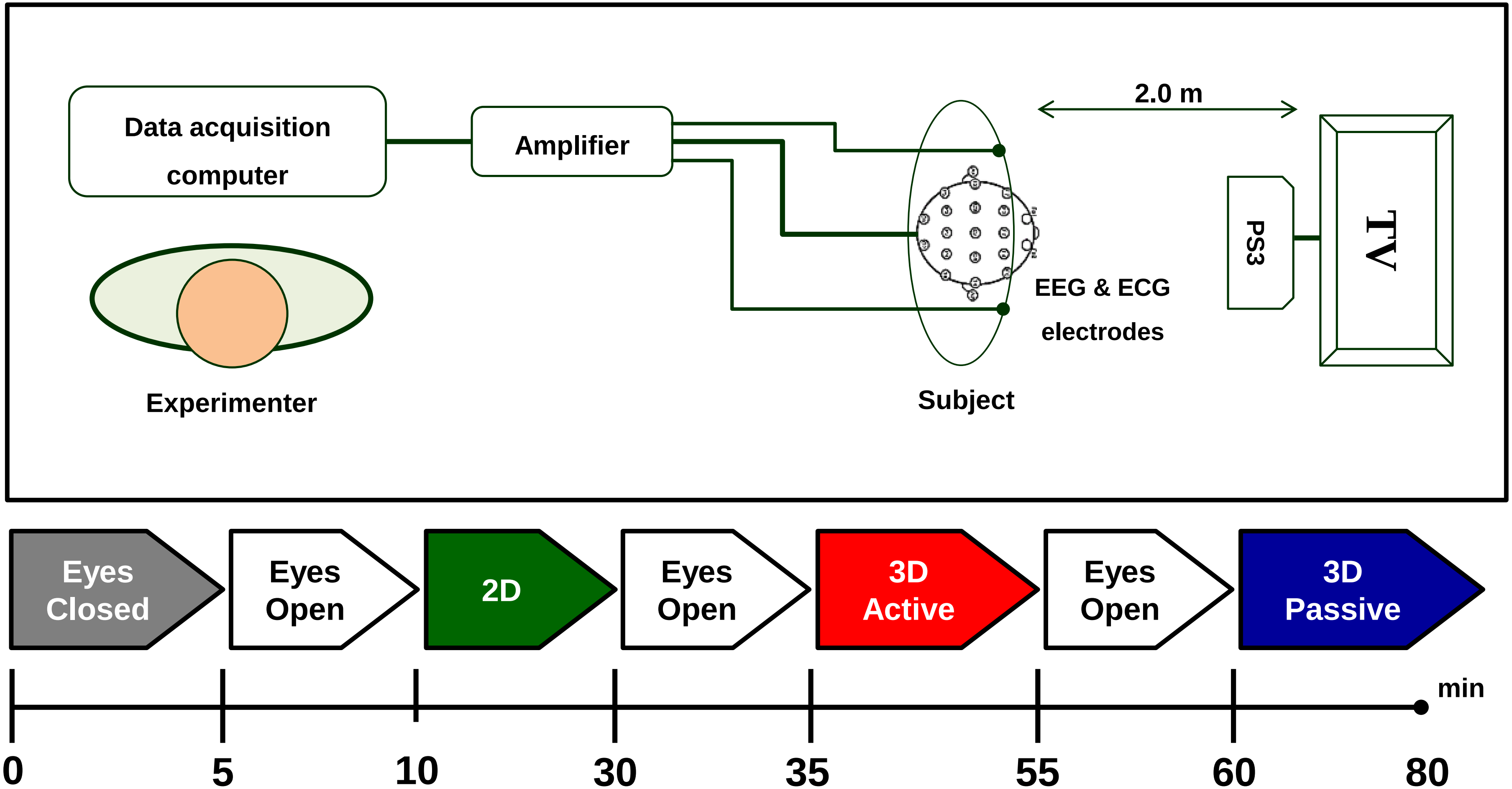


3D Active Shutter Glasses

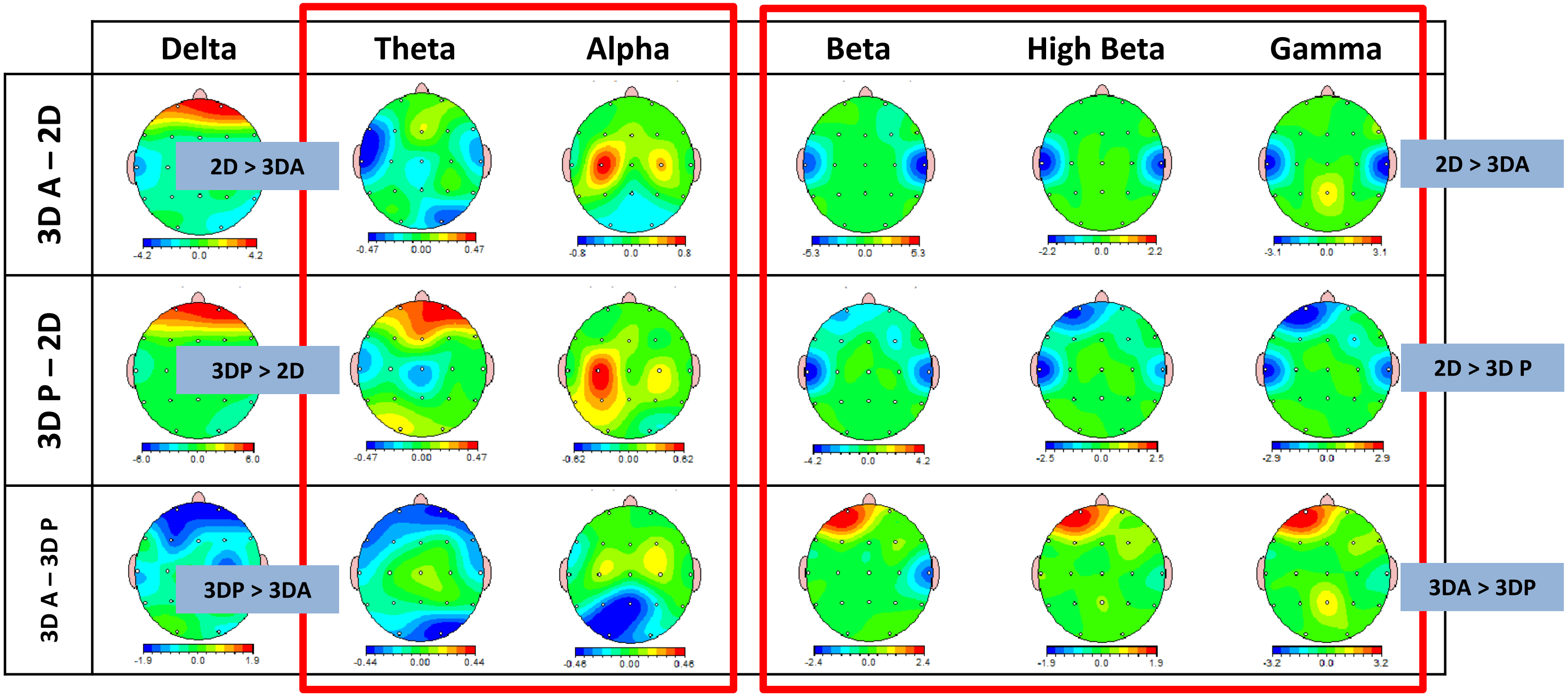


Methodology

Experimental Design



EEG Power Difference



- 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)

Higher bands (θ – α):
local processing
i.e. problem solving, hearing

Lower bands (θ – α):
global & distributed processing
i.e. working memory, attention

	Delta	Theta	Alpha			
3D A – 2D	*T3, *T4, *T5, *T6, *O1, *O2			*C4, *CZ, *P3, *P4, *PZ, *T3, *T4	*T3, *T4	*T3, *T4
3D P – 2D	C3, P4, O1, T3, T5, CZ, *T4, *T6, *O2	O1, FZ	C4, FZ	FP1, FP2, C3, P4, *F3, *F4, *F7, *PZ, *T3, *T4	FP1, *F3, *F4, *F7, *T3, *T4	F7, *F3, *F4, *T3, *T4
3D A – 3D P	F3, F4, C4, T5, *FZ, *T3, *O2	FP1, O1, *FP2, *T3, *T4, *O2	O2, T4, *F7, *O1	FZ, PZ, *C4, *CZ	*FP2, *F3, F4	*F3, F4

