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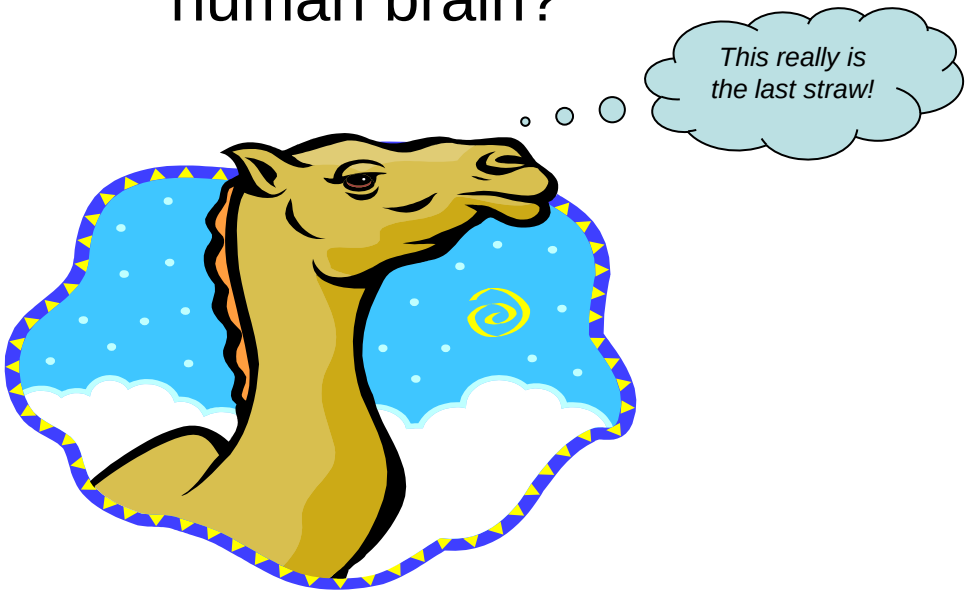
Breaking the Camel's Back:

Can global cognitive overload be quantified in the human brain?



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Outline

* Context and background
* Assumptions
* Experimental design and procedure
* Results
* Interpretations
* Caveats
* Future Research

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In the beginning…

How to augment human cognition??

PET, MRI, fMRI, TMS, rTMS, MEG??? X

Electroencephalography (EEG) ✓

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Build something…

With practical, commercial applications that has the capability to augment cognition via…

…improving human performance (Positive Psychology - Seligman)
…preventing dysfunction (e.g. PTSD)
…and/[or]
…rehabilitating dysfunction (e.g. depression, addiction, PTSD)

That is – create a cost-effective, portable device capable of global cognitive load/overload measurement

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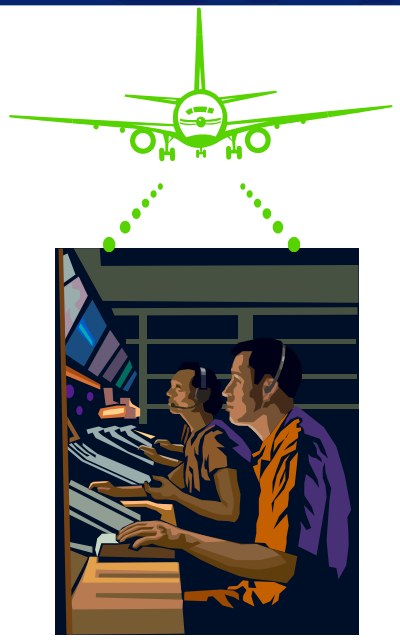
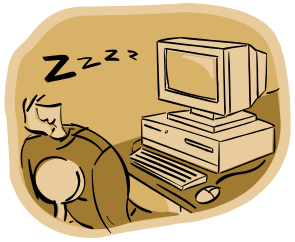
Context

