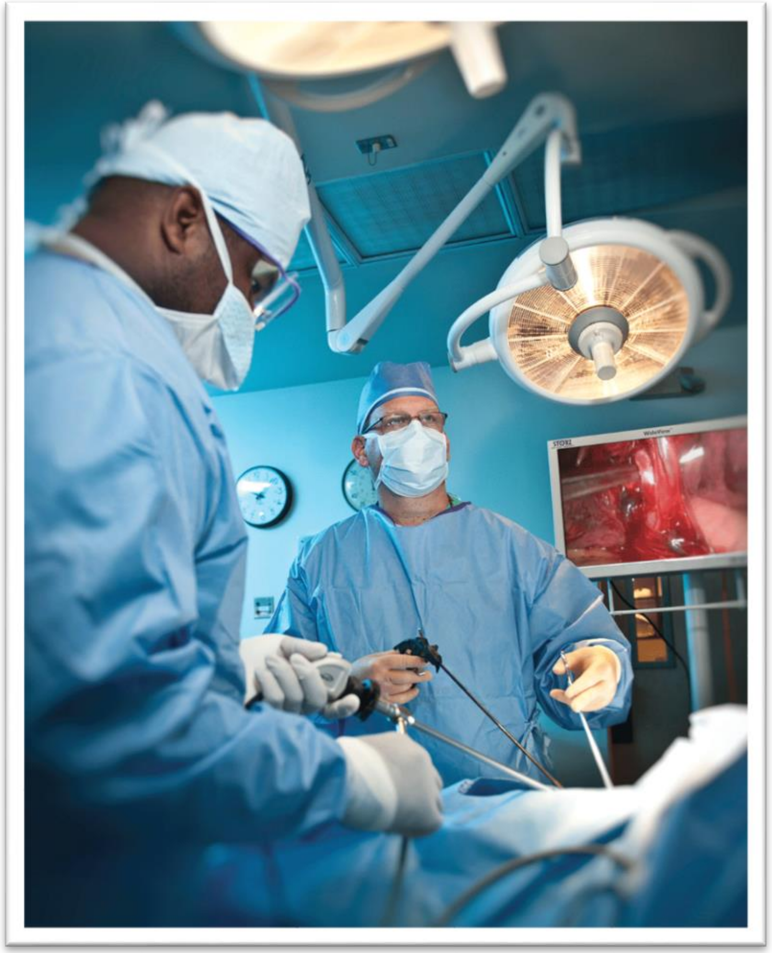
Neuroscience of Game-Based and Multimedia Learning

Neuroscience of Game-Based and Multimedia Learning

1. Educational Neuroscience of Game-Based Learning
    - Video games and neuroscience
    - Design of a game based on neuroscience findings
    - Neurophysiological methods in serious games and virtual worlds
2. Educational Neuroscience of Multimedia Principles
    - Modality
    - Redundancy
    - Signaling

1 Video Games

Development of Motor Skills



Fewer errors during laparoscopic surgeries
Better videoendoscopic surgical skills

Development of Motor Skills

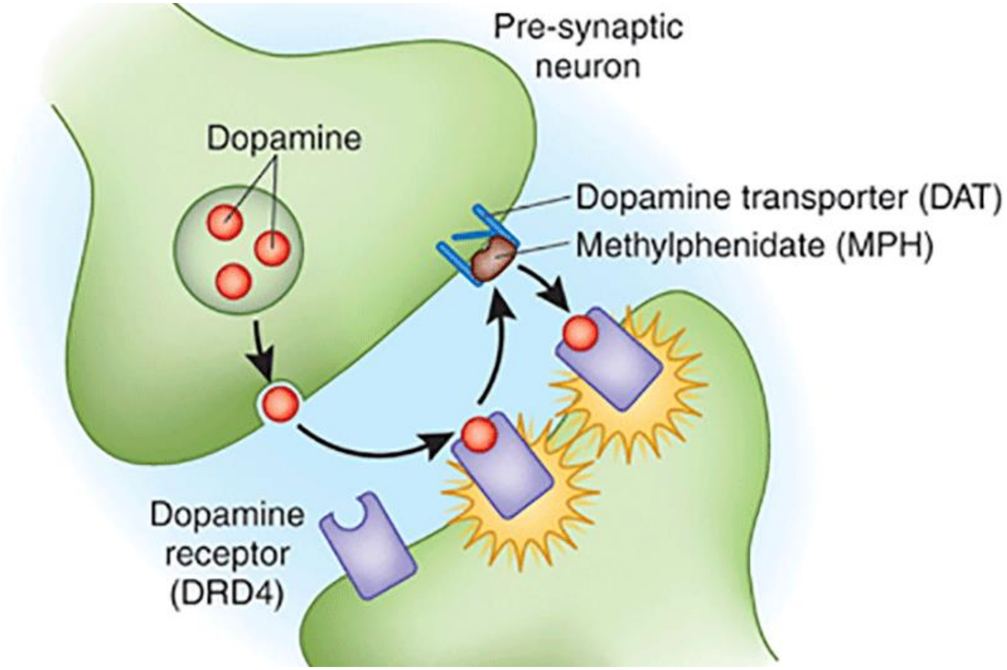
Motion sensing interfaces

Video Games

Development of Cognitive Skills

- Visual selective attention
- Spatial attention
- Mental rotation
- Top-down attentional control

1 Brain’s reward system during games



Motivation to gain points or rewards

Activation of brain’s reward system
Release of dopamines
Improved ability to store and recall information

Brain's reward system during games

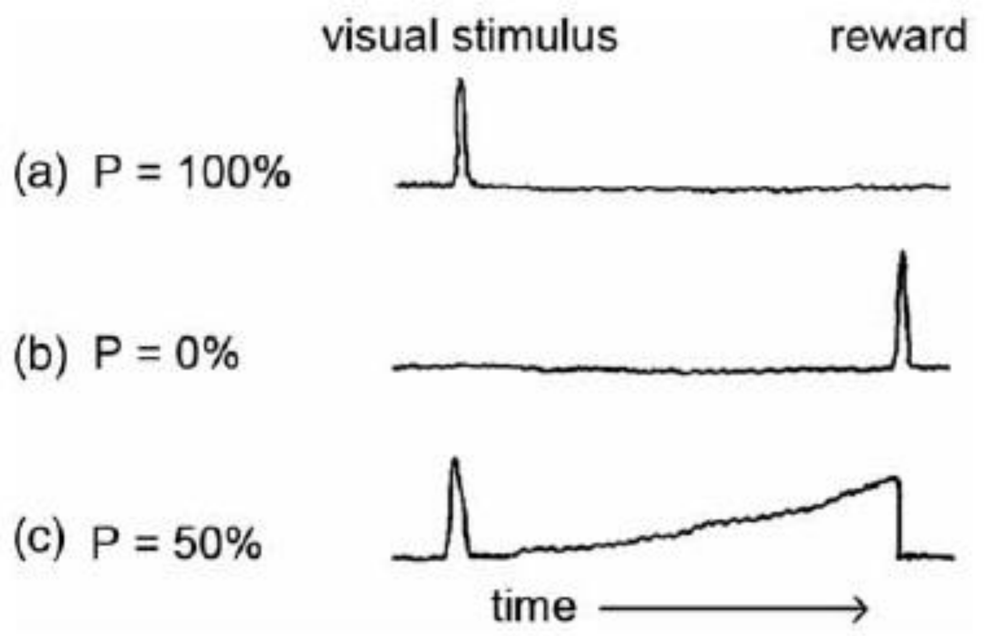
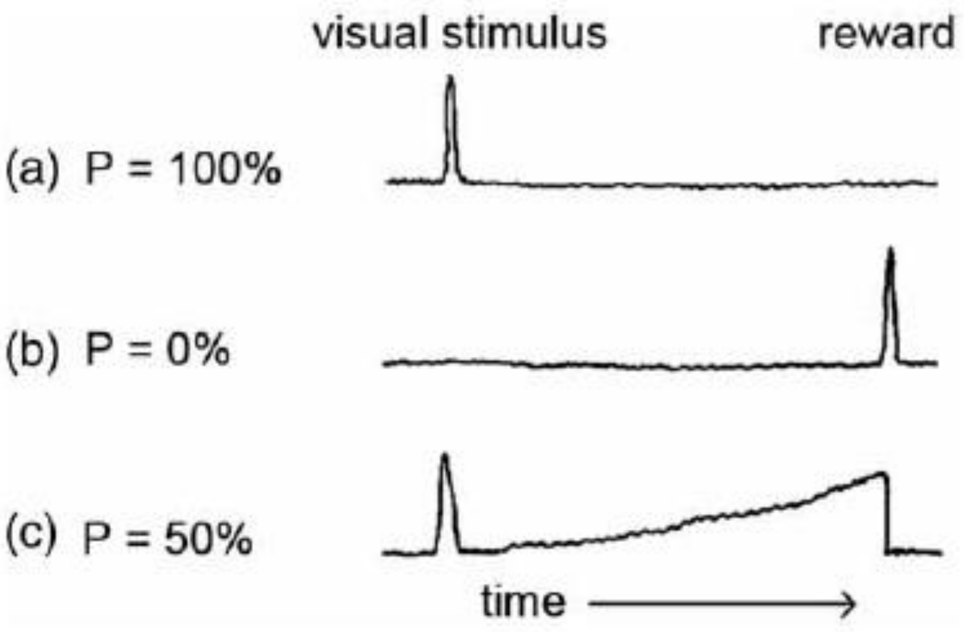


Figure 1. Uptake of the neurotransmitter dopamine generated in response to the probability (P) of receiving a reward. (Howard-Jones et al., 2015b)

Brain's reward system during games



Behaviorism > Schedules of Reinforcements > A variable interval schedule

Greater stability and slower decline in the response rate

Brain’s reward system during games

50% uncertainty
in games

88% certainty
in academic tasks

1 Brain's reward system during games

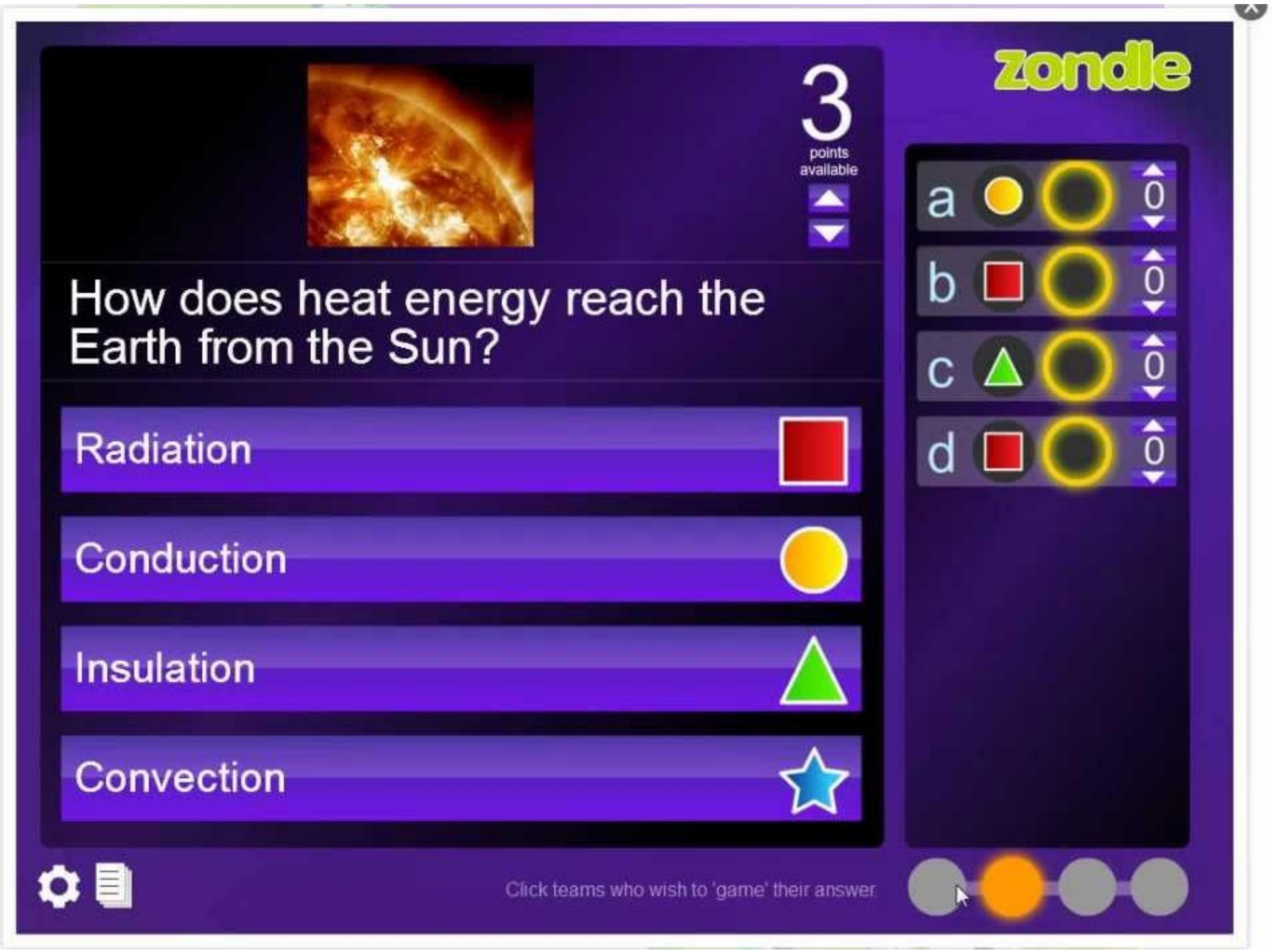
Learning ➕ Game = Increased reward signals

memory formation

motivation

learning

Zondle Team Play (Howard-Jones et al., 2015b)