2D > 3DA

2D > 3DA

3DP > 2D

2D > 3DP

3DP > 3DA

3DA > 3DP

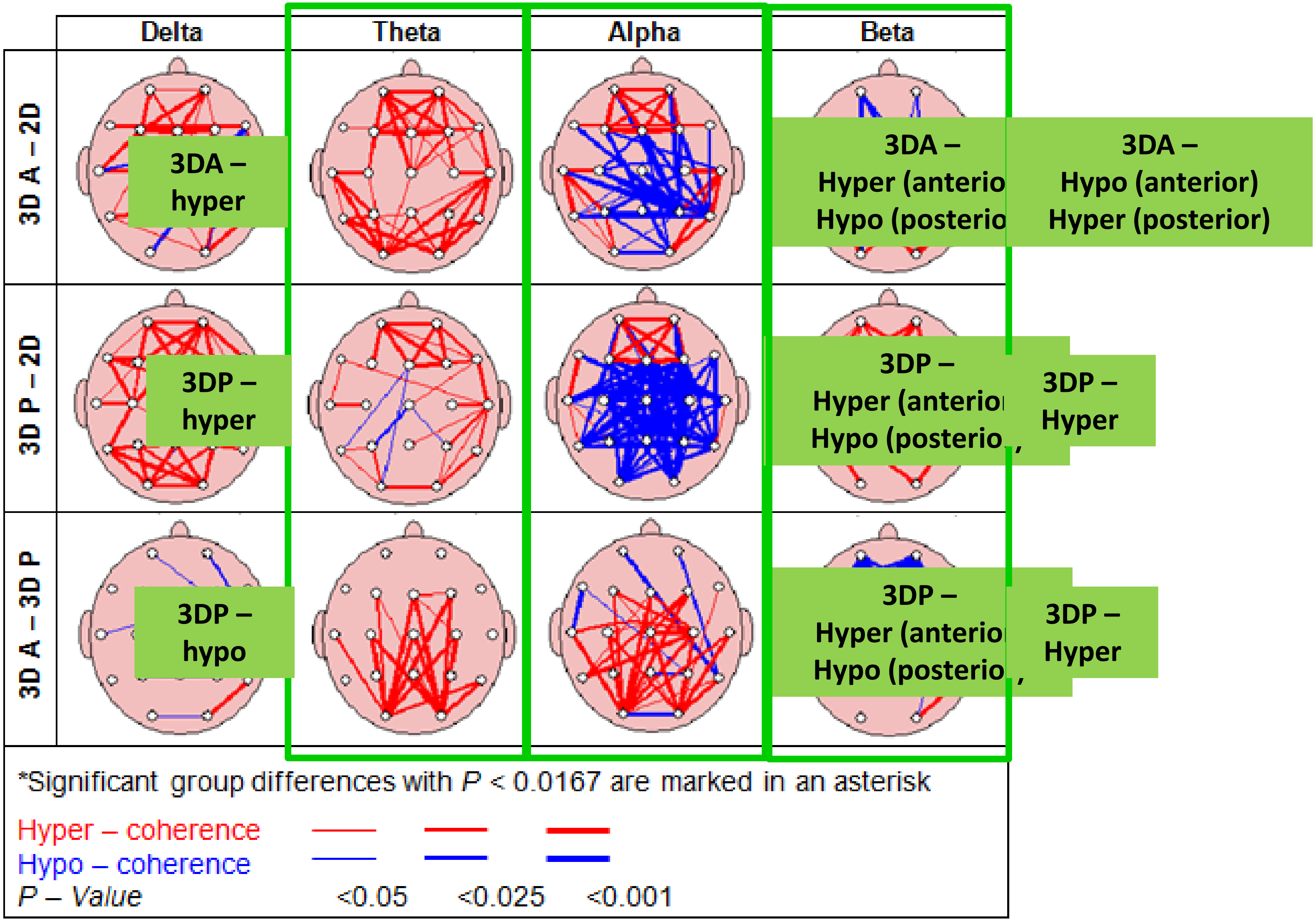
P < 0.0167

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**

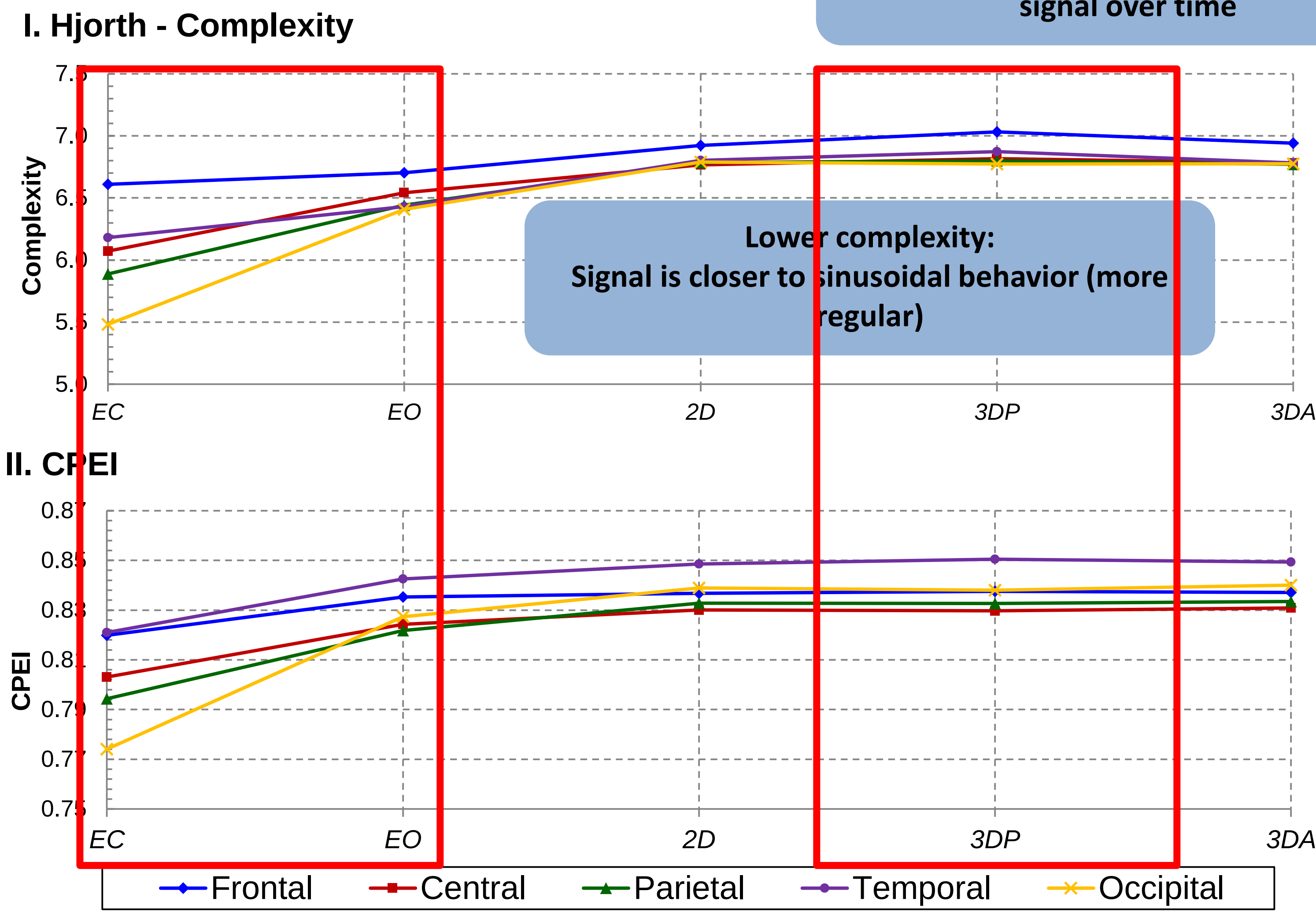
P – Values in **green** indicate that activation in **3D passive are greater than 2D/ 3D active**