Defence Forces



Air traffic control

Medicine



Occupational applications

Therapeutic applications

Legal applications

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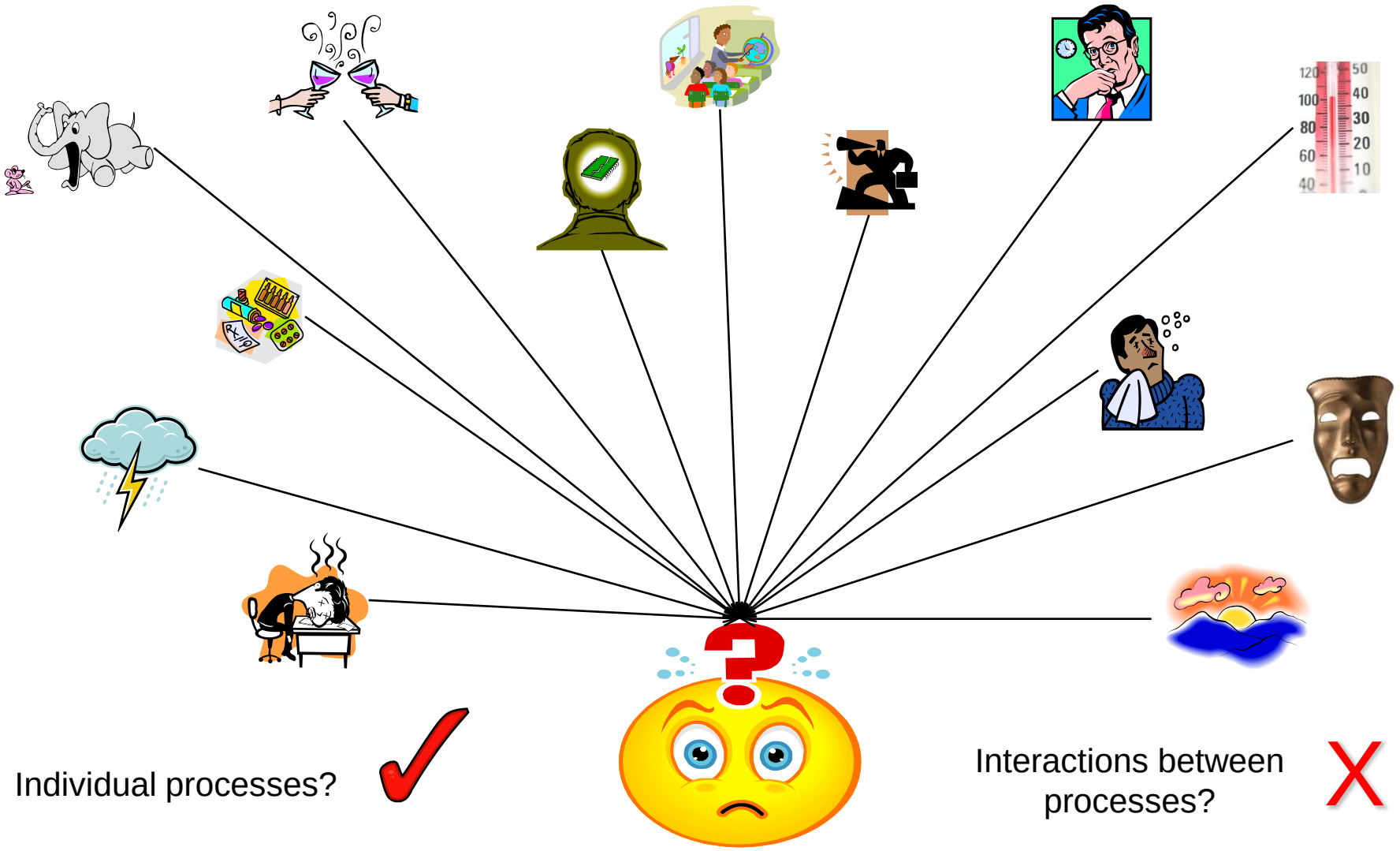
Background



Individual processes?

Interactions between processes?