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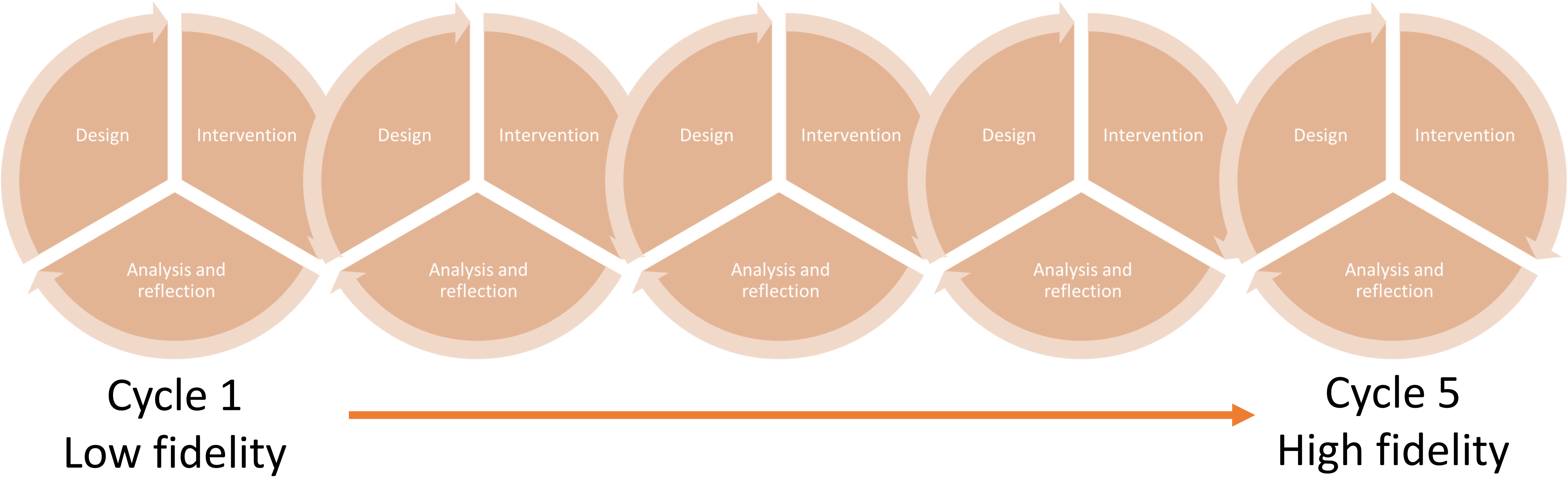
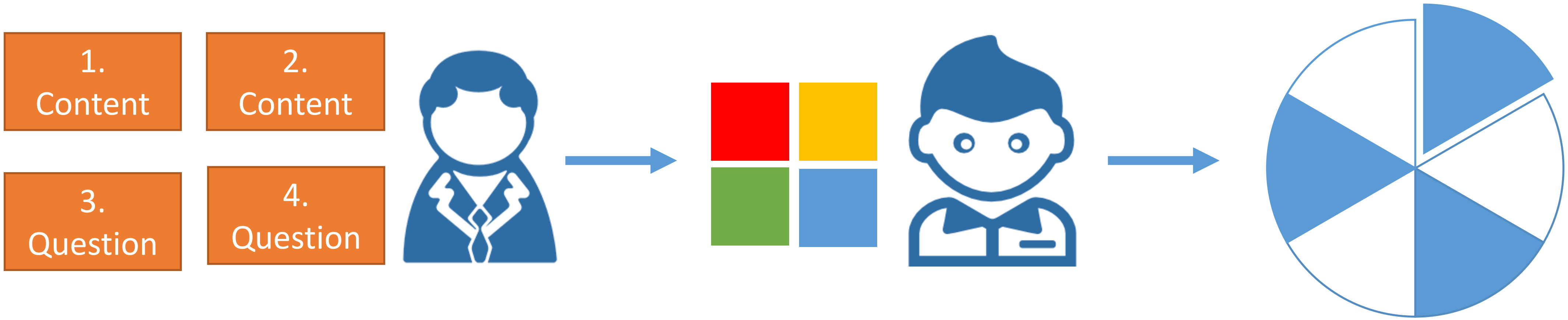
Zondle Team Play

- Increased student engagement through inclusion of chance-based components
- A close intermingling of learning and gameplay elements
- A more extended ‘window of enhanced attention’ or ‘teachable moment’ as a result of anticipation of an uncertain reward
- A generally positive scoring system to support motivation

Zondle Team Play



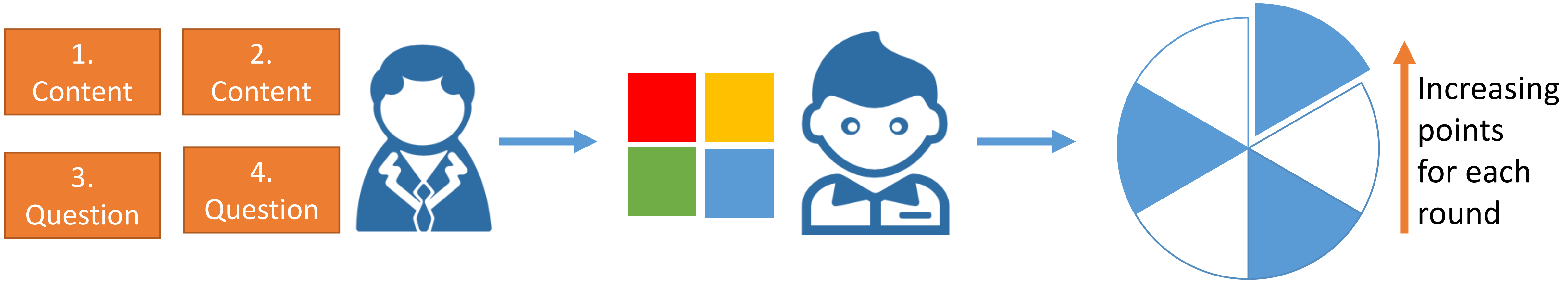
1 Zondle Team Play | First Cycle



- Engaged learners
- Heightened attention during anouncement of correct answer and turning wheel of fortune
- More focus on game rather than learning
- Teacher’s quick transition to announcement of correct answer
- Modest improvement in post test scores
- Teacher’s divided attention between game hosting and teaching

1

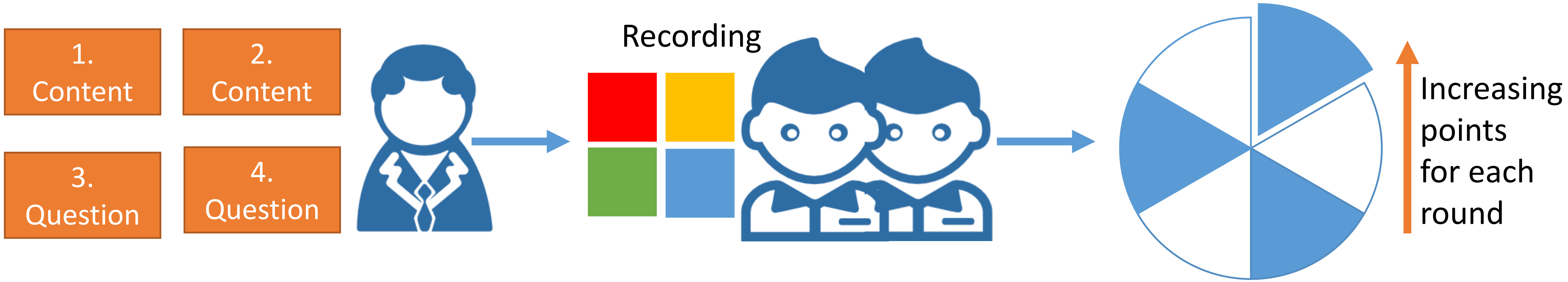
Zondle Team Play | Second Cycle



- Learning gain
- Teacher’s difficulty in managing the game
- Highly animated students due to continual raising of points
- Emotional teacher-student empathy

1

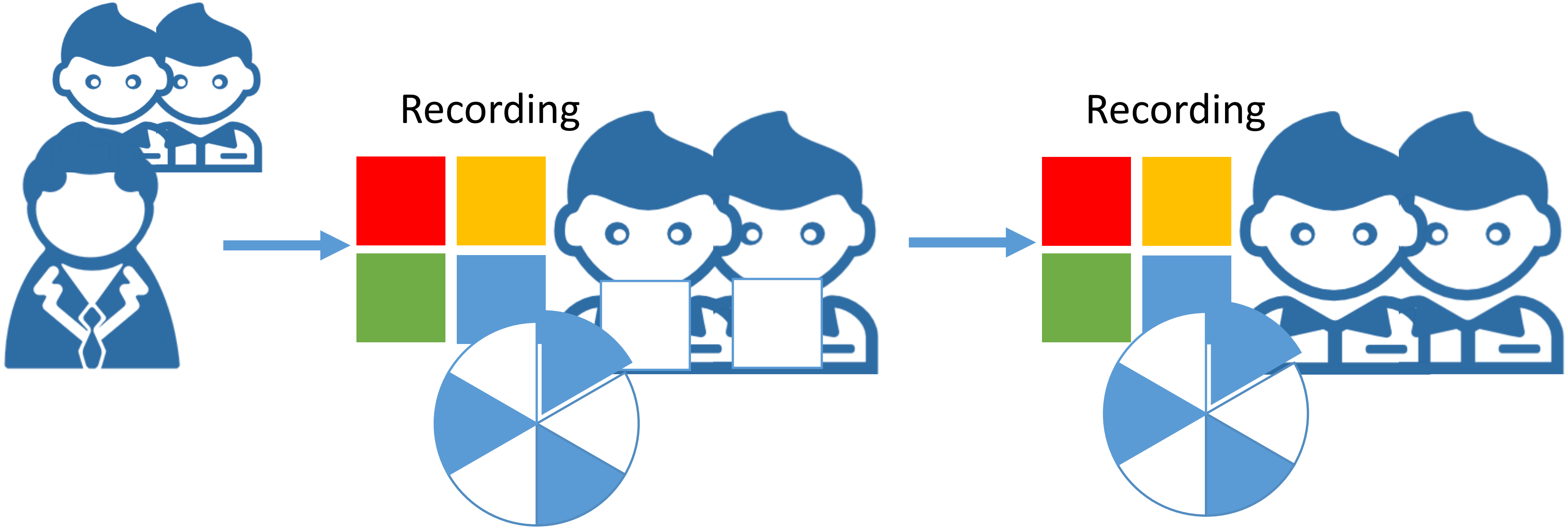
Zondle Team Play | Third Cycle



- Learning gain
- Teacher’s increased focus on teaching
- Students’ increased engagement

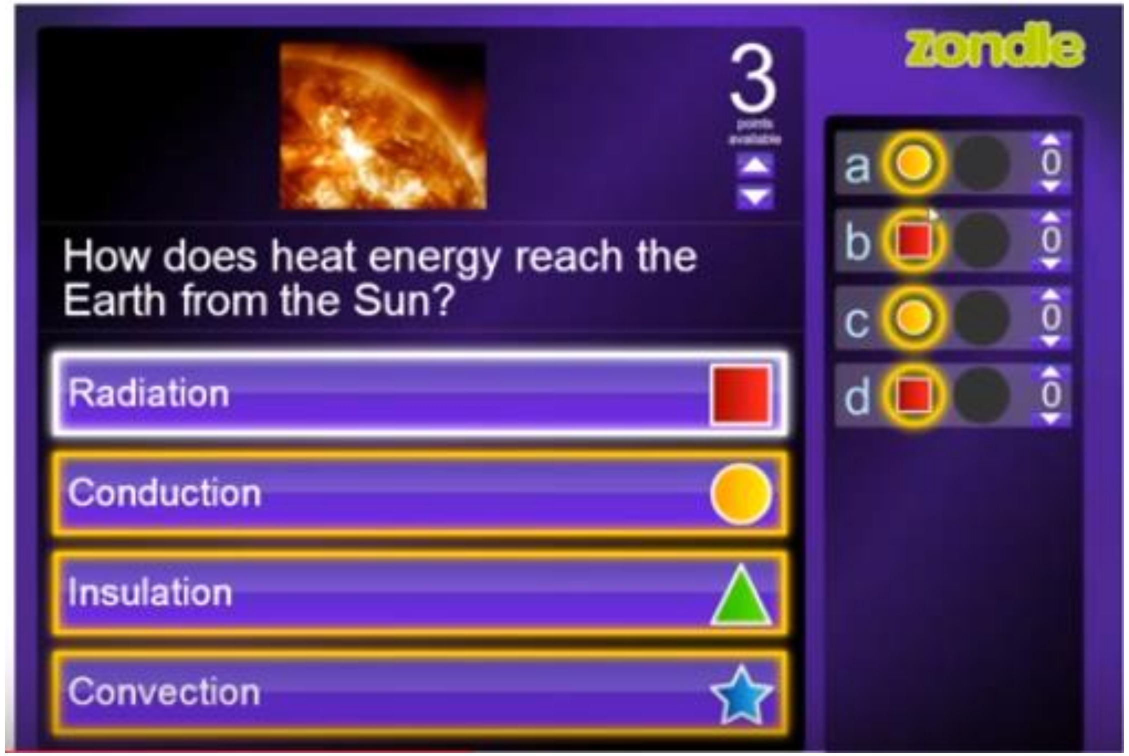
1

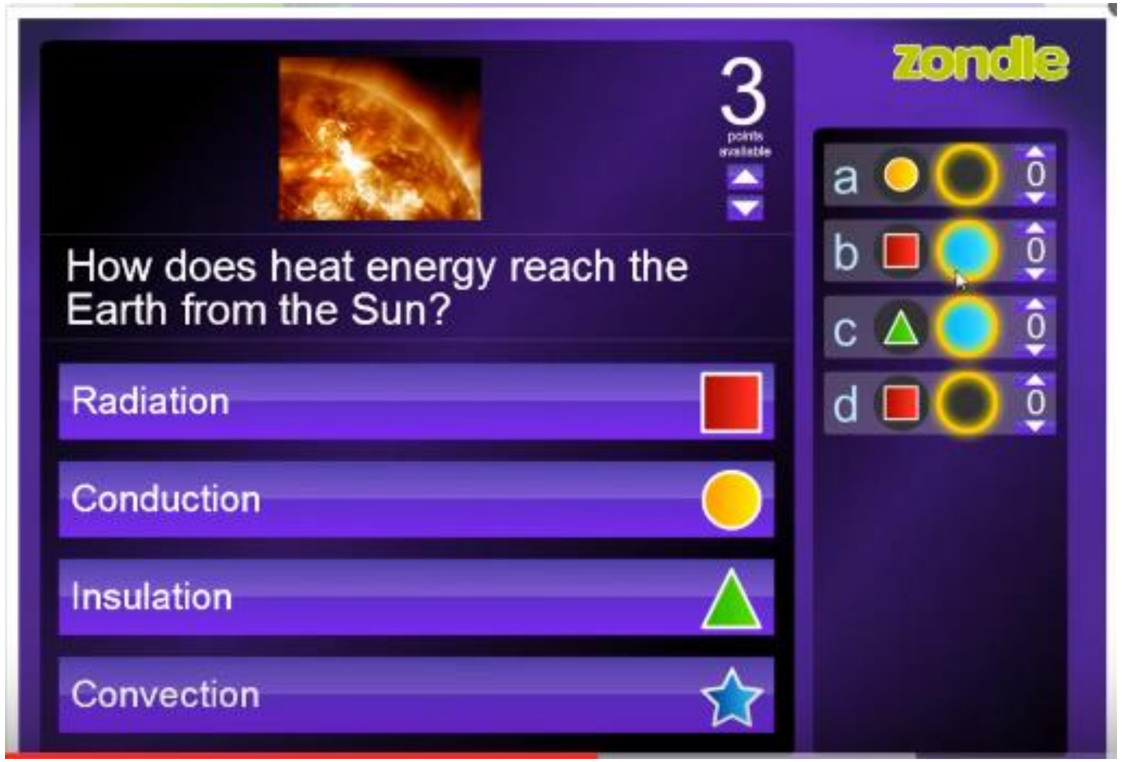
Zondle Team Play | Fourth Cycle



- Learning gain
- Students' talks about learning content
- Attention on teacher and questions
- Students hiding their cards until the last minute