EEG Coherence Difference

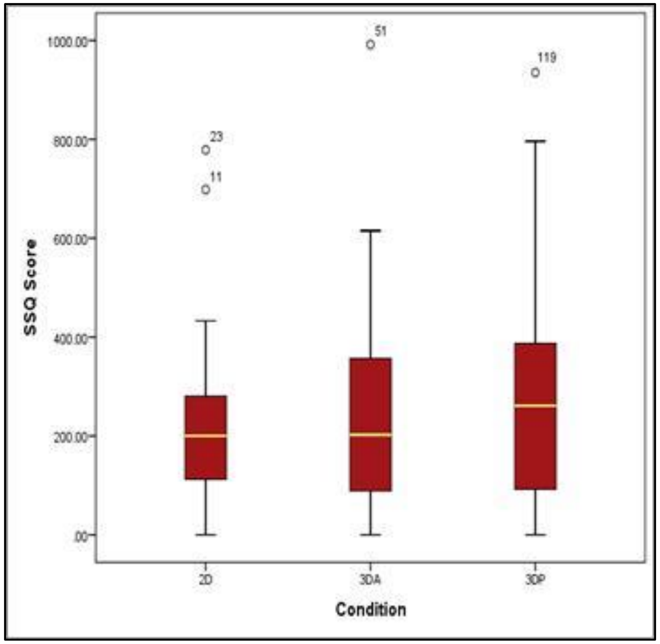


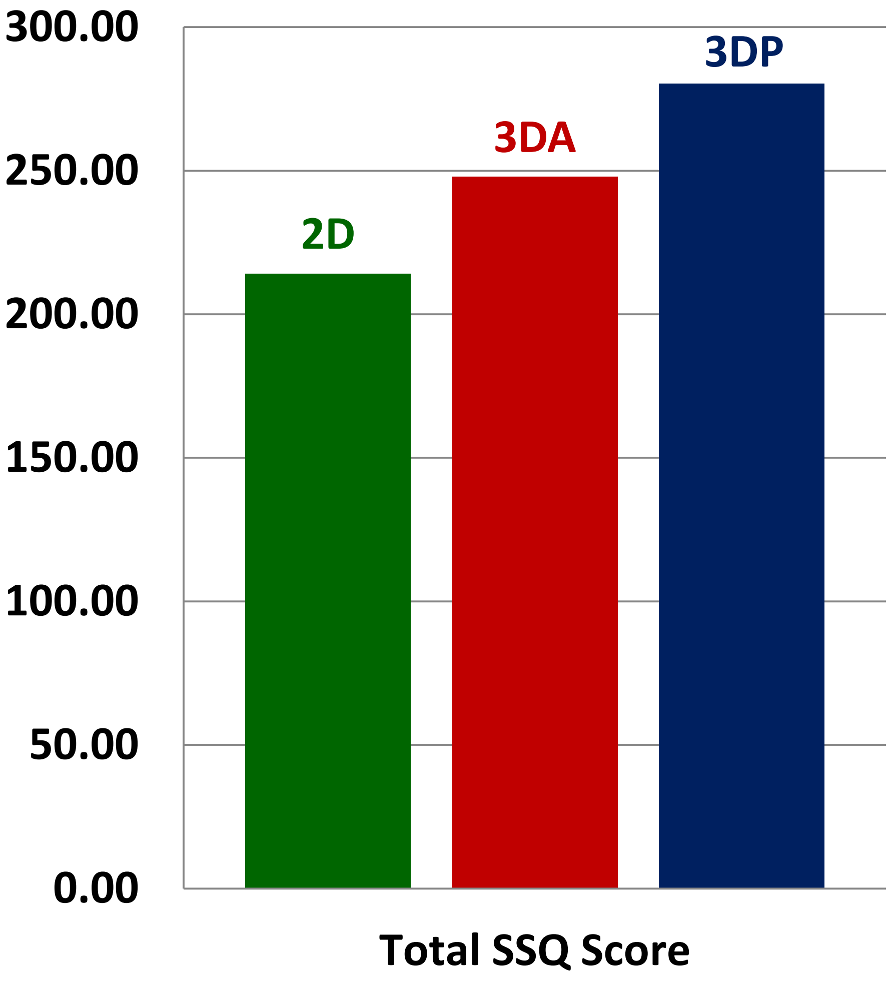
Signal Reg

Higher complexity:
More sudden frequent changes in the signal over time



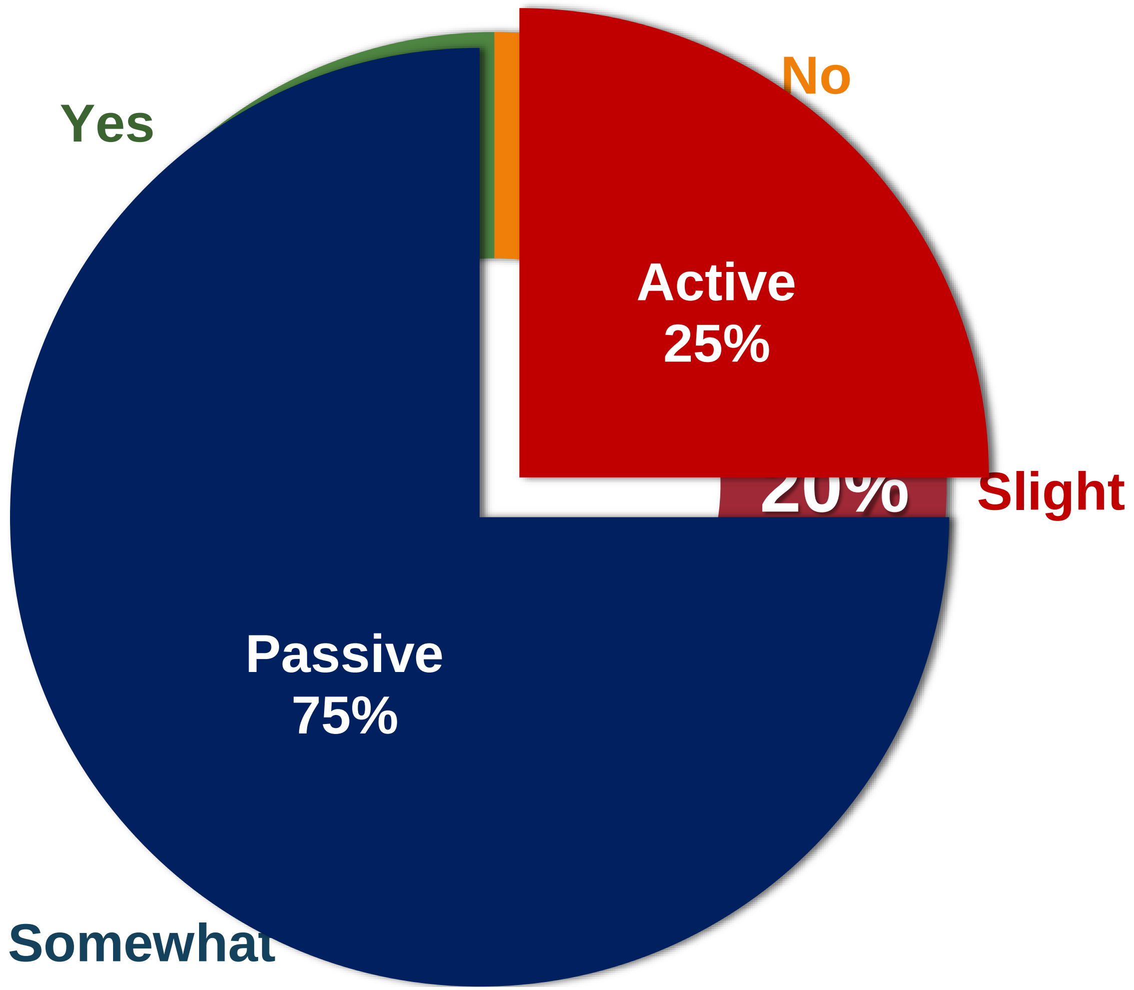
SSQ


1000.00
800.00
600.00
400.00
200.00
.00
SSQ Score
51
119
23
11
2D
3DA
3DP
Condition


300.00
250.00
200.00
150.00
100.00
50.00
0.00
3DP
3DA
2D
Total SSQ Score

Subjective Feedback

3D Active or 3D Passive?



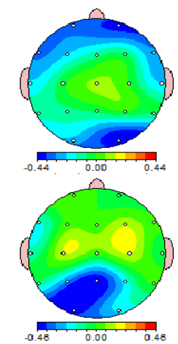
Results summary

3D Active Failures

EEG absolute power is lower than 2D (in all bands)

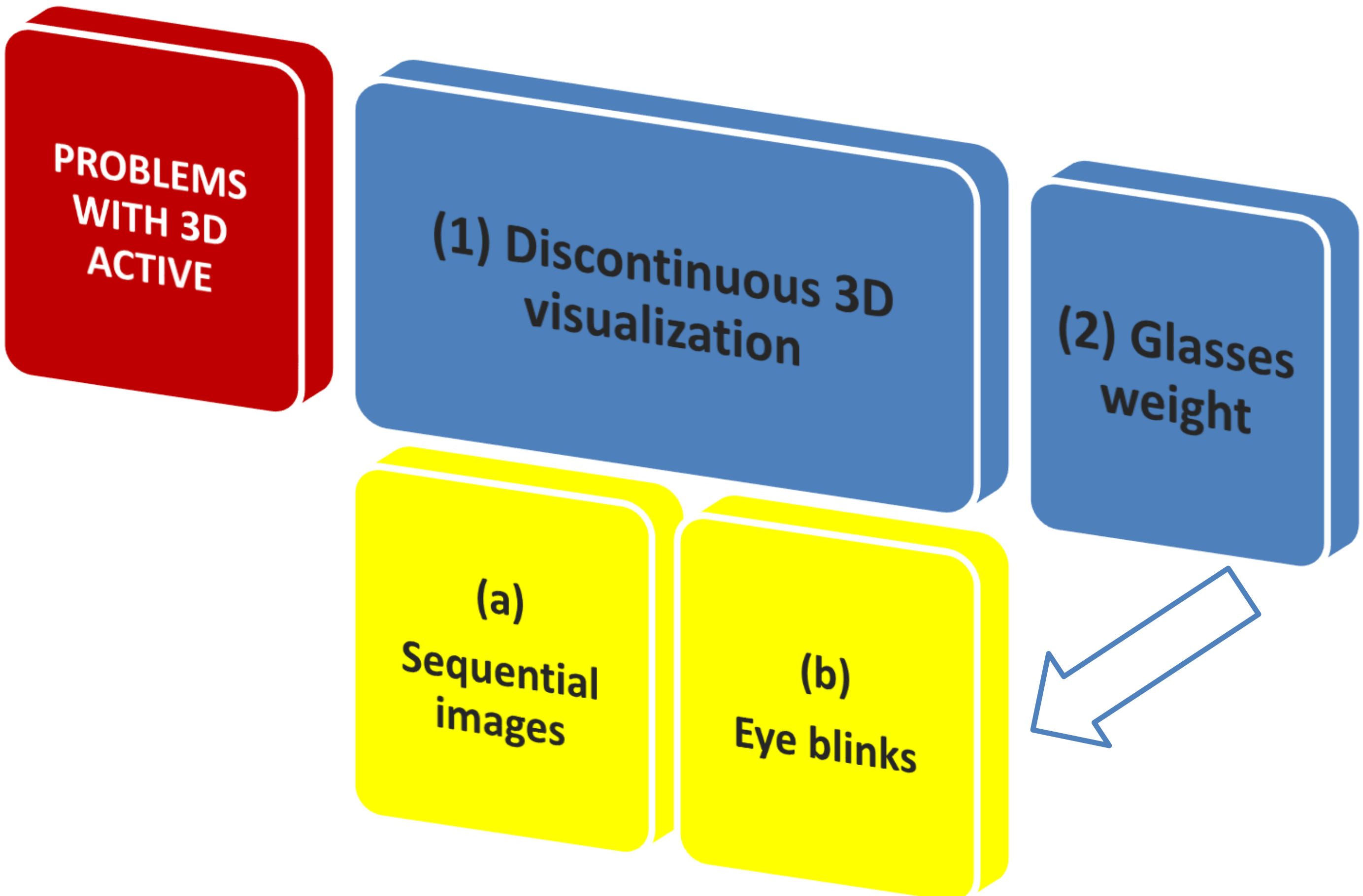
Majority subjects preferred 3DP viewing mode

EEG power is significantly lower than 3DP (in occipital lobe)