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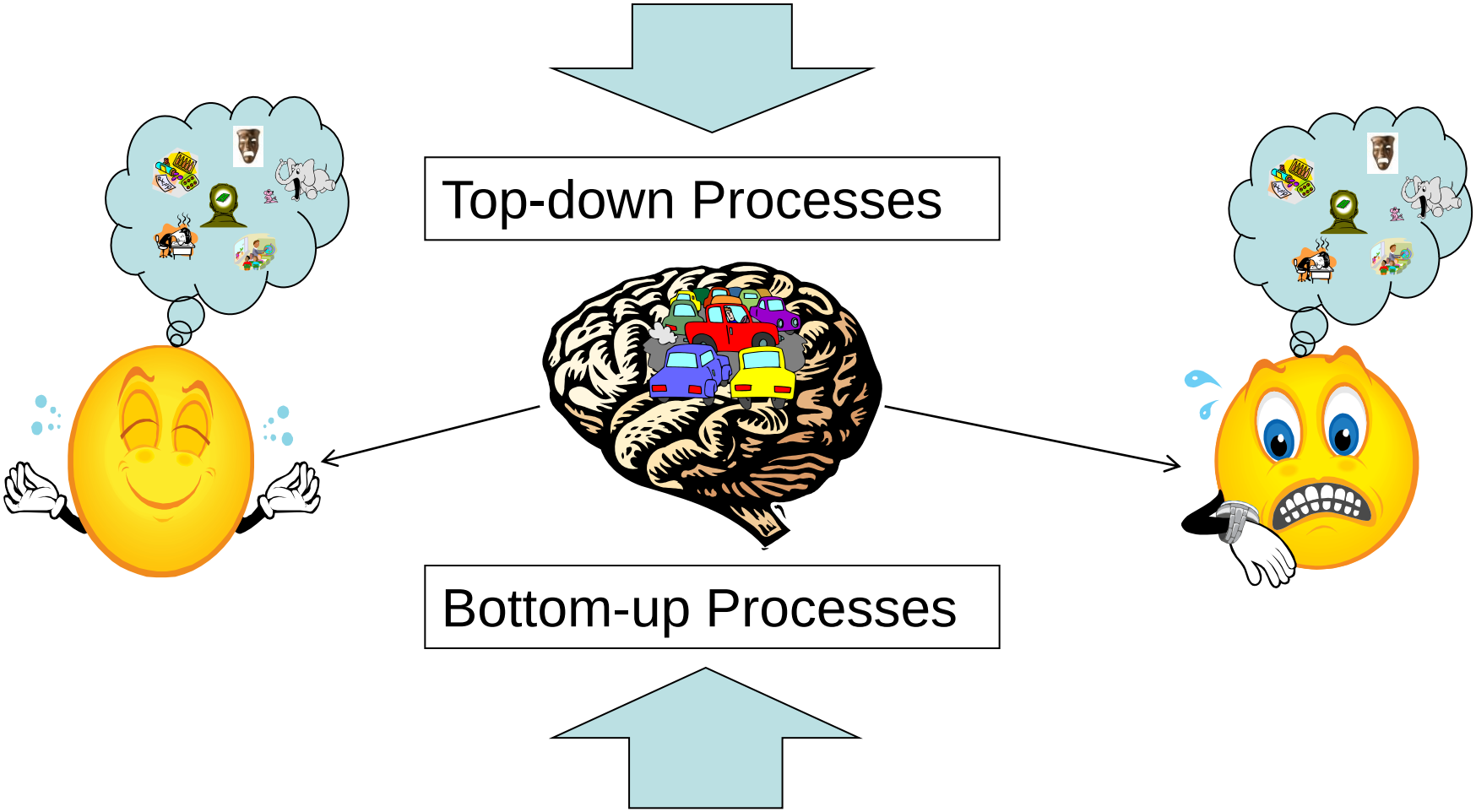
Assumptions



Bottom-up + top-down = processing bottle-neck

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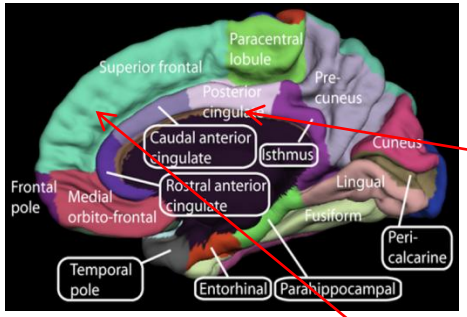
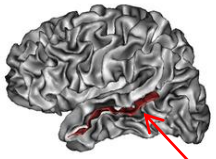
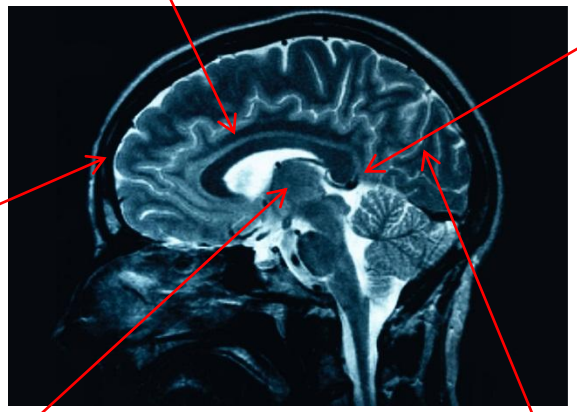
Brain Areas of Interest