1 Zondle Team Play | Fifth Cycle





Zondle Team Play | Fifth Cycle

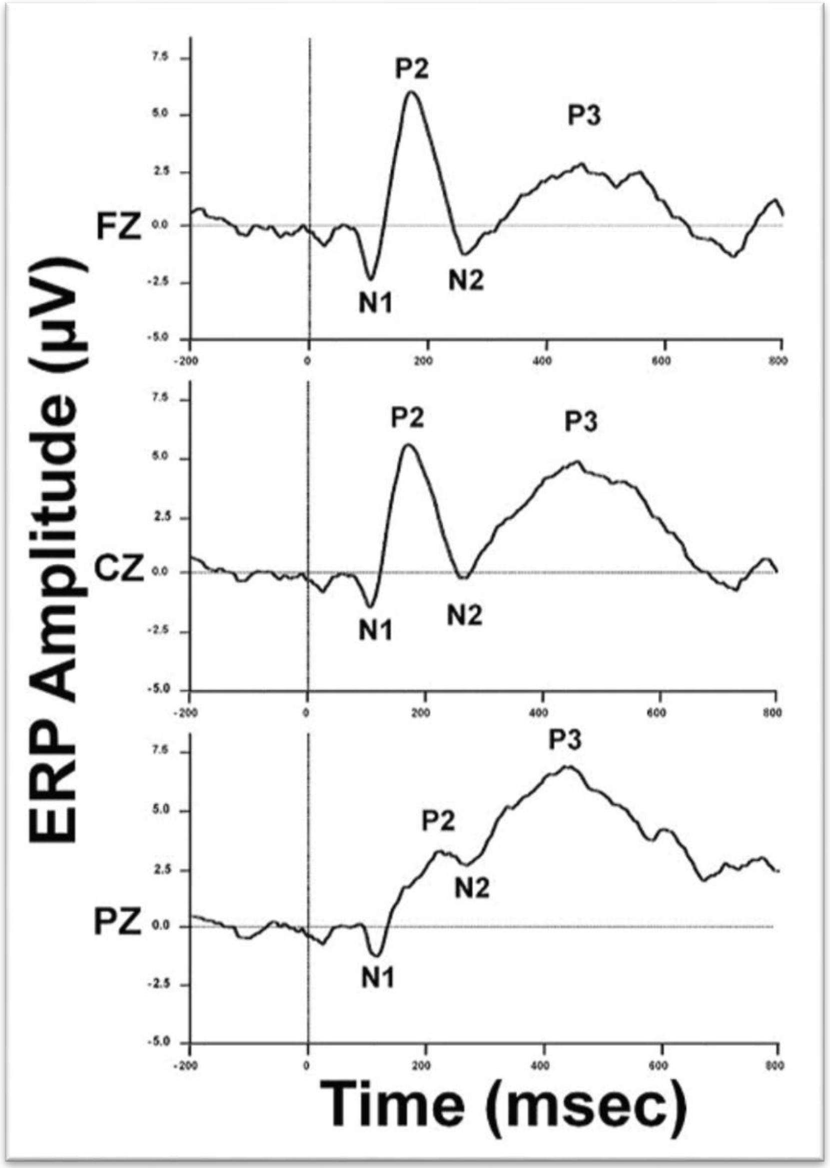
Neurophysiological methods in Serious Games and Virtual Worlds

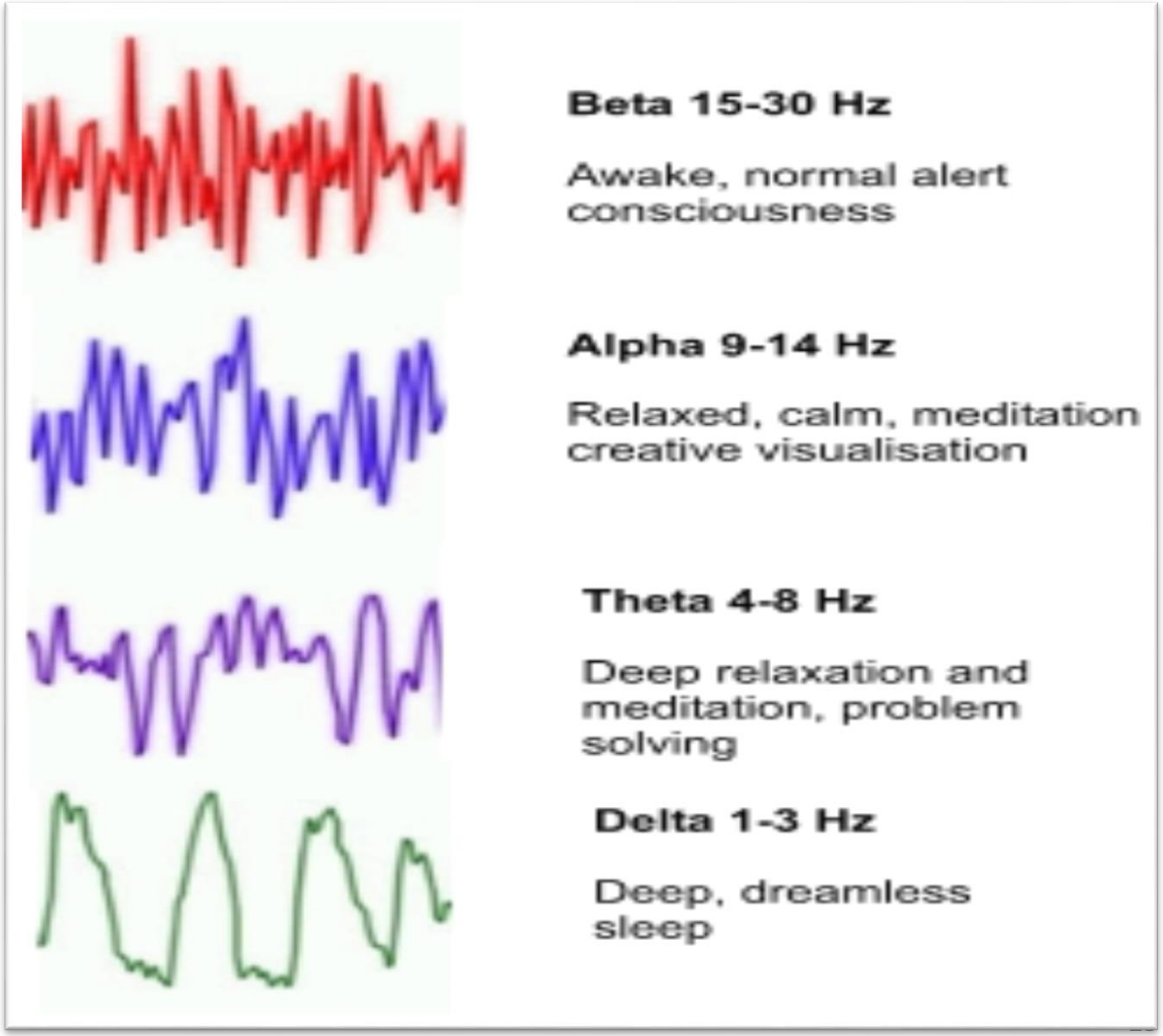
Why do we use neurophysiological methods for serious games and virtual worlds?

- To asess efficacy of game-based approaches
- To enhance game adaptivity to the user by collecting user data dynamically

EEG

EEG


ERP Amplitude (μV)
Time (msec)
FZ
CZ
PZ
P2
P3
N1
N2
7.5
5.0
2.5
0.0
-2.5
-5.0
-200
0
200
400
600
800

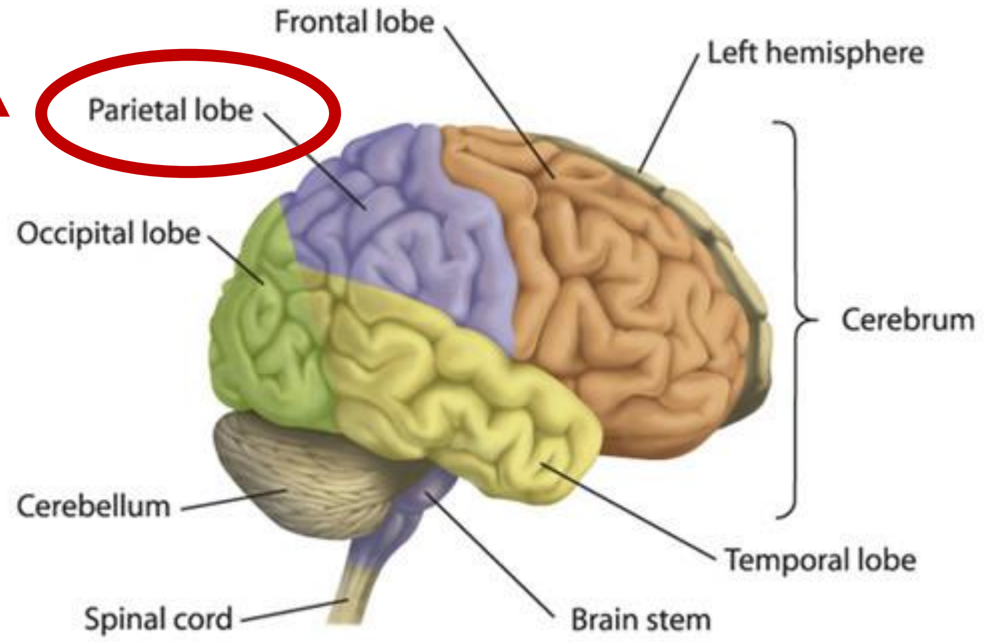

Beta 15-30 Hz
Awake, normal alert consciousness
Alpha 9-14 Hz
Relaxed, calm, meditation creative visualisation
Theta 4-8 Hz
Deep relaxation and meditation, problem solving
Delta 1-3 Hz
Deep, dreamless sleep

EEG in Game-Based Learning

- ERPs to assess **cognitive workload** during gaming
- ERPs to differentiate between participants **highly engaged** and **less engaged**
- Changes in EEG oscillations in gaming events with different **cognitive demands**
- EEG oscillations to assess **attention, concentration, and interest** during playing games

EEG in Game-Based Learning

Presence in virtual worlds

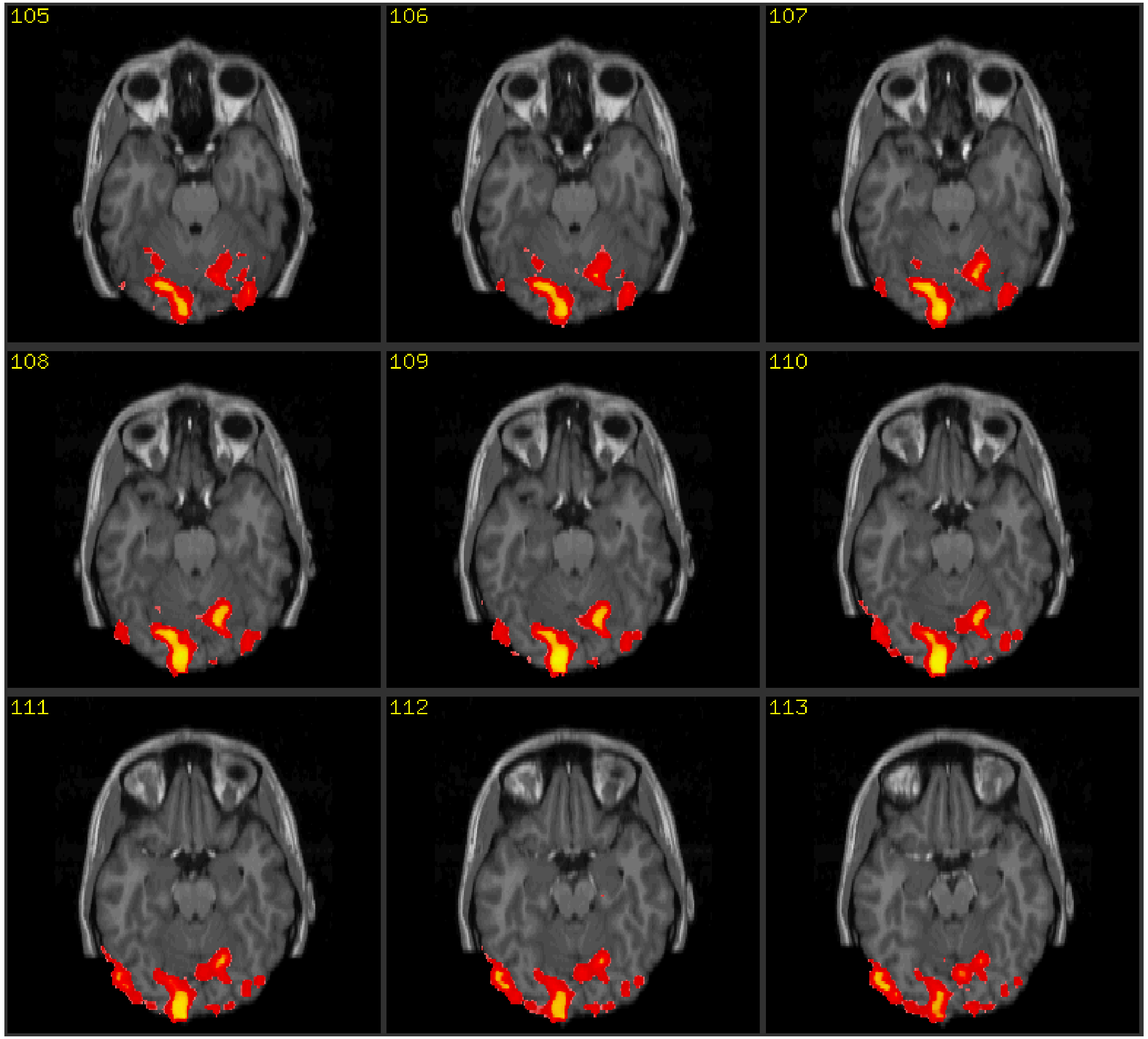


(Baumgartner et al., 2008)