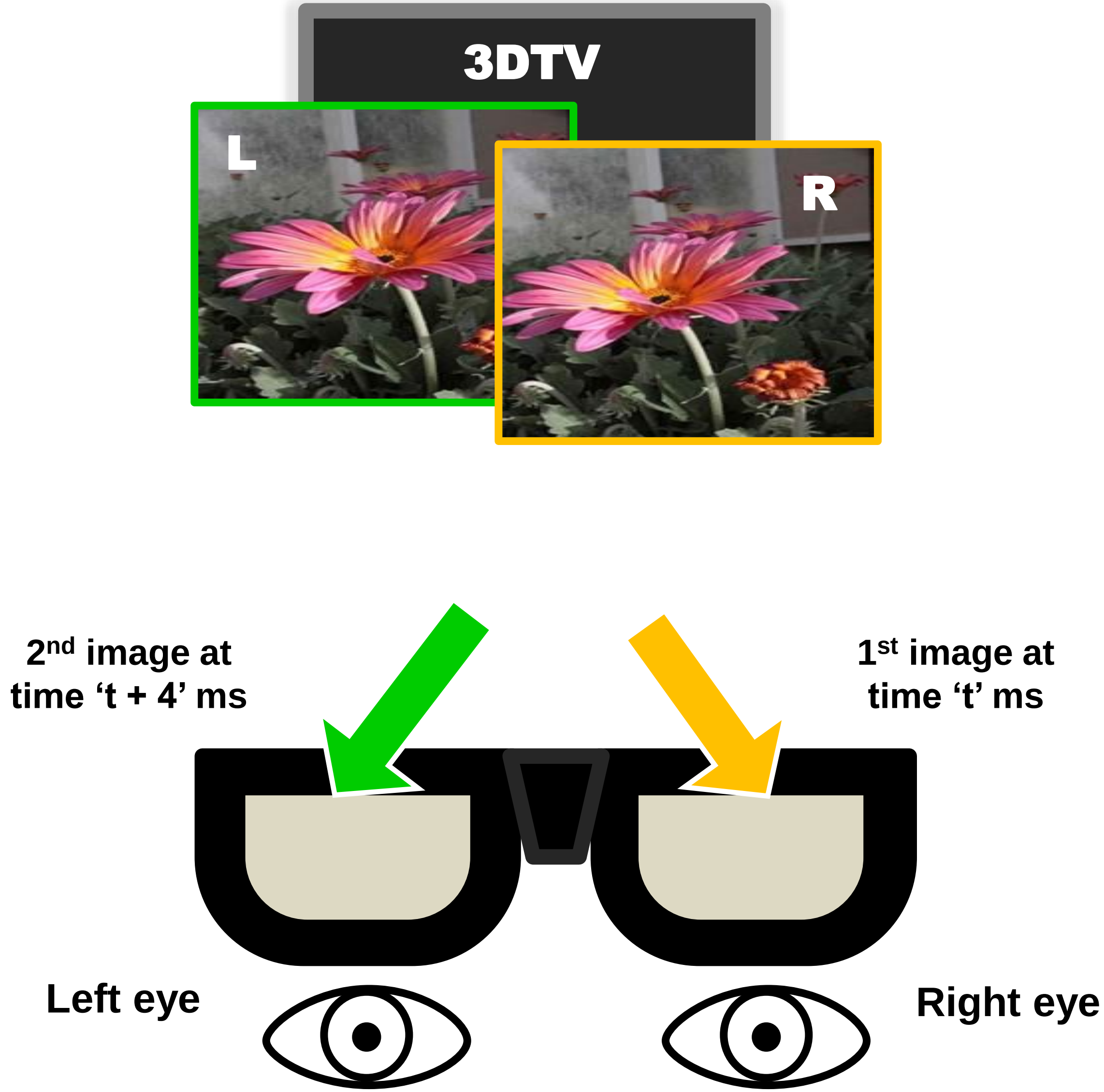


Signal complexity is comparable or lower to 2D

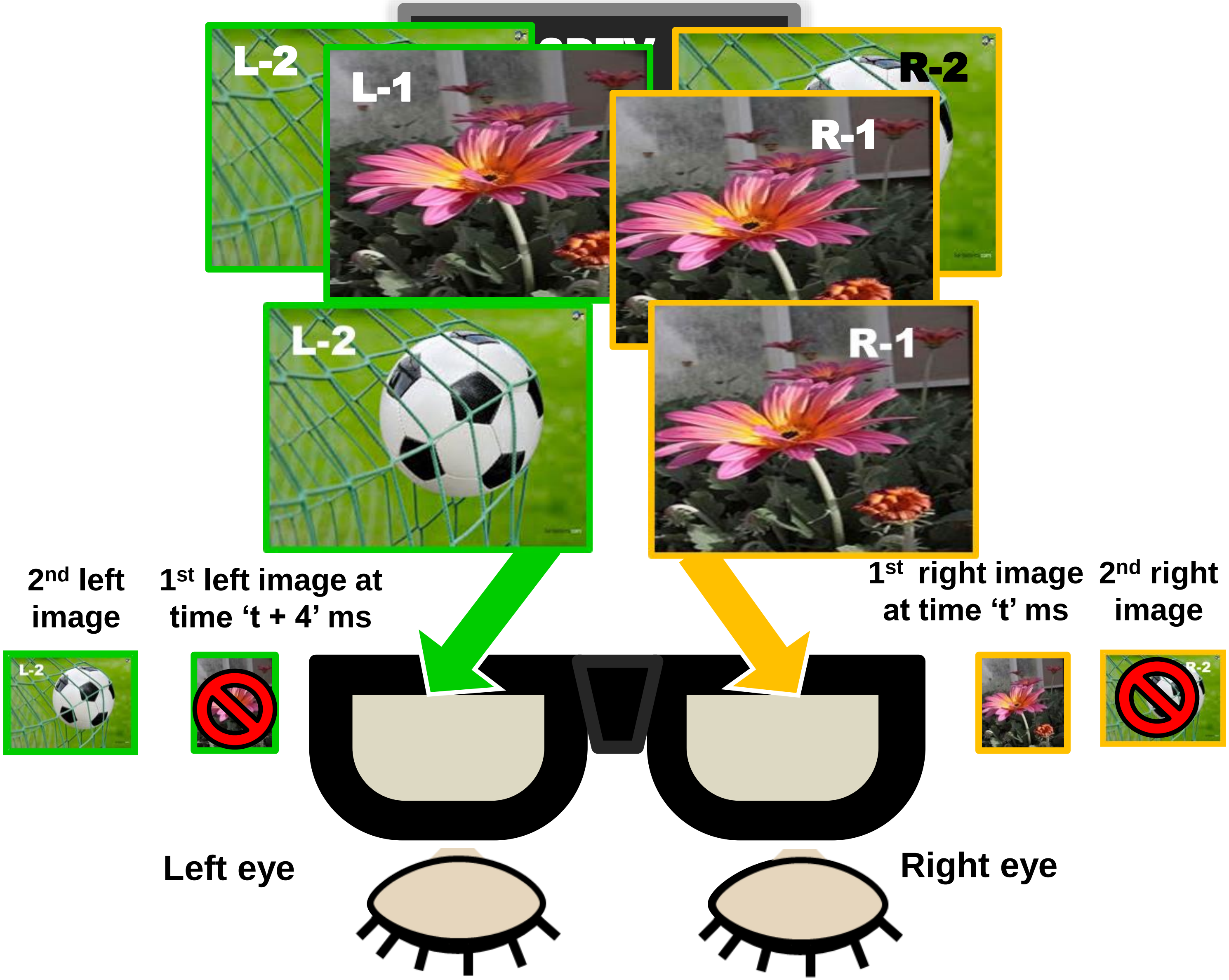
Why 3D Active results in lower brain activation than 2D?



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



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



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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

Freq. Bands	Location and reported changes	Role in Memory	Critics
Theta Power (Fell et al., 2011)	Medial Temporal (rhinal cortex and hippocampus) Theta Power increased before stimulus presentation reflects preparation for stimulus-triggered memory processing	Prediction of **LTM** formation	Patients of temporal lobe epilepsy were used for experimentation and the memory material was word recognition
Theta Coherence (Weiss et al., 2000)	High coherence left frontal (Fp1,F7), anterior and posterior temporal sites (T4,T6) and right posterior parietal-occipital regions (P4, O2).	**LTM retrieval**, high information processing	The material of memory was abstract and concrete nouns
Theta Phase (Rutishauser et al., 2010)	Theta phase of single neurons at hippocampus (bilateral) is associated with the performance in memory task	Prediction of successful **LTM** formation	The experiment was performed in patients of epilepsy and the memory task was old-new paradigm (recognition memory)
Alpha Power (Fell et al., 2011)	Medial Temporal Alpha Power increased before stimulus presentation indicates activation of contextual information	Prediction of successful **LTM** formation	Patients of temporal lobe epilepsy were used for experimentation and the memory material was word recognition

Summary of EEG Theta, Alpha and Gamma Frequency bands in LTM recall …

Freq. Bands	Location and reported changes	Role in Memory	Critics
Alpha Power (Klimesch et al., 1997)	Variations in alpha power as a function of memory performance	**LTM retrieval**	The variations in alpha are not so clear with respect to attentional demands, memory load, and level of intelligence of the participants.
Theta and Alpha (Khader et al., 2010)	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	LTM encoding and retrieval	The retention duration was only 5 to 7 seconds in the delayed matching-to-sample task
Gamma power (Sederberg et al., 2007)	Increased gamma power left temporal lobe, hippocampus, inferior PFC and occipital lobe during encoding of nouns	Prediction of LTM correct retrieval	The results obtained from epileptic patients and the study material was common nouns. There may be effect of background knowledge during encoding the nouns.
Theta and Gamma power (Sederberg et al., 2003)	Theta activity in tight temporal and frontal cortex was high; while gamma was high over widespread cortical sites	LTM retrieval	The sample size was only 10 and the age range was 8 to 17 years
Theta and Gamma power (Osipova et al., 2006)	High theta at right temporal and high gamma power over occipital regions	Predicts encoding and retrieval of LTM	The experiment was based on recognition memory and used old/new paradigm, which is ERP experiment

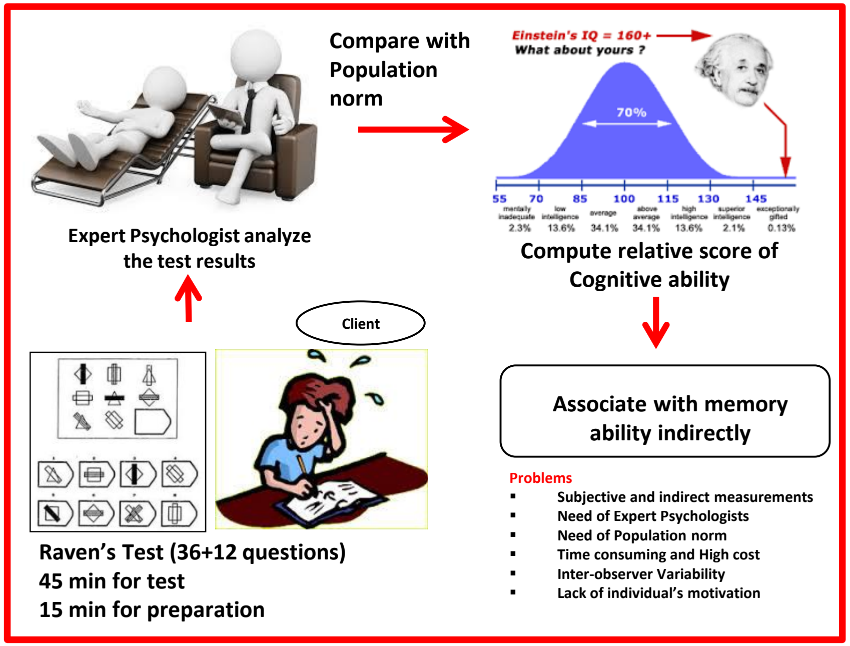
Summary of P300 Studies related to LTM recall