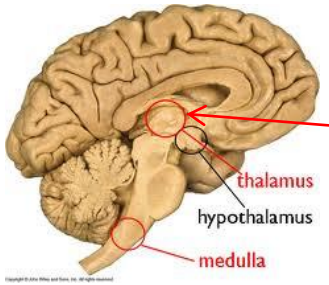
Anterior Cingulate Cortex (ACC)



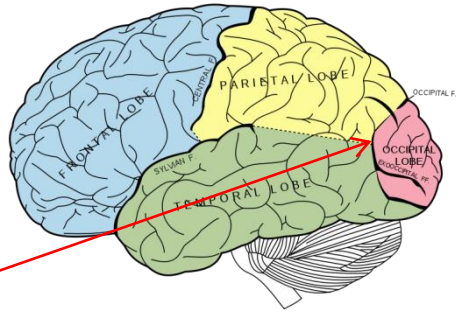
Superior temporal sulcus (STS)



Frontal areas



Thalamus



Parietal-occipital lobe boundary

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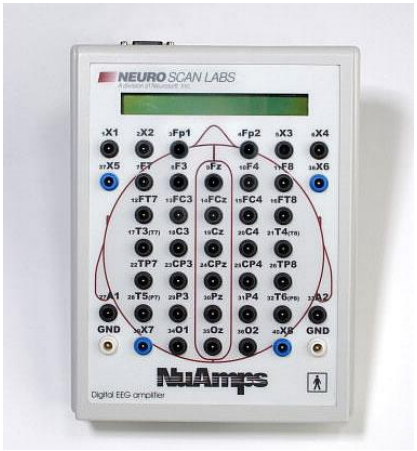
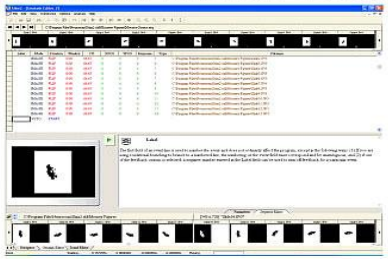
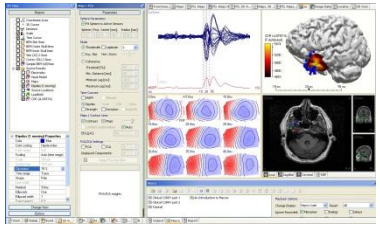
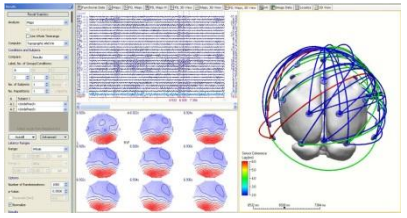
CNeL Equipment