Brain-Computer Interface (BCI)

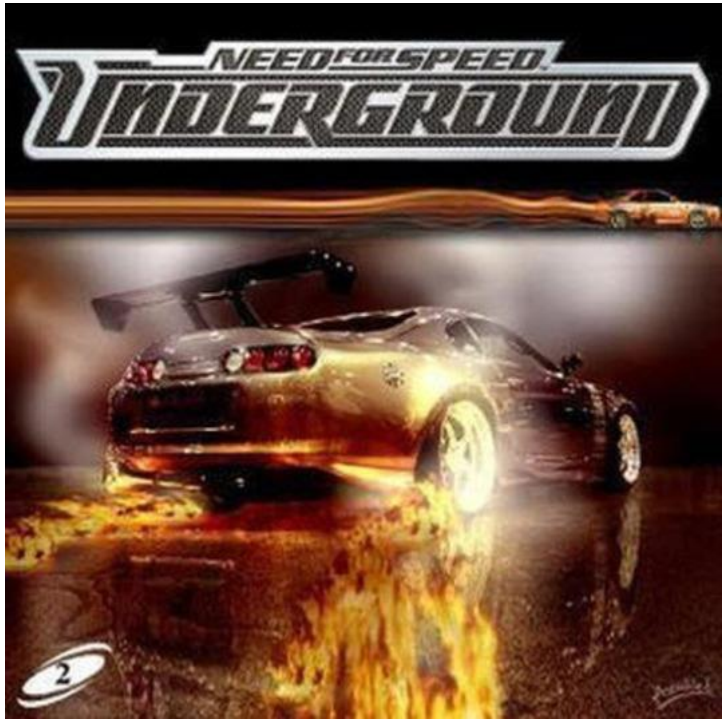
Neurofeedback games

fMRI



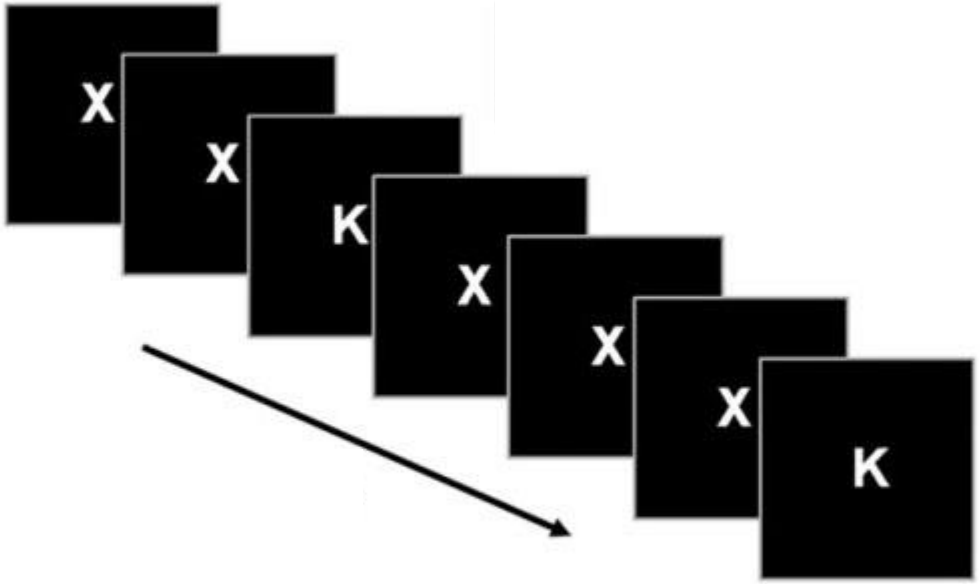
1 fMRI in Game-Based Learning

The impact of violent video game on the players' brain (Hummer et al., 2010)



Nonviolent game

Violent game

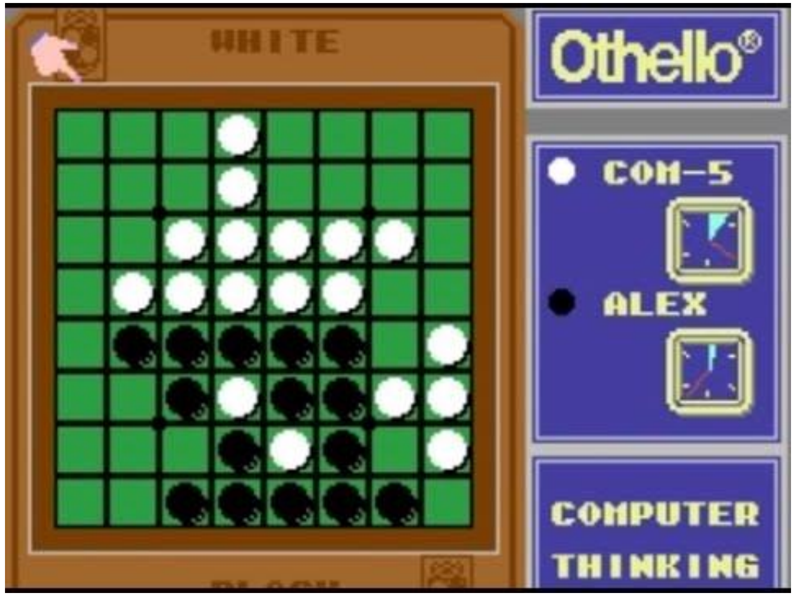


No-go Task

1

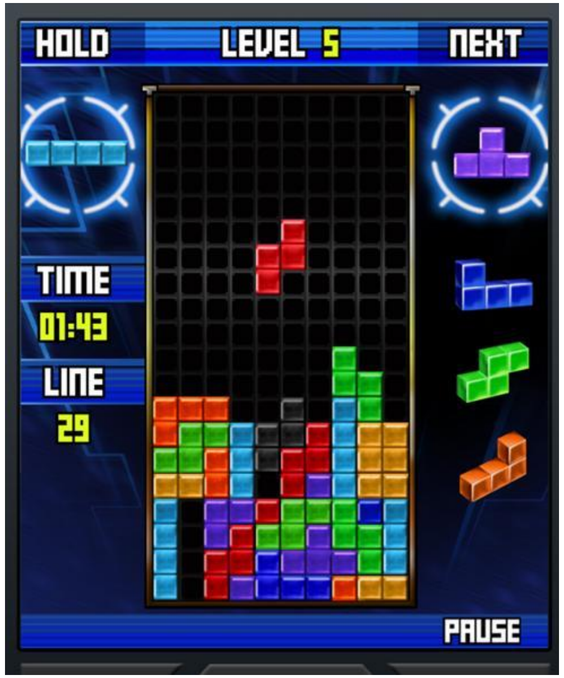
fMRI in Game-Based Learning

The effect of genre of video game on the player' brain (Saito, 2007)



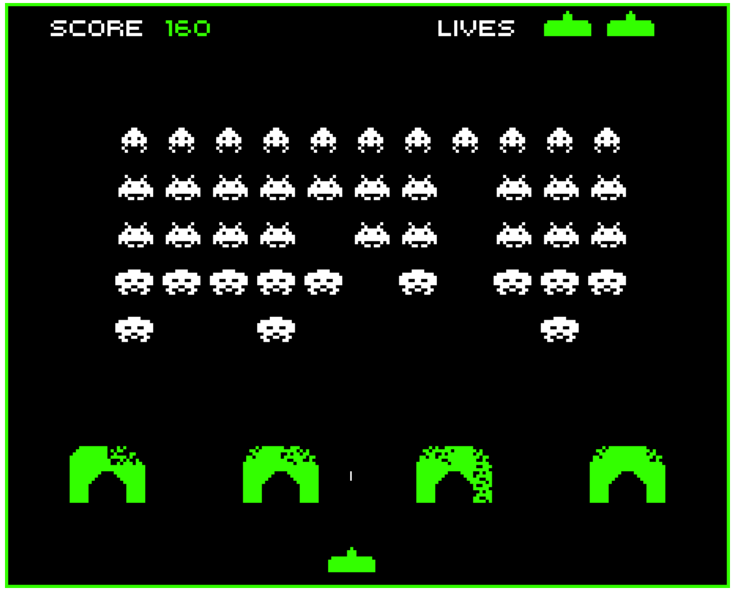
Othello

A typical board game,
requires logical thinking and
memorization of spatial information



Tetris

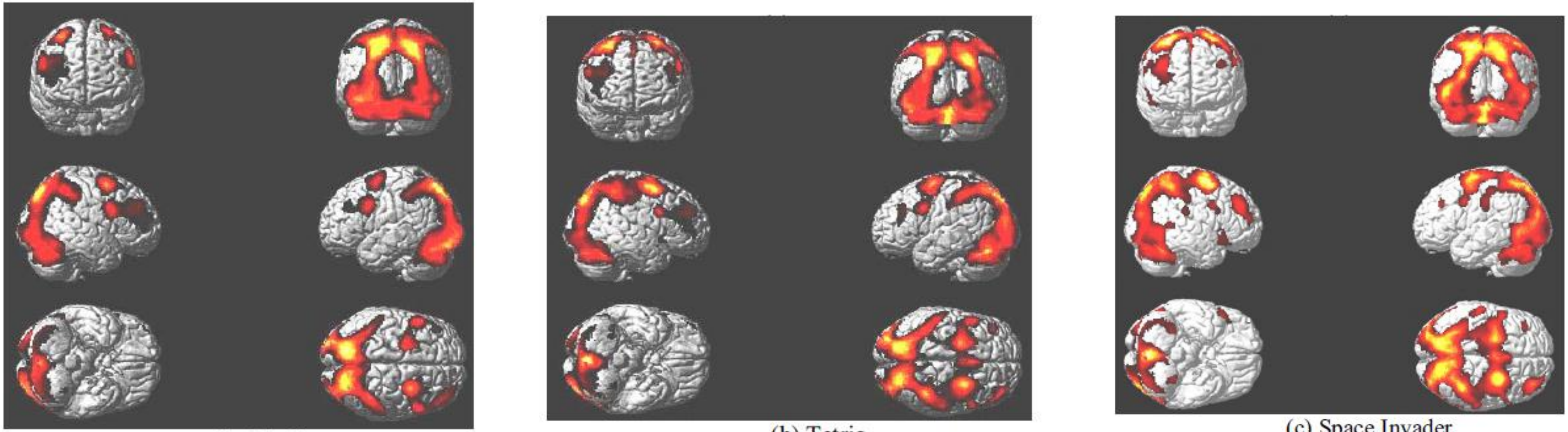
A puzzle game,
requires both rapid
reaction and
spatial logical thinking



Space Invader

A shooting game,
requires real-time reaction
and unexpected judgment

The effect of genre of video game on the player’ brain



(a) Othello (b) Tetris (c) Space Invader

Space Invader and Tetris requiring real-time reaction activated the parietal cortex and the premotor cortex more widely than Othello (Saito, 2007).

Othello and Tetris, which require spatial logical thinking, activated a broader area of the dorsal prefrontal cortex than Space Invader (Saito, 2007).

fMRI in Game-Based Learning

- **Presence in simulation environments**

Activation of a distributed network in the brain, e.g. activation in the dorsal and ventral visual stream, the parietal cortex, the premotor cortex, mesial temporal areas, the brainstem, the thalamus and the dorsolateral prefrontal cortex

- **Flow**

Neural activation patterns in reward-related midbrain structures, as well as cognitive and sensorimotor networks

- **Joint attention (Collaboration and social interaction)**

Additional activation patterns in the Posterior Superior Temporal Sulcus (pSTS) region in case of joint attention

fNIRS

fNIRS in Game-Based Learning

Differences in blood oxygenation between novice players and master-level players (Hattahara et al., 2008)