Study	Feature	Role in Memory	Critics
P300 and face recognition (Meijer et al., 2007)	P300 Amplitude	Large P300 amplitude for recognized faces at Pz site **(semantic recognition memory)**	The stimuli were acquired through the participants themselves, there may effect of picture recognition on P300 amplitude instead of face recognition.
P300 and memory recall (Jongsma et al., 2012)	P300 Amplitude	Increase in the amplitude of P300 at Pz site during **semantic memory** (recalling digits)	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.
P300 and visual recognition (Vianin et al., 2002)	P300 Amplitude	Large P300 amplitude at posterior sites (P3, P4, Pz, O1, O2, Oz) for **semantic recognition memory** between healthy and schizophrenic patients	The sample size used in this study was small, i.e., 10 participants in patient group and 14 participant in control group.
P300 and LTM scanning (Singhal and Fowler, 2004)	P300 Amplitude	Amplitude of Visual P300 at Pz was marginally high in LTM	The sample size was only 16 participants and the retention time was 24 hours.
P300 and cognitive impairment (Parra et al., 2012)	P300 Amplitude	Reduced P300 amplitude at Fz and Pz sites in mild cognitive impairment (MCI)	The sample size n=30 is relative small with three groups, control, MCI and Alzheimer's disease (AD).
P300 and Alzheimer's (Parra et al., 2012)	P300 Amplitude	Smaller P300 amplitude in Alzheimer's patients at Fz, Cz, Pz sites	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.

Problem Formulation

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

Existing Practice



  - 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.

Problem Formulation …

- 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**

Problem Formulation …

- 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.

H_1

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

H_2

- **The use of stereoscopic 3D multimedia educational tools may provide good effects on the brain in LTM recall.**

Research Objectives

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

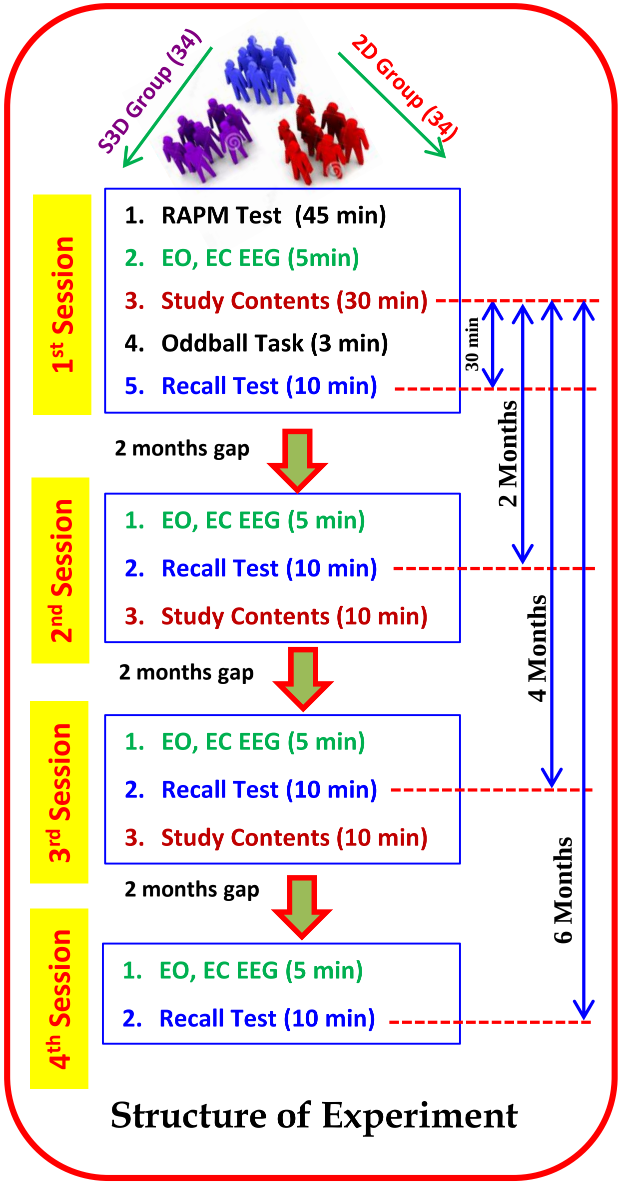
Control Variables
- General Intelligence
- Age (18-30 Years)
- Contents of Learning

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

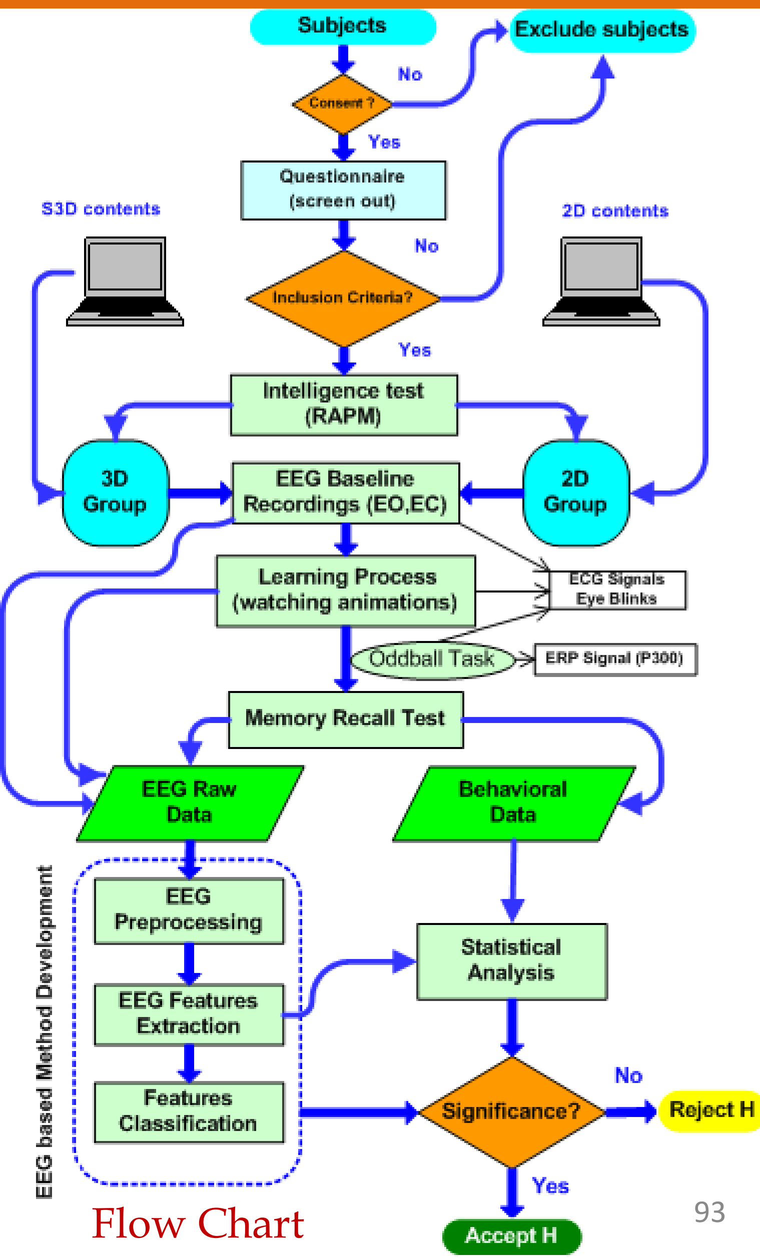
Learning Contents
- Human Anatomy & Physiology animated contents (2D and S3D)
- Duration of Contents 10 min (presented 3 times)

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



Flow Chart

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

Step 1. Feature Extraction: Compute EEG absolute Phase delay of theta, alpha and gamma frequency bands of 171*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.

MLR (Score %)	Value Range	Grade	Description
$Score\ (\%) = \frac{\hat{Y} \times 100}{20}$	≥90% to 100%	A	**Excellent** long-term memory ability in retrieval of semantic concepts, facts and knowledge.
	≥80% to <90%	B	**Very Good**
	≥70% to <80%	C	**Good**
	≥60% to <70%	D	**Average**
	≥50% to <60%	E	**Fair**
	49% and below	F	**Unsatisfied**

1. $n \times \left(\frac{n-1}{2}\right)$, where n is the number of electrodes
2. Compute the cross-spectra of *x* and *y*, *which produce* cospectrum (r—real) and quadspectrum (q—imaginary)
3. Phase angle (or $\theta_{xy} = arctan \frac{q_{xy}}{r_{xy}}$).
4. Absolute phase delay in degree, $\sqrt{\theta_{xy}^2}$

(REF)

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

Where xi is EEG feature and y is memory score

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

Or $Y = X\beta + \varepsilon$

Y *is the dependent variable*

X_i *is the* i^{th} *independent variables*

β_i *is the* i^{th} *regression weight (unknown)*

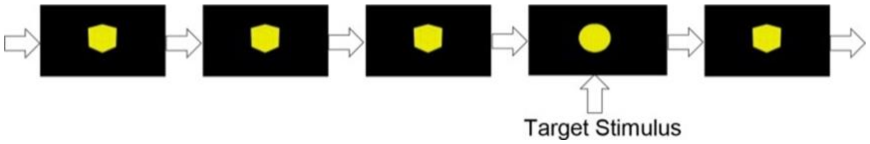
ε *is the error between actual and predicted value*

Using Ordinary Least Squares to estimate the β

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

REF: R. W. Thatcher, D. North, and C. Biver, "EEG and intelligence: Relations between EEG coherence, EEG phase delay and power," *Clinical Neurophysiology*, vol. 116, pp. 2129-2141, Sep 2005.