GENTASK SEQUENCE EDITOR







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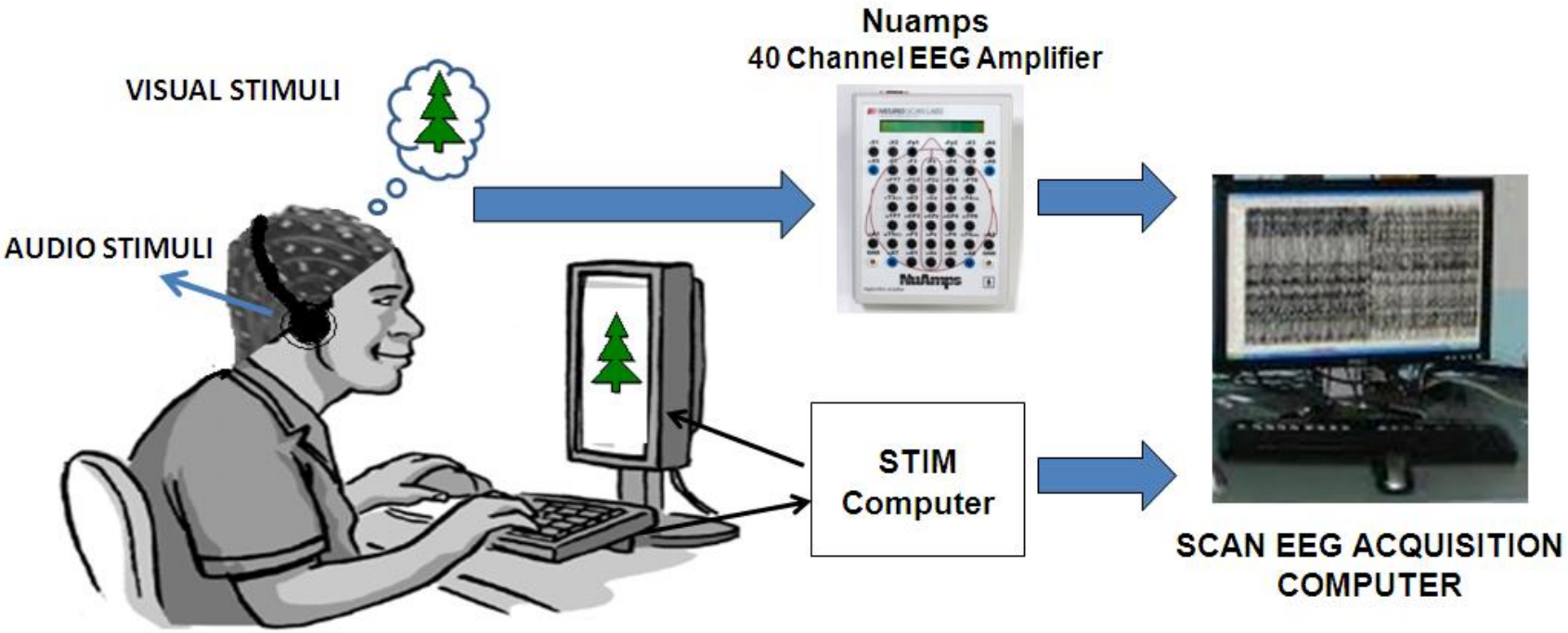
Procedure



Cognitive load experimental set up

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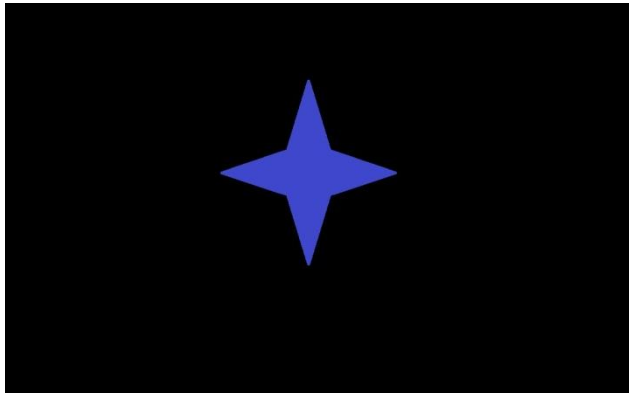
Baseline



We would now like to record 2 minutes worth of data with your eyes closed. As much as possible we would like you to clear your mind during this task and try not to think about anything...if your mind wanders, just let it go. When you are ready, close your eyes and press the "Y" key on the keyboard. At the completion of the 2 minutes you will hear a short tone - when you hear this, please open your eyes. Please also rememeber to try to keep movement to a minimum.

When ready, place your finger over the "Y" key, close your eyes, then press the key to commence...