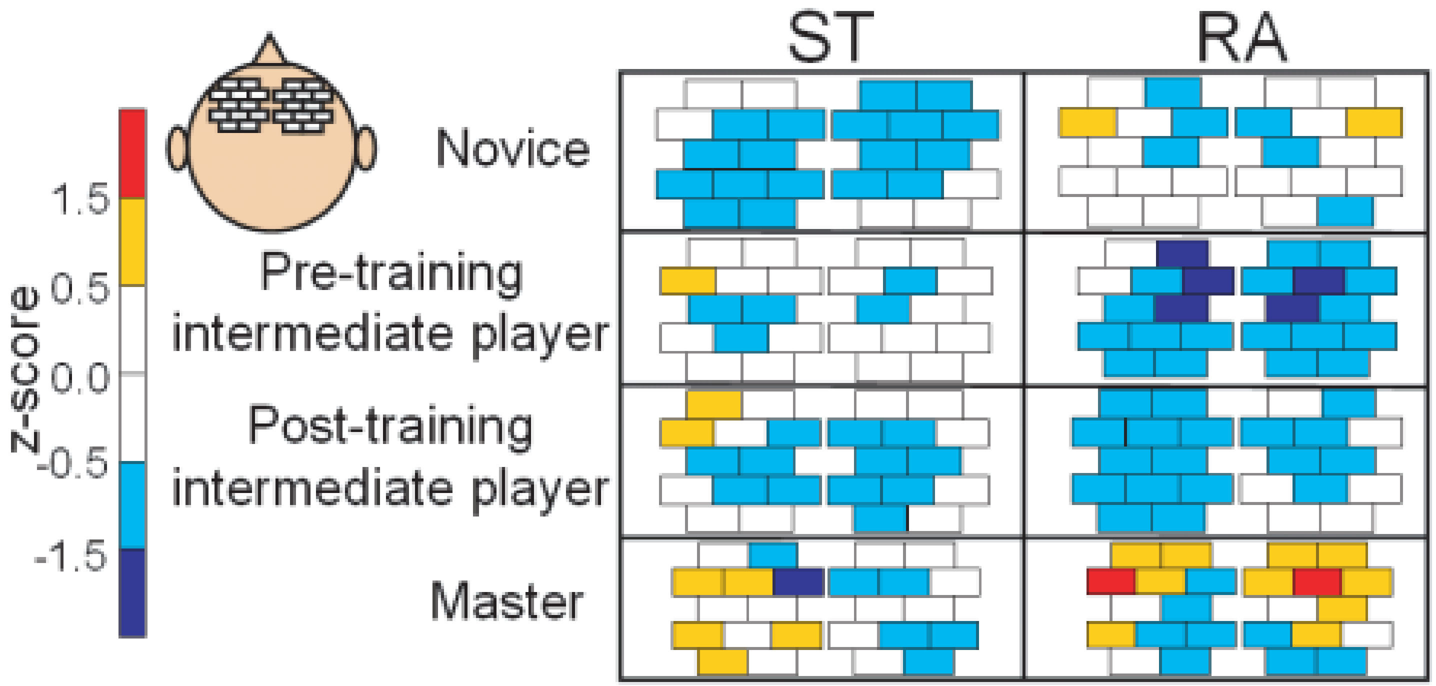
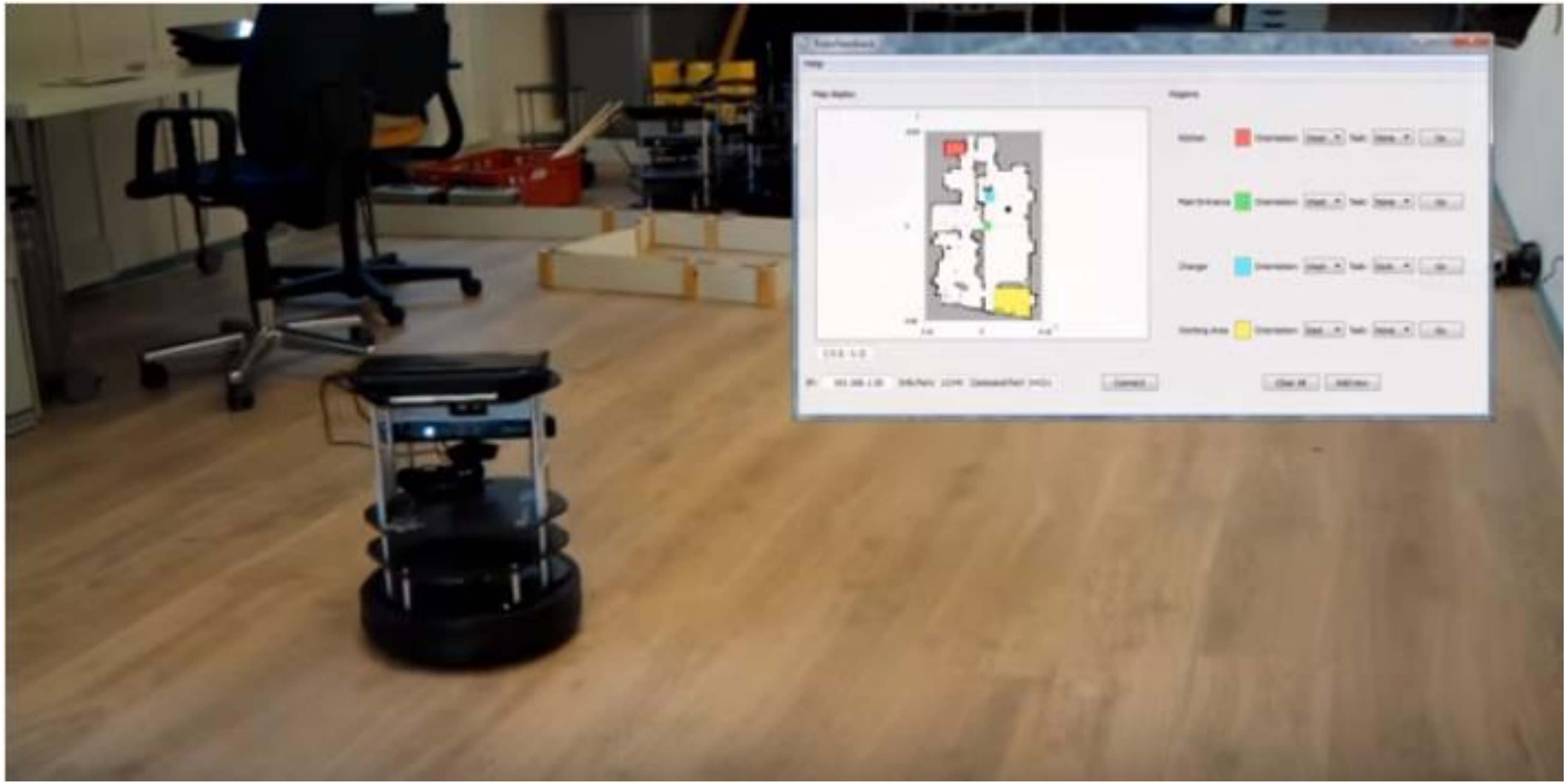


Figure 4: Results of Experiment 1: oxy-Hb activation by task

Human-Robot Interface



Which method to use?

EEG	fMRI	fNIRS
• High temporal resolution • Interacting with the game or controlling game • Neurofeedback with no time delay	• High-spatial resolution • Accessing to deep brain structures • Less flexible and comfortable system • Most expensive method in terms of maintainance and purchase	• Reduced sensitivity to motion-artefacts • Quick preperation time

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    - Redundancy
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Multimodality

2 Multimedia Learning

Multimodality (Adreano et al., 2009)

Multimodality

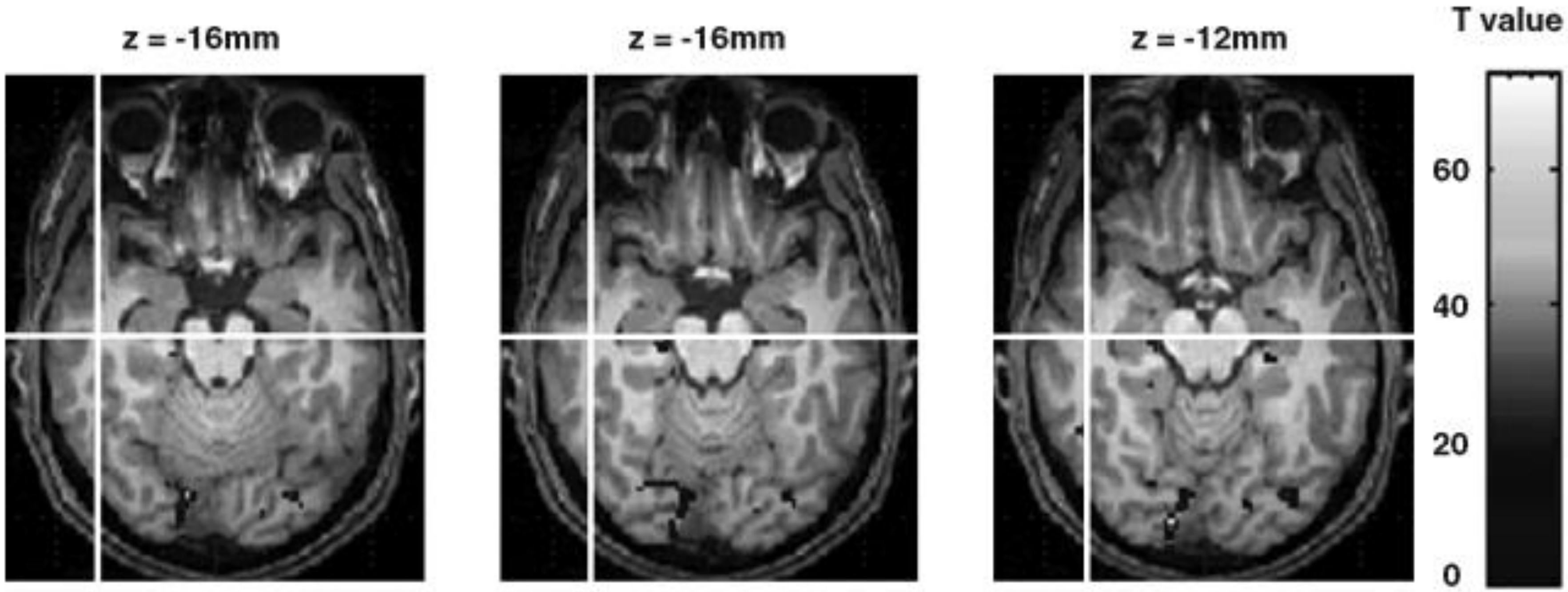
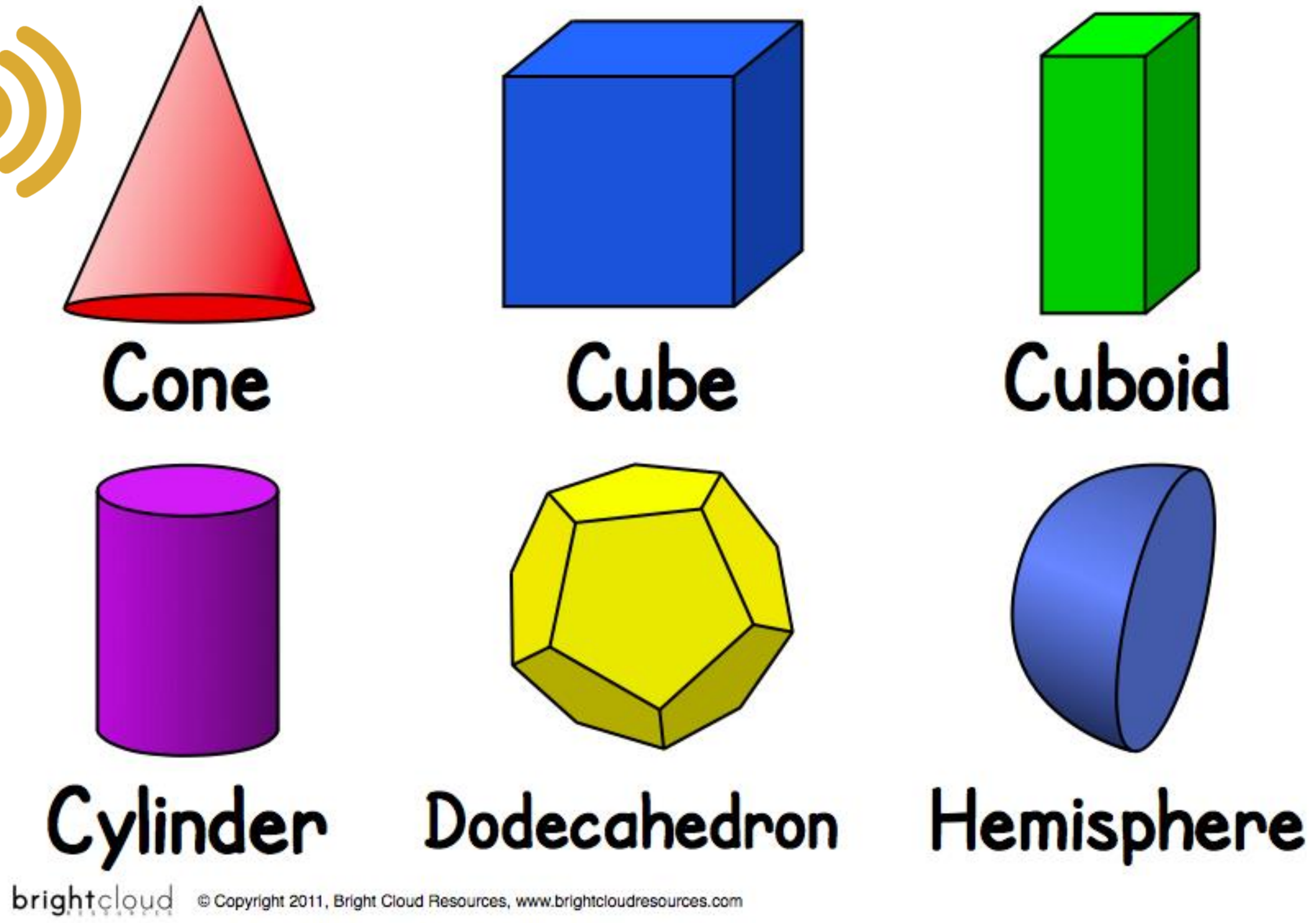
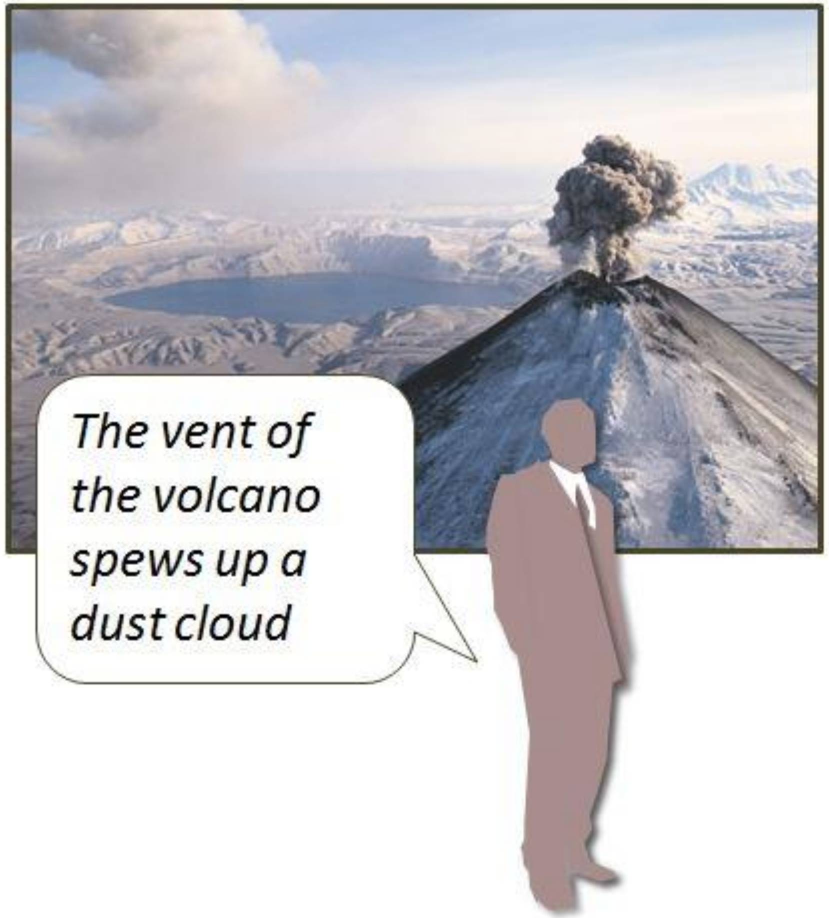