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

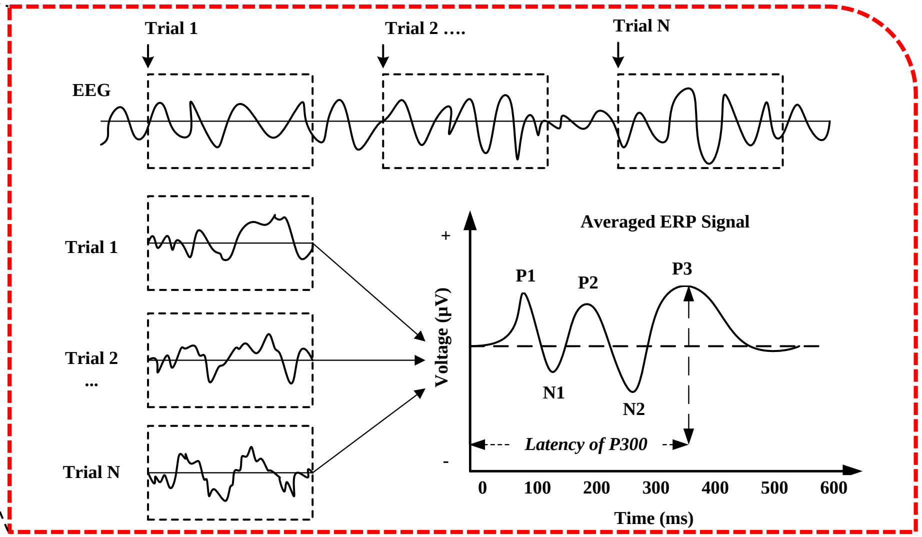
Step 2: Feature Extraction

- Amplitude
- Latency

Step 3: Multiple Linear Regression

$$Y = X\beta + \varepsilon$$

Step 4: Proposed LTM Grading



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

$$s_{max,i} = max_t\{s(t)|w_i(t)\}$$

$$\text{where,} w(t) = \{\, 276ms \leq t \leq 500ms\}$$

Latency *(tsmax)*— The latency of an ERP component is that point in time where the maximum signal value occurs.

$$ts_{max} = \{t|s(t) = S_{max}\}$$

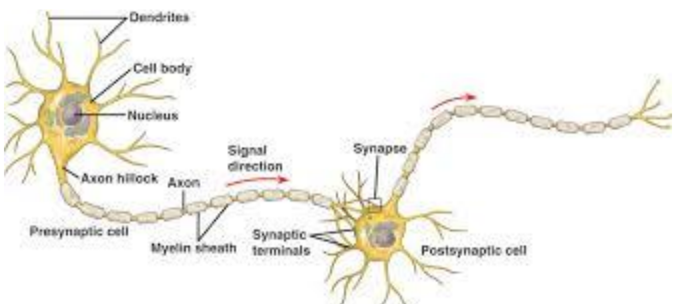
Where s_{max} is the maximum signal value **(REF)**

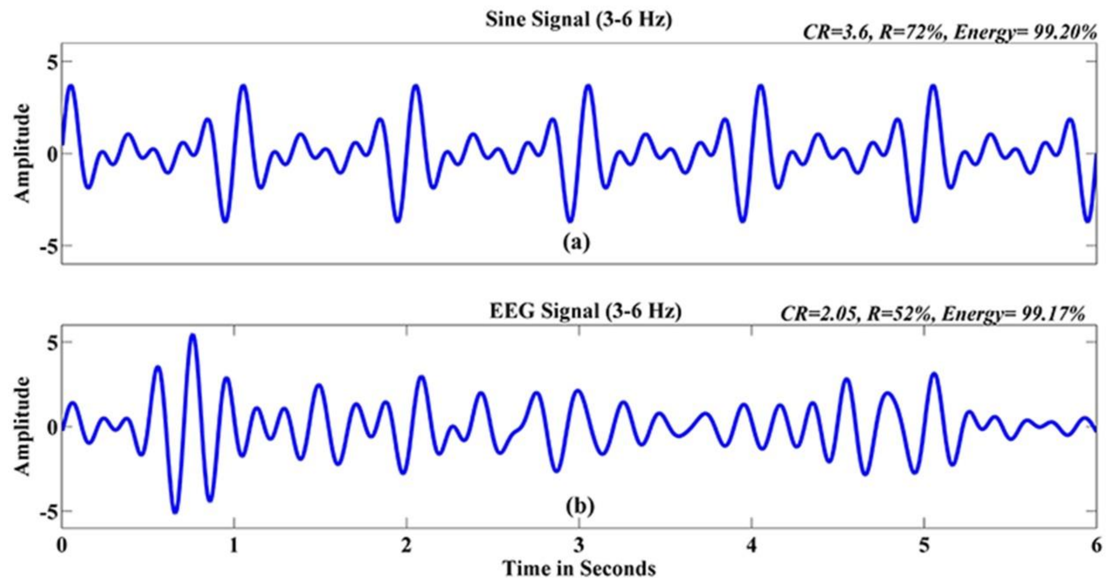
REF: V. Abootalebi, M. H. Moradi, and M. A. Khalilzadeh, "A new approach for EEG feature extraction in P300-based lie detection," *Computer Methods and Programs in Biomedicine*, vol. 94, pp. 48-57, 2009.

Proposed EEG Feature Extraction Scheme
S3D vs. 2D

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



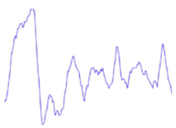


Example of periodic sine signal and EEG signal of 3-to-6 Hz with redundant information, CR (compression ratio), R (redundancy)

Resting State …EEG has more redundant info
Cognitive Tasks…EEG has less redundant info

Proposed EEG Feature Extraction Scheme
S3D vs. 2D

EEG Signals



DWT Coefficients → Optimum DWT Coefficients → DWT Coefficients encoded to bit stream

Discrete Wavelet Transform (DWT) → **Threshold & Rounding-off** → **Arithmetic Coding** → **Feature Extraction**

$$A_i = \frac{1}{\sqrt{M}} \sum_n x(n) \cdot \varphi_{j,k}(n)$$

Where, $\varphi_{j,k}(n) = 2^{j/2} h\left(2^j n - k\right)$

$$D_i = \frac{1}{\sqrt{M}} \sum_n x(n) \cdot \psi_{j,k}(n)$$

Where, $\psi_{j,k}(n) = 2^{j/2} g\left(2^j n - k\right)$

$$\widehat{D}_{jk} = \begin{cases} D_{jk}, |D_{jk}| \geq \alpha, \\ 0, |D_{jk}| < \alpha, \end{cases}$$

$$\alpha = \hat{\sigma}\sqrt{2 \log N}$$

$$\hat{\sigma} = \frac{\text{median}\left(|D_{jk}|\right)}{0.6745}$$

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

Arithmetic Coding Algorithm:

$\Phi_k(S) = [\alpha_k, \beta_k), k = 0,1, \ldots, N,$

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

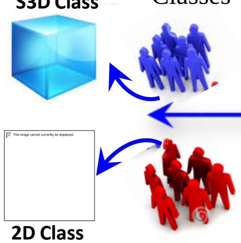
$$CR = \frac{\text{size of original signal } X}{\text{size of compressed signal } X_c}$$

$$R = \frac{1}{CR} \times 100$$

R, Cr Features

Standardized Features set → Reduced Feature set → Performance Evaluation → Classes

Features Standardization → **Features Selection** → **Classifier** → **Cross Validation**



Classes

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.

kNN classifier:

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

Output: $c_z \in L$,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 of k closest training objects for z;

$c_z = \underset{v \in L}{\text{argmax}} \sum_{y \in N} I\left(v = class(c_y)\right)$;

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

$$FDR = \frac{(m_1 - m_2)}{(\sigma_1^2 - \sigma_2^2)}$$

Where, m_1 and m_2 are mean values and σ_1^2 and σ_2^2 are the respective variances of a feature x_i in two classes.

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

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

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Experimental Results

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**

Results: Proposed LTM Assessment Scheme Based on Resting State EEG

Steps of the Proposed Scheme

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

↓

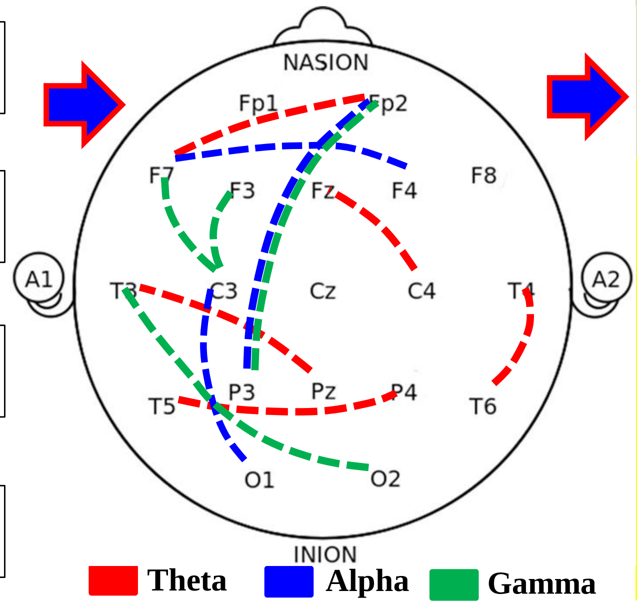
Step 2. Feature Selection: Apply correlation to identify significant related electrodes pairs with memory score

↓

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.



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.