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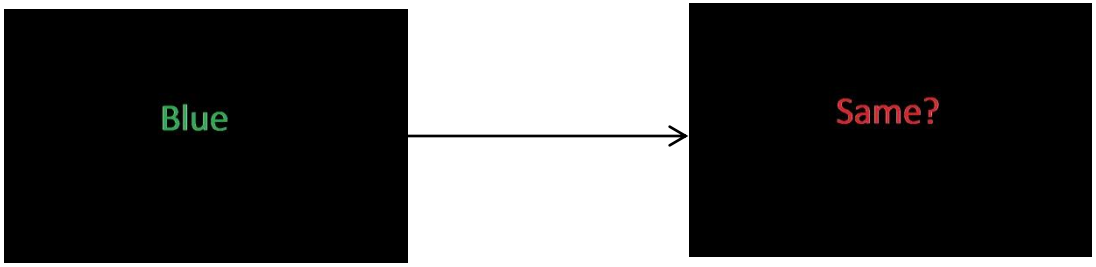
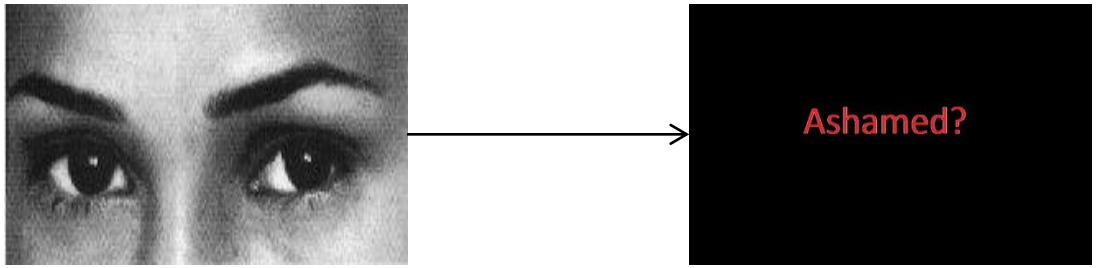
Mild Cognitive Load Condition

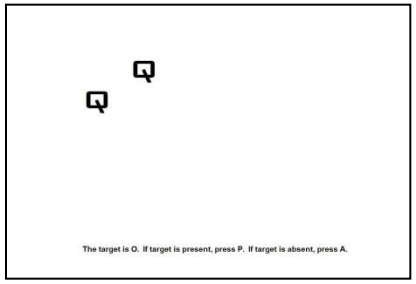
(1) *Stroop task*

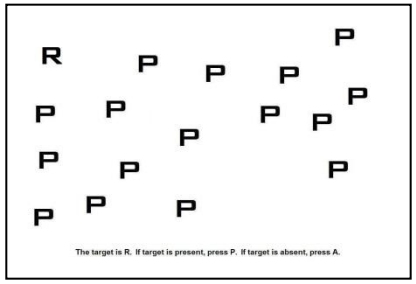


(2) *Emotion recognition task*



(3) *Visual search task*





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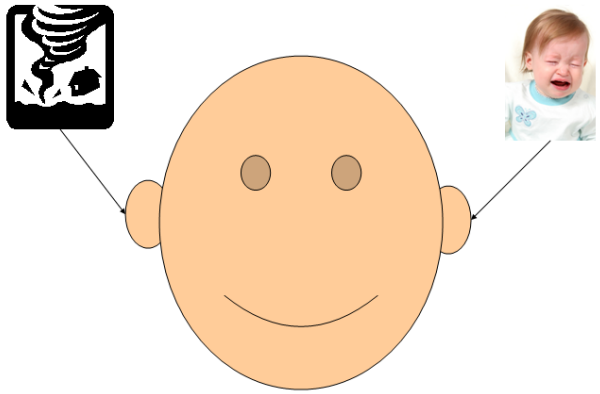
Heavy Cognitive Load Condition

Audio distraction
{dichotic listening}

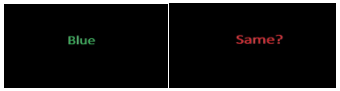


Visual distraction
(neutral & aversive)

Distracter questions –
Human?

Emotion
recognition

Stroop



Memory task - How many sharks did you see?