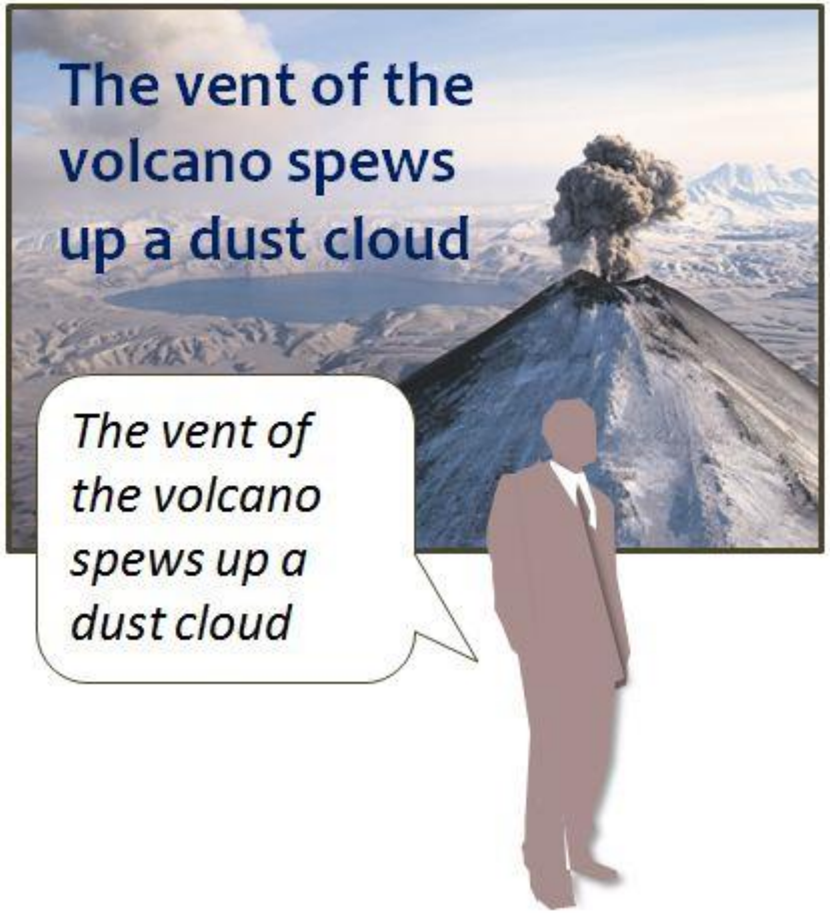
FIG. 2. Cluster of selective activation to presentation with audio as compared to without. Activations in visual cortex and hippocampus are visible. (Adreano et al., 2009)

Multimodality



Redundancy


The vent of the volcano spews up a dust cloud


The vent of the volcano spews up a dust cloud
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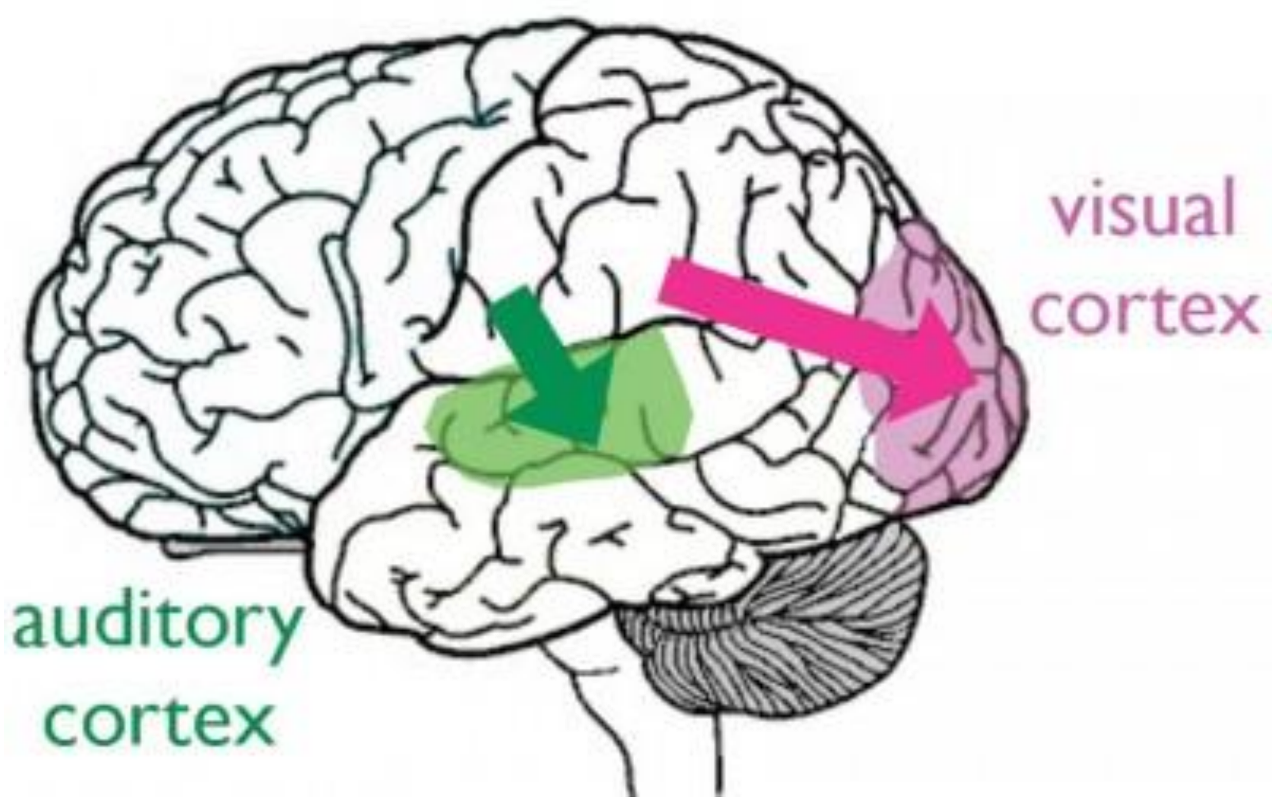
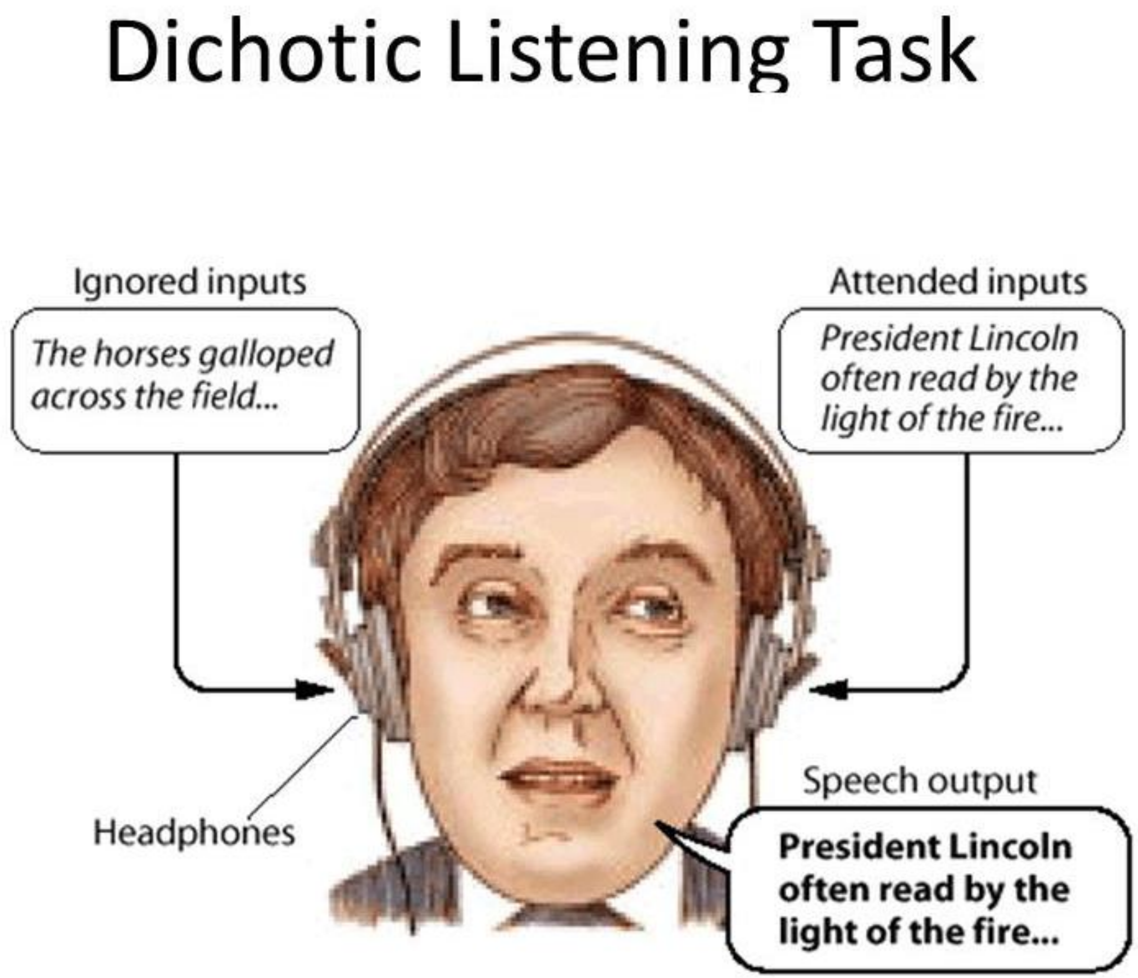
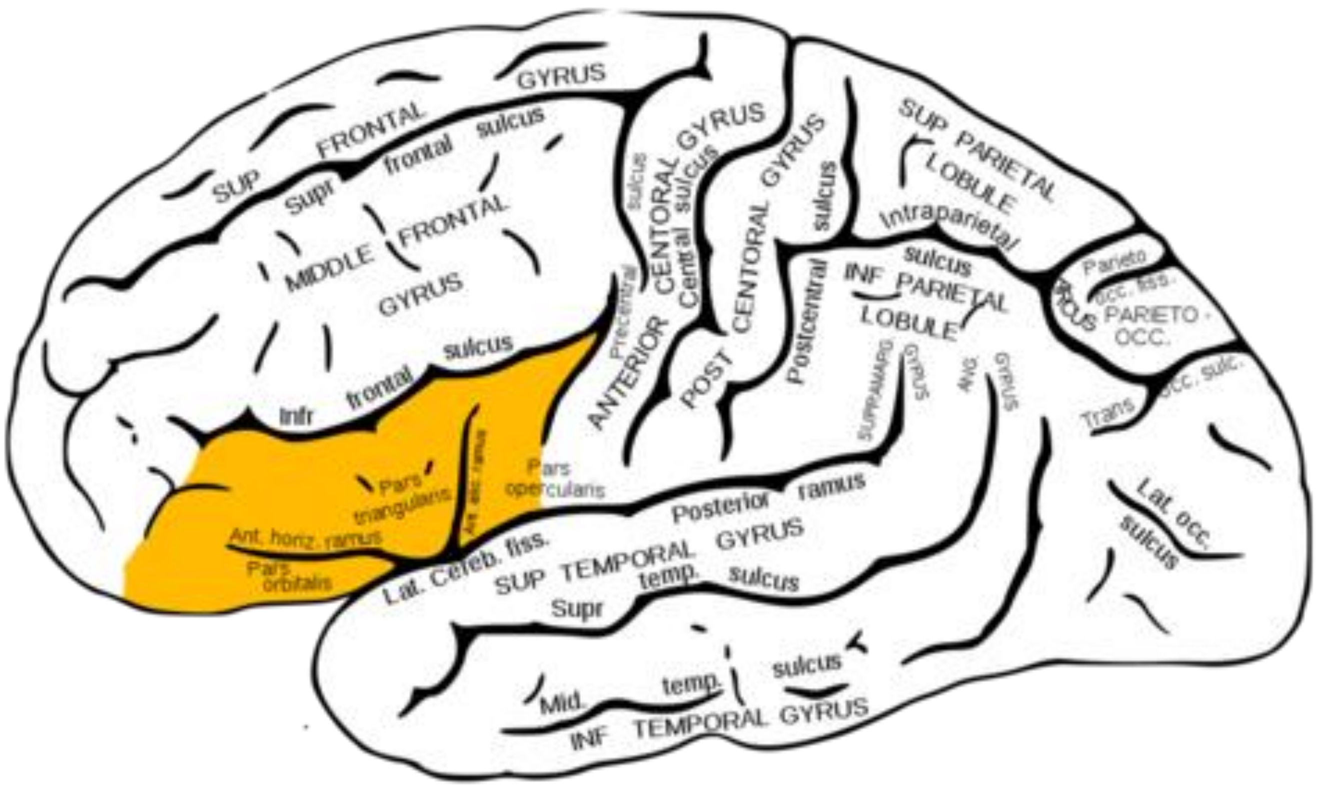
Redundancy