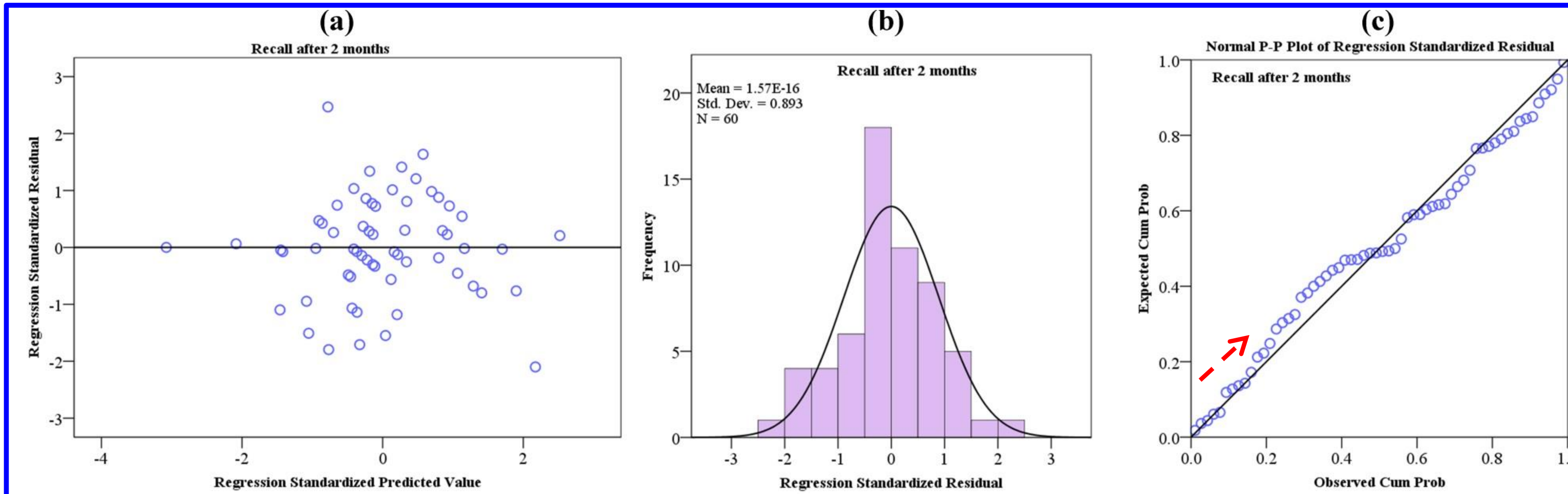
30 min retention:
$F(12,51)=4.421, p<0.0001, R=0.714, R^2=0.560$

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:
$F(12,37)=2.019, p=0.050, R=0.629, R^2=0.396$

Patent Filed (PI 2016704028)



Results: Proposed LTM Assessment Scheme Based on Resting State EEG

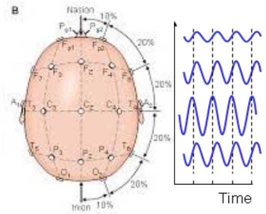
Here, ***y1, y2, y3, and y4*** are percentage observed LTM scores in session 1, session 2, session 3 and session 4. The corresponding percentage predicted LTM scores are represented as $\hat{y}1, \hat{y}2, \hat{y}3,$ ***and*** $\hat{y}4$, respectively.

Subject No	Session 1 (30 min Retention)			Session 2 (2 months Retention)			Session 3 (4 months Retention)			Session 4 (6 months Retention)		
	$y1$	$\hat{y}1$	Grade	$y2$	$\hat{y}2$	Grade	$y3$	$\hat{y}3$	Grade	$y4$	$\hat{y}4$	Grade
1	90	83.64	B	75	67.41	D	70	70.69	C	80	67.45	D
2	70	78.22	C	50	60.05	D	50	66.36	D	60	73.25	C
3	75	82.09	B	65	67.38	D	80	75.53	C	85	79.05	C
4	70	66.71	D	70	67.16	D	85	76.57	C	80	77.35	C
5	85	79.93	C	50	60.71	D	55	67.76	D	60	67.05	D
6	95	85.45	B	75	65.48	D	75	71.20	C	90	71.02	C
7	85	89.21	B	70	62.74	D	65	73.33	C	70	74.13	C
8	90	76.58	C	80	73.16	C	90	80.04	B	95	87.17	B
9	80	80.17	B	75	72.22	C	60	58.70	E	50	50.14	E
10	90	78.92	C	60	61.36	D	80	68.61	D	75	76.87	C

LTM Grading		
	≥90% to 100%	A
	≥80% to <90%	B
	≥70% to <80%	C
	≥60% to <70%	D
	≥50% to <60%	E
	49% and below	F

Results: Comparison of Proposed LTM prediction Scheme with RAPM Test

Proposed EEG based LTM Assessment



EEG Recording (5 min)

Raw EEG Signals

EEG Analysis by proposed LTM assessment scheme method (in sec)

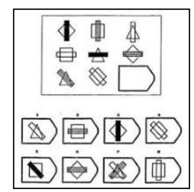
EEG Machine setting (maxi. 5-10 min)

Quantitative LTM Assessment & Grading

Advantages

- Quantitative and direct measurements
- Assign Grade
- No need of Expert Psychologists
- No need of Population norm
- Efficient and accurate

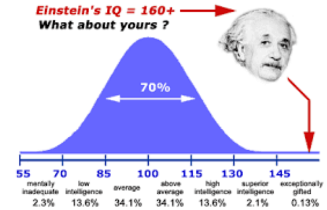
Existing Practice



Raven's Test (36+12 questions)
45 min for test
15 min for preparation

Expert Psychologist analyze the test results

Compare with Population norm



Compute relative score of Cognitive ability

Associate with memory ability indirectly

Problems

- Subjective and indirect measurements
- Need of Expert Psychologists
- Need of Population norm
- Time consuming and High cost
- Inter-observer Variability
- Lack of individual's motivation

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.

Session		F-statistic	p-value	R-value	R-squared	Adjusted R^2
RAPM test	01	F(1,62)=10.235	0.002	0.376	0.142	0.128
	02	F(1,58)=5.872	0.019	0.303	0.092	0.076
	03	F(1,55)=6.422	0.014	0.323	0.105	0.088
	04	F(1,48)=8.167	0.006	0.381	0.145	0.128
Proposed EEG Scheme	01	F(12,51)=4.421	0.001	0.714	0.510	0.395
	02	F(12,47)=4.994	0.001	0.749	0.560	0.448
	03	F(12,44)=2.816	0.006	0.659	0.434	0.280
	04	F(12,37)=2.019	0.050	0.629	0.396	0.200

Results: Proposed LTM Assessment Scheme Based on P300 Component

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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

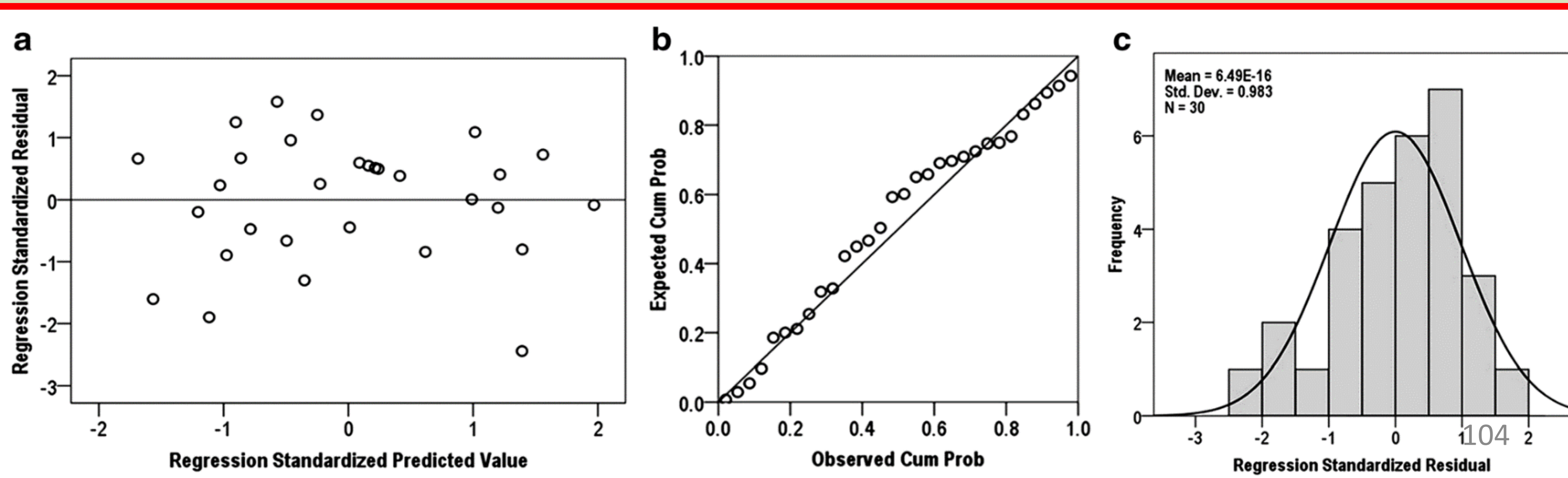
Correlation between P300 component (Pz) and LTM Recall

Variables	LTM Recall	RAPM	P3 amplitude	P3 latency
LTM Recall		0.653**	0.554**	-0.365*
RAPM	0.653**		0.540**	-0.495*
P3 amplitude	0. 554**	0.540**		-.328
P3 latency	-0.365*	-0.495*	-.328	

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-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)



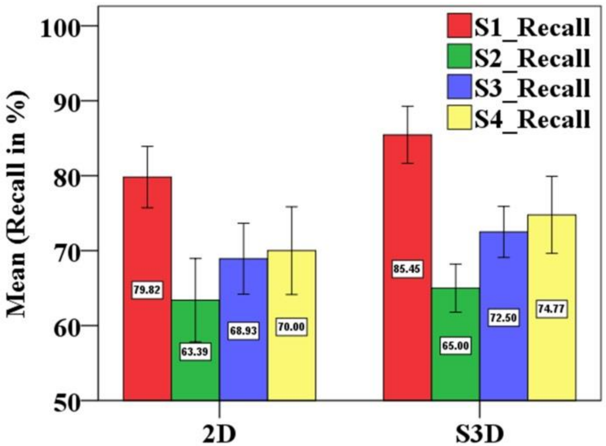
Experimental Results

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

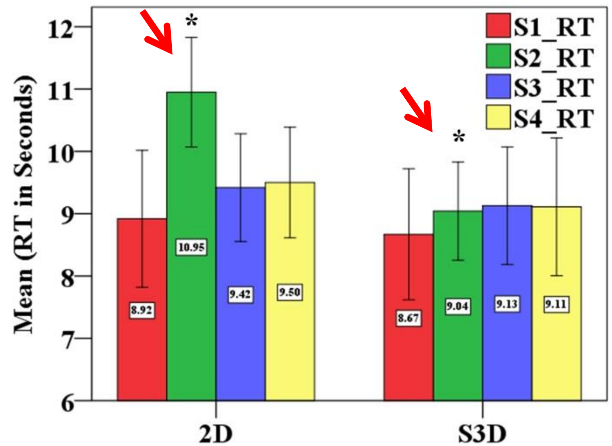
    - **Comparison of S3D vs. 2D for LTM recall**
    - **Proposed EEG Feature Extraction Scheme for S3D and 2D comparison**

Comparison of S3D vs. 2D

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

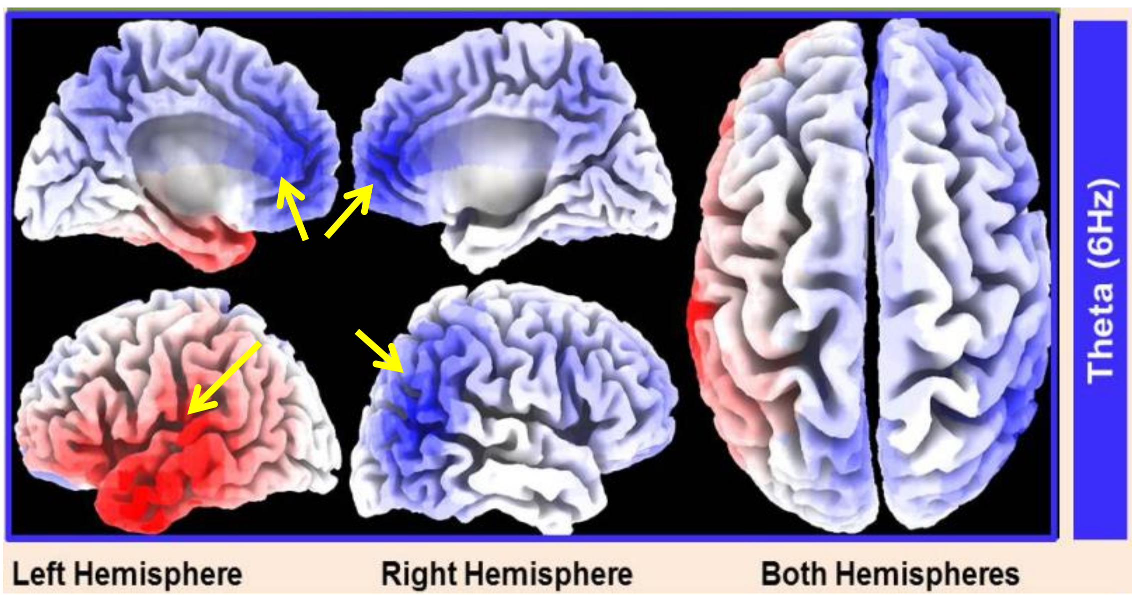


Results of Memory Recall



Results of Reaction Time (RT)

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



EEG sLORETA Results

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

$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN} \times 100$$

OR

$$Accuracy = 1 - Error\ Rate$$

$$Error\ Rate = \frac{FP + FN}{TP + FN + FP + TN} \times 100$$

$$Sensitivity(TPR) = \frac{TP}{TP + FN} \times 100$$

$$Specificity(TNR) = \frac{TN}{FP + TN} \times 100$$

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

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

Confusion Matrix for two class problem

	Positive Prediction	Negative Prediction
Positive Class	True Positive (TP)	False Negative (FN)
Negative Class	False Positive (FP)	True Negative (TN)

REF: G. E. Batista, R. C. Prati, and M. C. Monard, "A study of the behavior of several methods for balancing machine learning training data," *ACM Sigkdd Explorations Newsletter,* vol. 6, pp. 20-29, 2004.

Results: Comparison of Proposed EEG Feature Extraction Scheme with State of the art EEG Feature Extraction Methods

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$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN} \times 100$$

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

Feature Methods	Dataset-1 Memory Recall vs. EO Feature Matrix (560×64)	Dataset-2 Intelligence Test vs. EO Feature Matrix (400×64)	Dataset-3 S3D vs. 2D Feature Matrix (1320×64)
Proposed EEG Scheme	96.07	95.58	90.45
Delta Power	94.67	91.17	69.34
Theta Power	92.85	80.88	71.28
Alpha Power	89.1	67.64	69.29
Beta Power	87.35	73.52	69.78
Gamma Power	87.48	67.64	67.35
ApEn	68.75	87.5	53.46
SamEn	86.75	83.82	53.68
CPEI	68.5	75	60.81
Hjorth Complexity	73.5	75	65.51
Fractal Dimension	75	58.82	61.76

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

Article Published

BRIEF COMMUNICATION

Published in Brain Topography.

A Novel Approach Based on Data Redundancy for Feature Extraction of EEG Signals

Hafeez Ullah Amin[1] · Aamir Saeed Malik[1] · Nidal Kamel[1] · Muhammad Hussain[2]

Received: 27 March 2015 / Accepted: 7 November 2015 / Published online: 27 November 2015

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

Keywords Data redundancy · Feature extraction · Classification · EEG signal

Introduction

RESEARCH **Open Access**

P300 correlates with learning & memory abilities and fluid intelligence

Published in J.NeurEng. & Rehab.

Hafeez Ullah Amin[1], Aamir Saeed Malik[1*], Nidal Kamel[1], Weng-Tink Chooi[2] and Muhammad Hussain[3]

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.

frontiers
in Computational Neuroscience

METHODS
published: 21 November 2017
doi: 10.3389/fncom.2017.00103

Check for updates

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)

PLOS ONE

Introducing Memory Grading Scale for semantic long-term retention using resting state EEG functional connectivity

--Manuscript Draft--

Manuscript Number:	PONE-D-17-42648R1
Article Type:	Research Article
Full Title:	Introducing Memory Grading Scale for semantic long-term retention using resting state EEG functional connectivity
Short Title:	Long-term memory grading
Corresponding Author:	Hafeez Ullah Amin Universiti Teknologi PETRONAS Bandar Seri Iskandar, Perak MALAYSIA
Keywords:	EEG Signals; functional connectivity; Phase delay; semantic Long-term Memory (LTM); Grading system; principal component; and multiple linear regression
Abstract:	Semantic long-term memory (LTM) store and retain concepts, facts and knowledge of

How Neurofeedback can be used?

Factors

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

3D Stimuli

- 3D Stimuli can be used in neurofeedback to use wide spread neuronal network for training
- Virtual Reality environment

Emotion Regulation Using Virtual Environments and Real-Time fMRI Neurofeedback

Valentina Lorenzetti[1,2,3†], Bruno Melo[4,5†], Rodrigo Basílio[4], Chao Suo[3], Murat Yücel[3], Carlos J. Tierra-Criollo[5] and Jorge Moll[4*]

[1]School of Psychology, Faculty of Health Sciences, Australian Catholic University, Melbourne, VIC, Australia
[2]Department of Psychological Sciences, Institute of Psychology Health and Society, University of Liverpool, Liverpool, United Kingdom
[3]Brain and Mental Health Laboratory, School of Psychological Sciences and Monash Institute of Cognitive and Clinical Neurosciences, Monash University, Melbourne, VIC, Australia
[4]D'Or Institute for Research and Education, IDOR, Rio de Janeiro, Brazil
[5]Biomedical Engineering Program, COPPE, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

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

J Neurosci. Author manuscript; available in PMC 2013 Jun 5.
Published in final edited form as:
J Neurosci. 2012 Dec 5; 32(49): 17830–17841.
doi: 10.1523/JNEUROSCI.6334-11.2012

PMCID: PMC3520425
EMSID: EMS50826
PMID: 23223302

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]

Abstract

Go to:

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

Improve attention using NFB

Clin EEG Neurosci. 2013 Jul;44(3):193-202. doi: 10.1177/1550059412458262.

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[1], El-Baz AS, Sears L, Tasman A, Sokhadze EM.

Author information

Open/close author information list

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,

Improve Learning and Memory using NFB

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Procedia - Social and Behavioral Sciences

Volume 30, 2011, Pages 608-610

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Neurofeedback Training to Enhance Learning and Memory in Patients with Cognitive Impairment

Parvaneh Haddadi, Reza Rostami, Afsaneh Moradi, Farzaneh Pouladi

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https://doi.org/10.1016/j.sbspro.2011.10.117

Abstract

The brain tumours can make cognitive impairment especially when they involve the limbic

Improve Working Memory using NFB

Format: Abstract ▾ Send to ▾

Clin Neurophysiol. 2013 Dec;124(12):2406-20. doi: 10.1016/j.clinph.2013.05.020. Epub 2013 Jul 1.

Neurofeedback training improves attention and working memory performance.

Wang JR[1], Hsieh S.

⊕ Author information

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.

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

PMID: 23827814 DOI: 10.1016/j.clinph.2013.05.020

Improve Working Memory …

Biomed Mater Eng. 2014;24(6):3637-44. doi: 10.3233/BME-141191.

Working memory training using EEG neurofeedback in normal young adults.

Xiong S[1], Cheng C[1], Wu X[1], Guo X[1], Yao L[2], Zhang J[1].

⊕ Author information

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: 25227078 DOI: 10.3233/BME-141191

[Indexed for MEDLINE]

Improve Intelligence using NFB

ELSEVIER

International Journal of Psychophysiology

Volume 75, Issue 1, January 2010, Pages 25-32

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]

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https://doi.org/10.1016/j.ijpsycho.2009.10.011

Abstract

Self-Regulation of Amygdala using NFB

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

Vadim Zotev, Frank Krueger, Raquel Phillips, Ruben P. Alvarez, W. Kyle Simmons, Patrick Bellgowan, Wayne C. Drevets, Jerzy Bodurka

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

Article | Authors | Metrics | Comments | Related Content

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

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Factors

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


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

Thank You

Email: aamir_saeed@utp.edu.my

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