Redundancy // Divided Attention

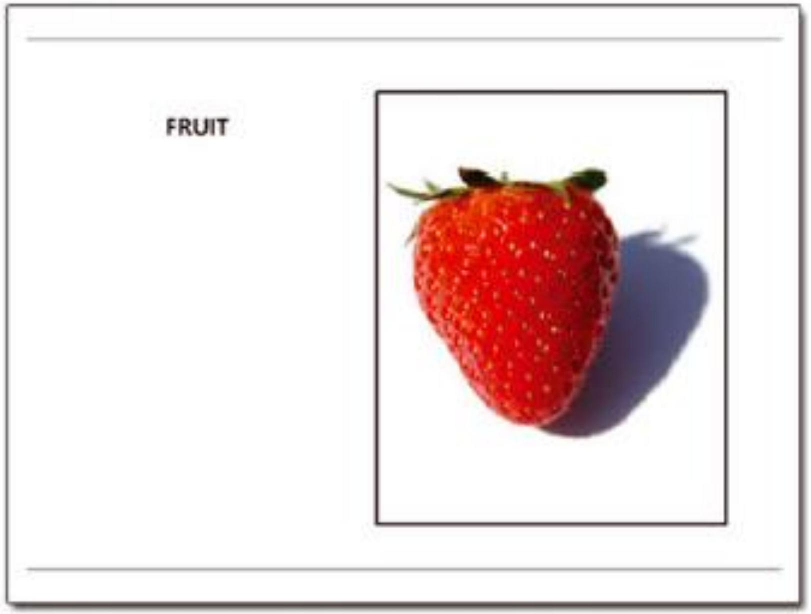


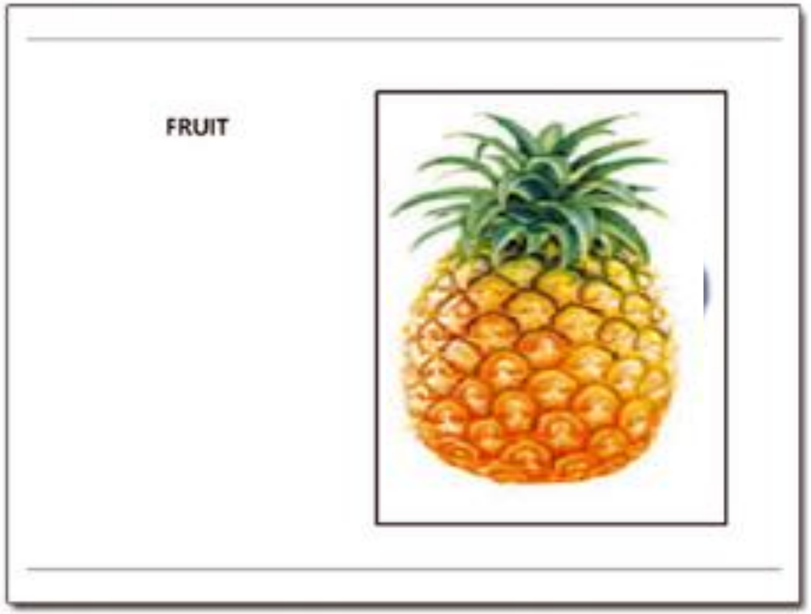
Redundancy // Divided Attention

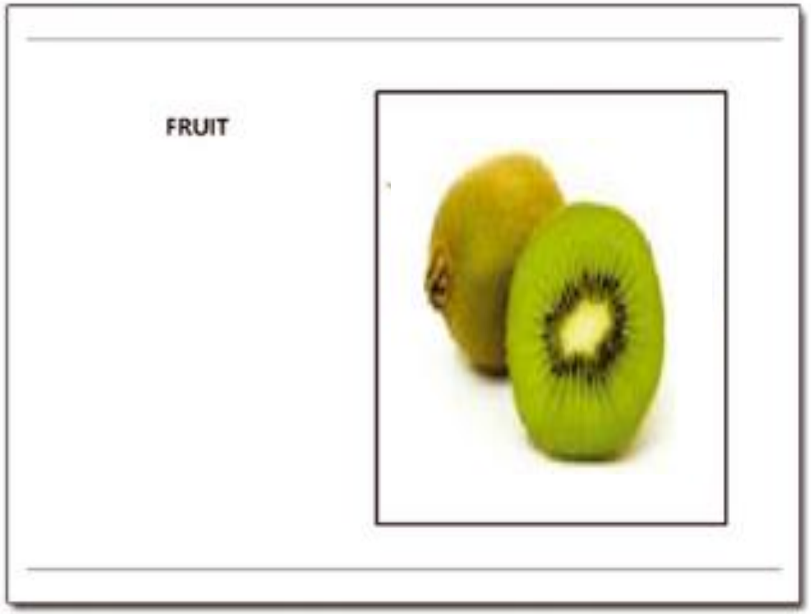


Left dorsal inferior frontal gyrus

Signaling | Contextual Cuing (Horvath, 2014)

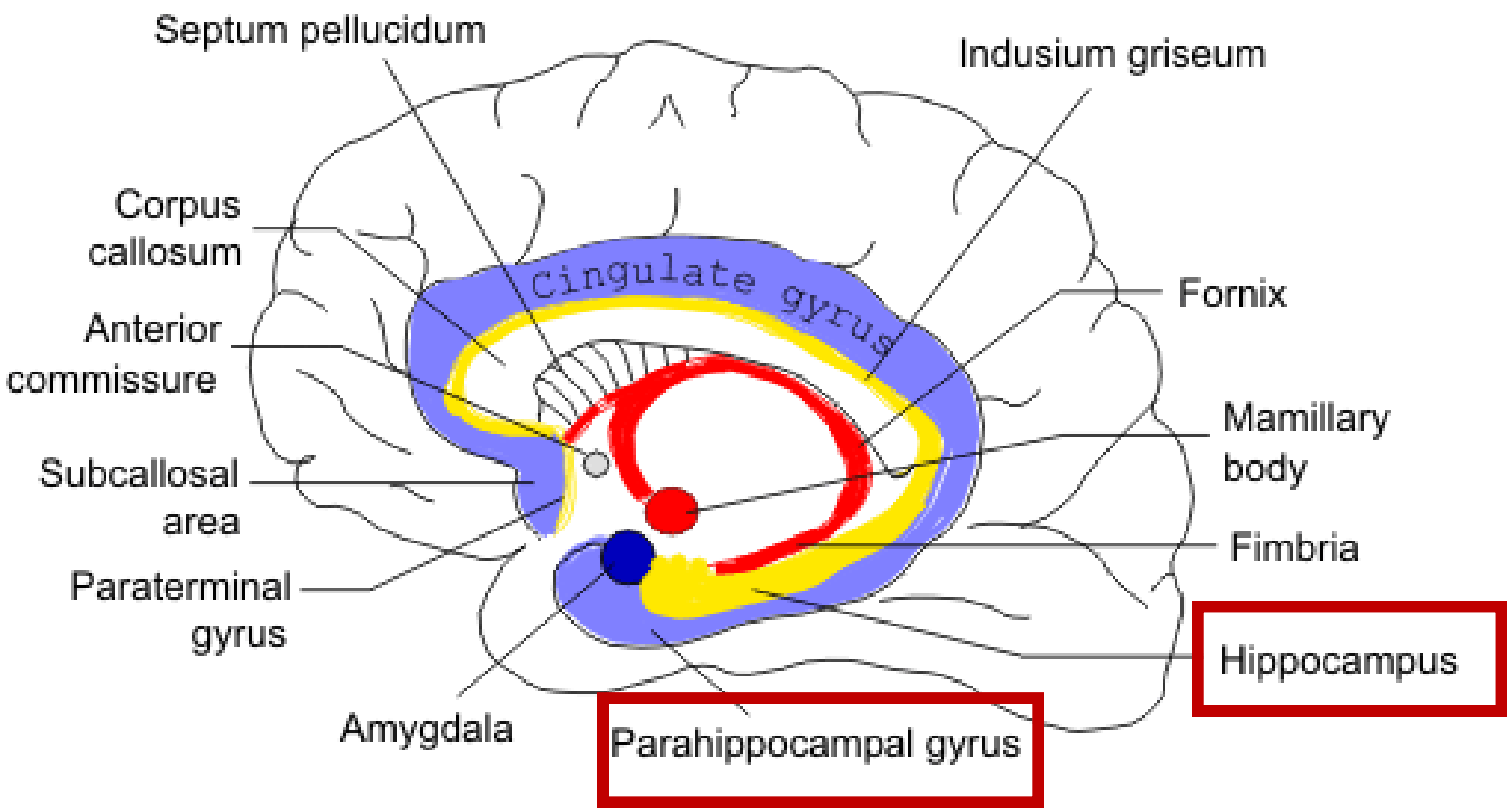






Contextual cuing

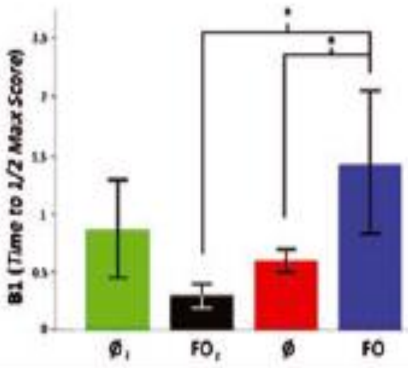
Signaling | Contextual cueing



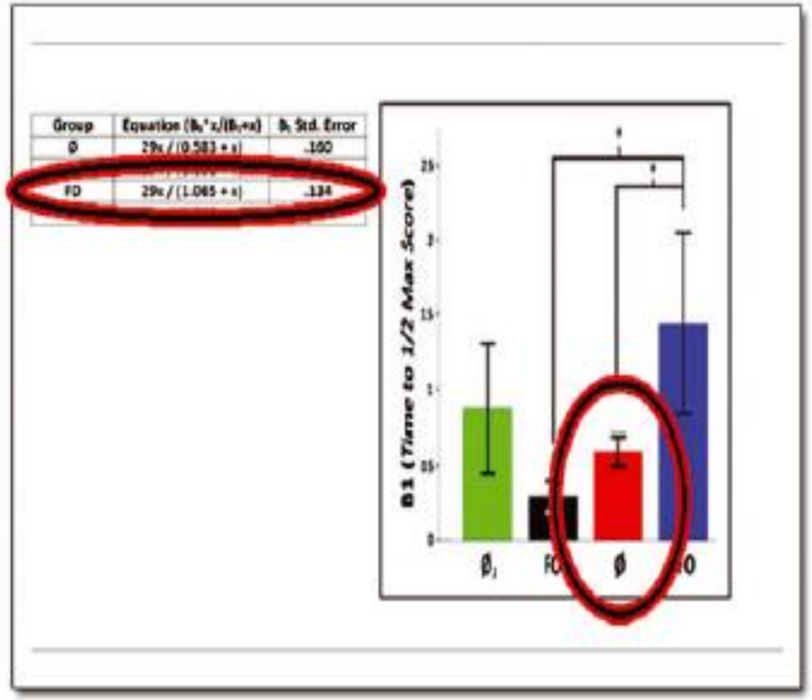
Signaling | Spatial Cueing (Horvath, 2014)

a

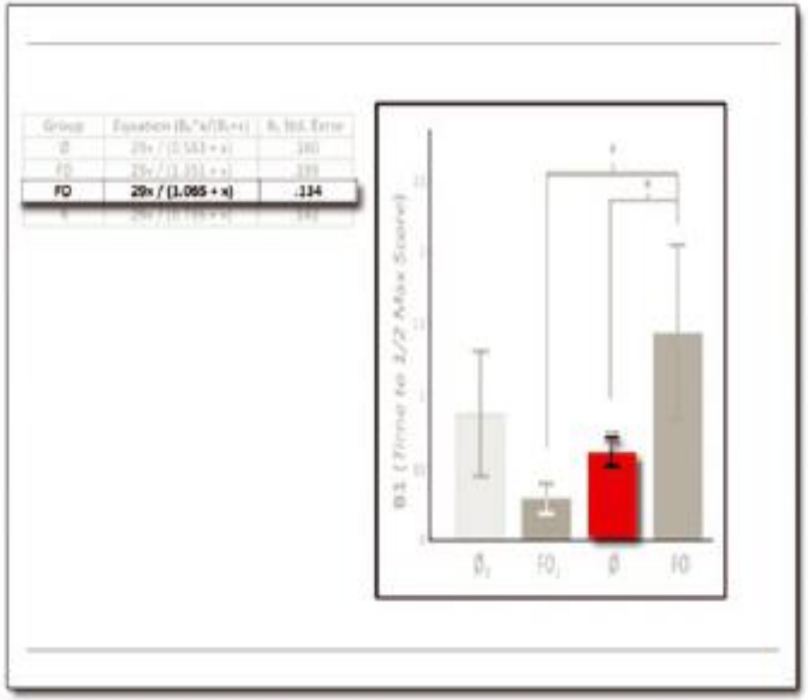
Group	Equation (B_0*x/(B_1+x))	B_1 Std. Error
Ø	29x / (0.583 + x)	.160
FO	29x / (1.351 + x)	.199
FD	29x / (1.065 + x)	.134
R	29x / (0.735 + x)	.142



b



c



Signaling | Spatial cueing

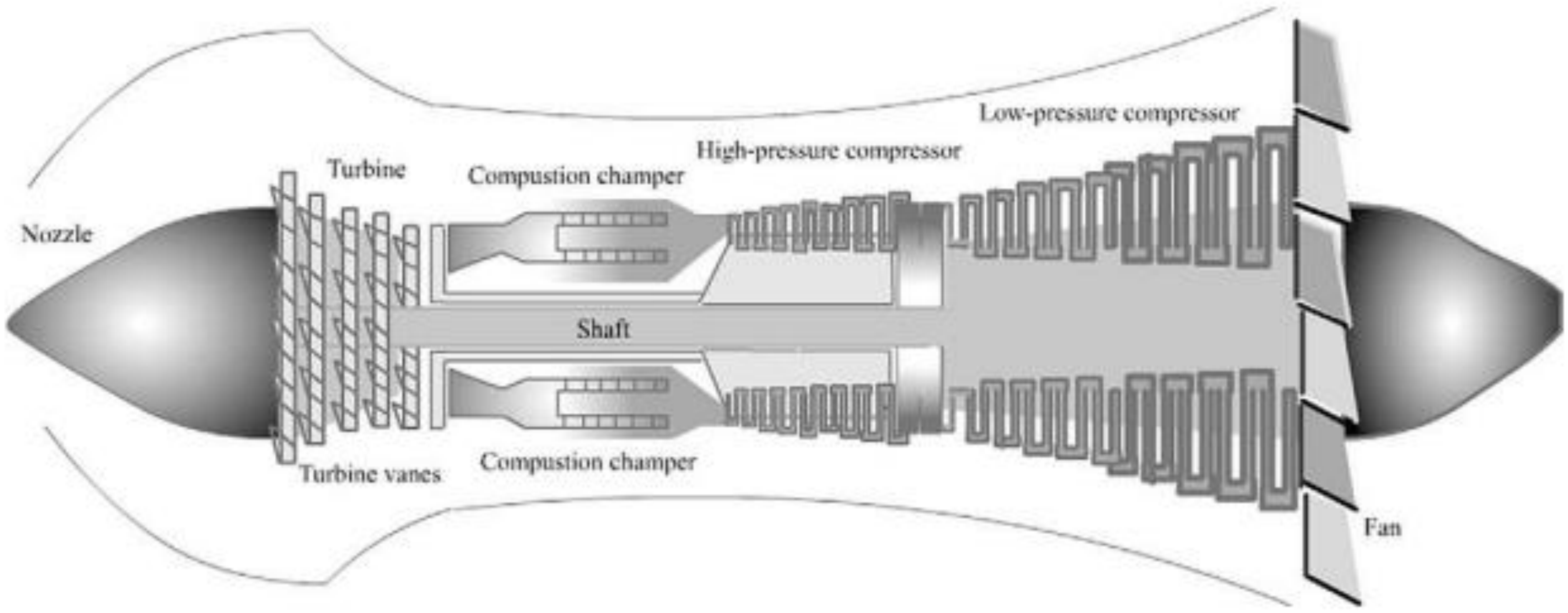


Fig. 1. The nonsignaled format of the material. (Ozcelik et al., 2010)

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Neuroscience and Educational Technology

Sibel DOĞAN

Today's Topics

- Cognitive Neuroscience and Technology Enhanced Learning
- Educational Neuroscience of Game-Based Learning
- Multimeda Learning

Outline

- Cognitive Neuroscience and Technology Enhanced Learning
- Bridging Technology enhanced Learning (TEL) and Cognitive Neuroscience
- Methods and Techniques in Cognitive Neuroscience
  - FMRI (Functional Magnetic Reasonance Imaging)
  - EEG (Electroencephalography)
  - EDA (Electrodermal Activity)
- Neuroscience with Potential Relevance for TEL

Cognitive Neuroscience and Technology Enhanced Learning

- Insights from the science of mind and brain are generating fresh perspective on education. The impact of these insights may be greatest where another force **« technology «** , is already impacting the methods and means by which we learn. However, little work has focused specifically on the potential of cogntive neuroscience to inform the design and use of technology-enhanced learning (TEL)

Bridging Technology enhanced Learning (TEL) and Cognitive Neuroscience

- Neuroscience – learning – memory
- A particular memory is distributed throughout the brain and does not reside in any one place, although there are some regions linked to particular aspects of memory (such as spatial memory, which depends more on the right hemisphere than left hemisphere).
- Neuroscientists generally believe that human learning, as in the formation of memory, occurs by changes in patterns of connectivity between neurons, i.e., the building blocks of the nervous system. However, forming connections between ideas (which we all agree happens in the mind) is not the same as forming connections between neurons in the brain, although changes in neural connectivity are likely to be necessary.

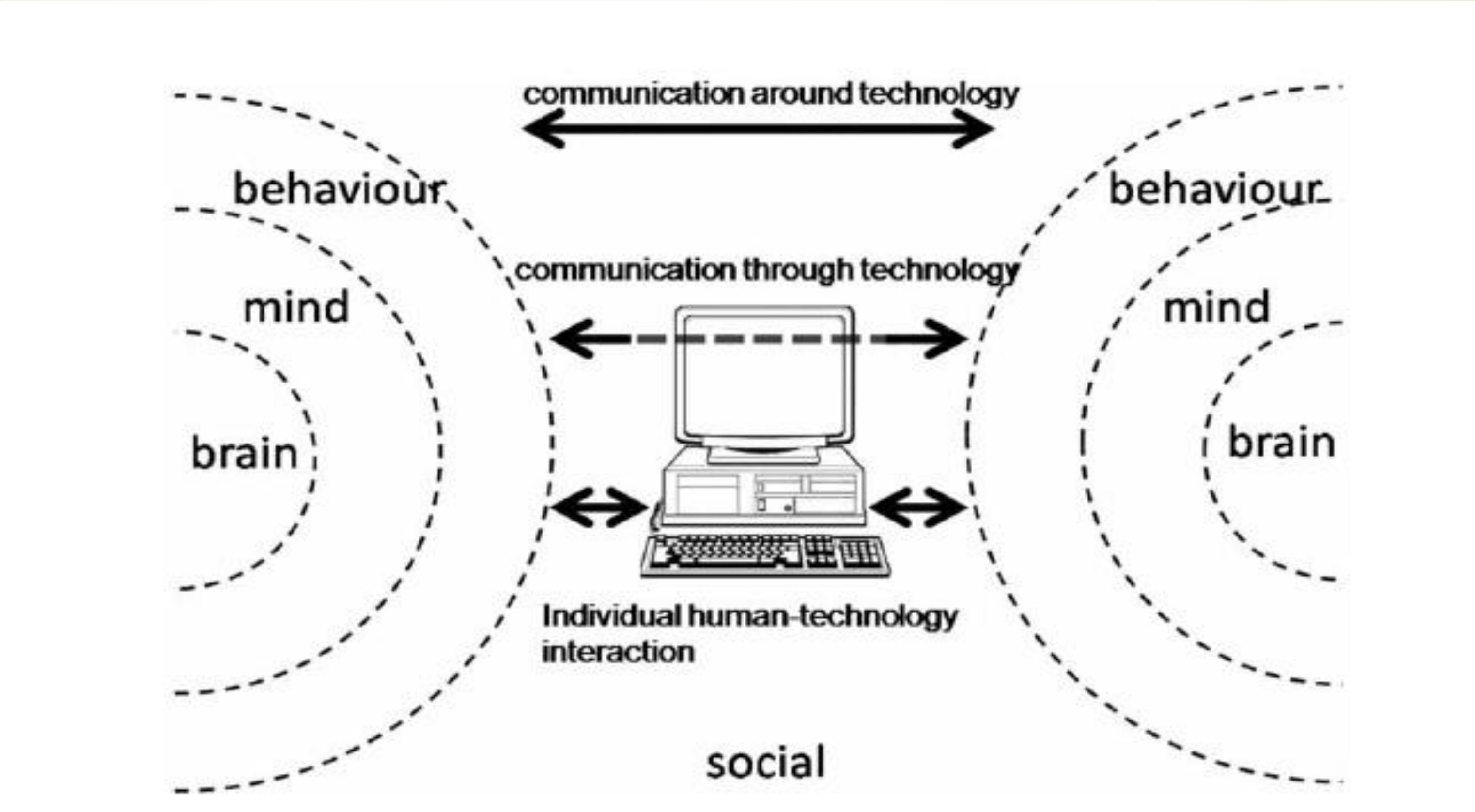
Bridging TEL and Cognitive Neuroscience

- Education- beyond the concept of memory.
- learning is often considered as happening between people, rather than just inside their brains. This is a very sensible perspective that has underpinned teaching for decades, and it naturally emphasizes the importance of social context and complexity.
- Cognitive neuroscientists are only just beginning to study these social aspects of learning. For that reason alone, neuroscience cannot offer anything like a complete story of learning in the classroom.

Bridging TEL and Cognitive Neuroscience

- Cognitive neuroscience emphasizes how neural processes give rise to mental processes and how, in turn, these mental processes influence our behaviour.
- The central role of mind in the **brain–mind–behaviour** sandwich makes cognitive psychology crucial to all cognitive neuroscience and in turn to neuroeducational TEL research.
- Much of educational research, however, also emphasizes the importance of social interaction. For this reason, it seems appropriate that neuroeducational consideration of TEL should include two or more individuals represented as brain–mind–behaviour models interacting within a social environment.

Bridging TEL and Cognitive Neuroscience

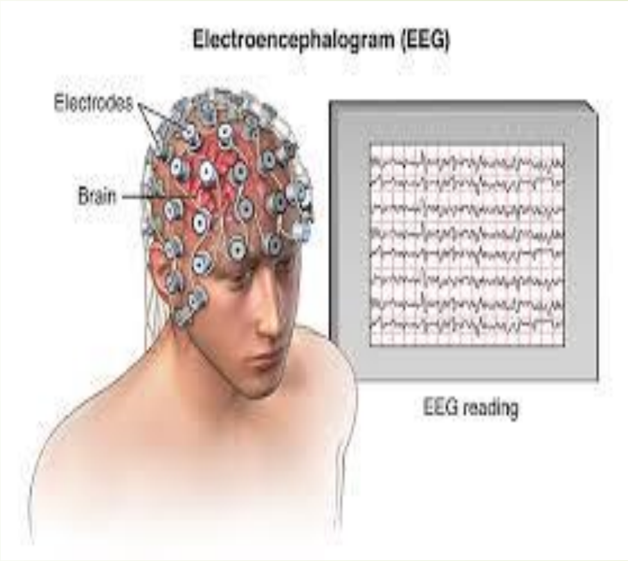


Methods and Techniques in Cognitive Neuroscience

- FMRI
  - More expensive than EEG.
  - Data are acquired in a specific and very noisy environment.
  - Chief advantage is spatial resolution that allows identification of activity within 3mm. However, its temporal resolution is a few second.

Methods and Techniques in Cognitive Neuroscience

- EEG
  - Measures electrical field near the scalp generated by Neural processing by generating four rhytms: alpha, theta, delta and beta.
  - Antonenko & Niederhauser (2010) – EEG was more effectve than self-report measures.



Methods and Techniques in Cognitive Neuroscience

- EDA (Electrodermal Activity)
  - İt is much simplier to measure and analyse than FMRI and EEG.
  - it has also been known as skin conductance, galvanic skin response (GSR), electrodermal response (EDR) and skin conductance response, (SCR).

  - (EDA) is the umbrella term used for defining autonomic changes in the electrical properties of the skin
  - Skin conductance can be an indicator for emotional arousals.
  - https://www.youtube.com/watch?v=-KupdgJERng

Methods and Techniques in Cognitive Neuroscience

- EDA -Lim & Reeves (2009)– World of Warcraft

heart rate and self-report to study the influence on physiological arousal of being able to choose avatar and visual point of view (POV) when playing 'World of Warcraft'. Their study demonstrated that being able to pick the character that will represent the player in the game led to greater arousal, especially for males. Different POVs did not appear, on their own, to affect the game player's arousal, but moderated the effect of avatar choice on the game player's heart rates. Importantly, **these effects were not observable in self-reports provided by participants, which suggests that simple physiological measures can capture aspects of user interaction that the user is not consciously aware of.**

Neuroscience with Potential Relevance for TEL

- Training of executive brain function
- Developmental disorders- dyscalculia and dyslexia
- Creativity
- Neurofeedback
- Engaging with others : Human and Artificial
- Multimodality
- Games and LEarning

Neuroscience with Potential Relevance for TEL

- **Training of executive brain function**
  - brain training programs are broadly defined as the engagement in a specific programme or activity that aims to enhance a congitice skill or genera cognitive ability as a result of repetation over a circumscribed timeframe.
  - Computer-based brain training games – reasoning skills and working memory
  - **Holmes, Gathercole and Dunnig** (2009), working memory training can result in long term retention of skills and transfer to gains in maths
  - **Shipstead, Redick and** Eangle (2012), meta analysis, methodological flaws in much of the evidence supporting current brain-training claims, concluding that there is a lack of convincing evidence for anything other than short term, specific training effects that do not transfer in this way

Neuroscience with Potential Relevance for TEL

- **Developmental disorders-**
  - **Dyscalculia**
  - **Dyslexia**

Nordness, Haverkost, & Volberding (2011)

- 3 Elementary students (second grade)
- Dyscalculia – Substraction
- Math Magic- Flashcard application
- Single subject, multiple baseline design
- Observation, Achievement Test
- Practice on a mobile computing device with a mathematic flashcard application can improve subtraction skills in second grade students with disabilities.

Mohammed & Kanpolat (2010)

- Elementary students
- Dyscalculia
- Classification Tasks
- Experimental Design
- Scale, Achievement Test
- Results showed that technolgoy usage can develop students' performances on mathematic because it provides students' with chance to make more practice on specific skill and immediate feedback.

Irish (2002)

- 6 students
- Dyscalculia
- Memory Math
- Single subject multiple baseline design
- Achievement Test, Interview, Observation
- Results showed that memory math can help students to improve their performances on math.

Stetter & Hughes (2011)

- High school students
- Reading problems
- Gates- MAcGinite Comprehension Test
- Single subject, multiple baseline design
- Observation, Achievement Test, Survey
- According to results, effects of technology usage is positive on students reading performances. Students preferred to use and enjoyed the technology provided.

Floyd & Judge (2012)

- University students
- Reading problems
- Classmate Reader
- Multiple baseline acrros participants
- Interview, Observation, Achievement Test, Survey
- Results indicated that technolgoy usage can improve students' reading comprehension skills

Results

- The results of these studies highlighted that these studies were conducted with small sample size none fo them was replicated. Moreover, none of these studies provided validity and realibilty since their results were only based on limited data which are obtained from achievement scores, or interviews and observations. Imagining technique can be a way to support their findings.

Kucian et. al., (2011)

- 32 students – 16 dyscalculia- 16 iwthout dyscalculia
- Rescue Calcularis
- 15 minutes a day- 5 weeks
- Behavioral tests and neuroimagining of brain function when performing the task.
- Both groups showed improvement in various aspects of spatial number reprresentation and mathematical reasoning in the training. The intensive training led initially to a general activation decrease of relevant brain regions probably due to reorganization and fine-tuning processes (with greater changes for dyscalculics), and then to an increase in task-relevant regions after a period of consolidation.

Lyytinen et. al., (2007)

- Graphogame –non commerical game
- Dyslexia
- Neuroimaging study showed that practice with the game can initiate print-sensitive activation in regions that later become critical for mature reading- visual word-form system.

Neuroscience with Potential Relevance for TEL

- Training of executive brain function
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- **Creativity**
- Engaging with others : Human and Artificial
- Games and Learning
- Multimodality

Neuroscience with Potential Relevance for TEL

- **Creativity**

A recent brain imaging study suggests that accessing the ideas of others may enhance creativity by reducing the need to deactivate automatic bottom-up processes (associated with fixation on own ideas) (Fink et al. 2010). That is, when we are trying to think of new ideas, we must suppress those within our immediate attention in order to find original and novel associations.

Neuroscience with Potential Relevance for TEL

- **Neurofeedback**

Neurofeedback is the monitoring of one's own brain activity with a view to influencing it.

A study investigating EEG neurofeedback concluded that it produced improvements in the musical performance of conservatoire students

Neuroscience with Potential Relevance for TEL

- **Engagement with others: human and artificial**
- Howard-Jones et al. (2010) found that players' neural circuits mirrored their artificial competitor's virtual actions as if they were their own, a type of neural response usually attributed to observing biological motion. However, effects may be greater if the technology appears moderately human-like.

Neuroscience with Potential Relevance for TEL

- **Multimodality**
- **Multimedia learning.**
  - Andreano et.al., (2009)
  - Virtual reality environment- icy environment, beach looking
  - Audiotory clues
  - İncreasng activation in hipocampus.

The future of Cognitive neuroscience and Technology Enhanced Learning

- Education will focus more on cognitive processes similar to those studied by cognitive neuroscience
- Cognitive Neuroscience and TEL already share an interest in the cognition of technology based learning
- Aims of neuroscientists and TEL researchers may converge in terms of « tool » development.
- TEL neuromyths need to be dispelled.

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Thank you ☺