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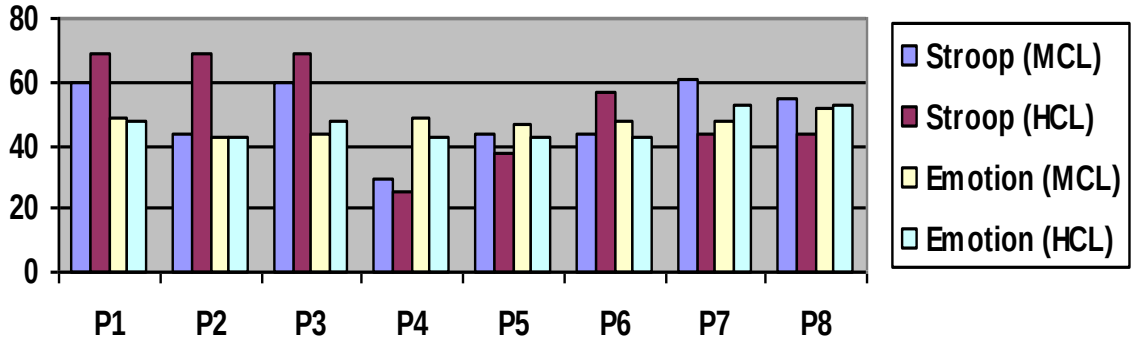
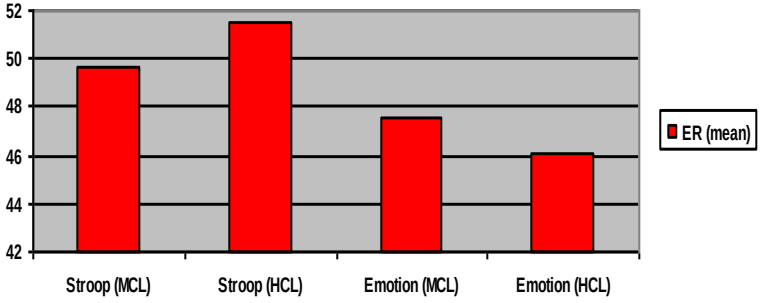
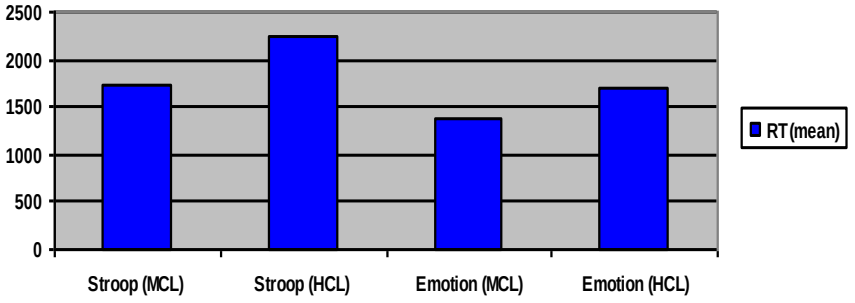
Behavioural Results







Stroop task $t(7) = 0.964$, $p > .05$
Emotion Recognition task $t(7) = -0.392$, $p > .05$

Stroop task $t(7) = 2.969$, $p = .024$
Emotion recognition task $t(7) = 3.634$, $p = .008$

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Real World Results

Comparative reaction times (in ms)

	Stroop (MCL)	Stroop (HCL) *(%age difference)*	Emotion (MCL)	Emotion (HCL) *(%age difference)*
P1	1493.73	1472.34 *(+1.45%)*	1182.49	1757.30 *(-32.71%)*
P2	2436.70	2711.74 *(-10.14%)*	2005.06	2509.19 *(-20.09%)*
P3	1630.51	2123.91 *(-23.23%)*	1499.11	2156.80 *(-30.49%)*
P4	2041.22	3694.34 *(-44.75%)*	1500.47	2284.38 *(-34.32%)*
P5	2046.76	2302.62 *(-11.11%)*	1574.22	1752.78 *(-10.18%)*
P6	1747.17	2256.82 *(-22.58%)*	1353.58	1645.78 *(-17.75%)*
P7	1730.42	2093.59 *(-17.35%)*	1112.69	1496.76 *(-25.66%)*
P8	1107.76	1474.82 *(-24.89%)*	888.55	1164.16 *(-23.67%)*
Group Average	**1779.28**	**2266.25** ***(-21.49%)***	**1389.52**	**1845.89** ***(-24.72%)***

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What a 20% performance decrement might mean…

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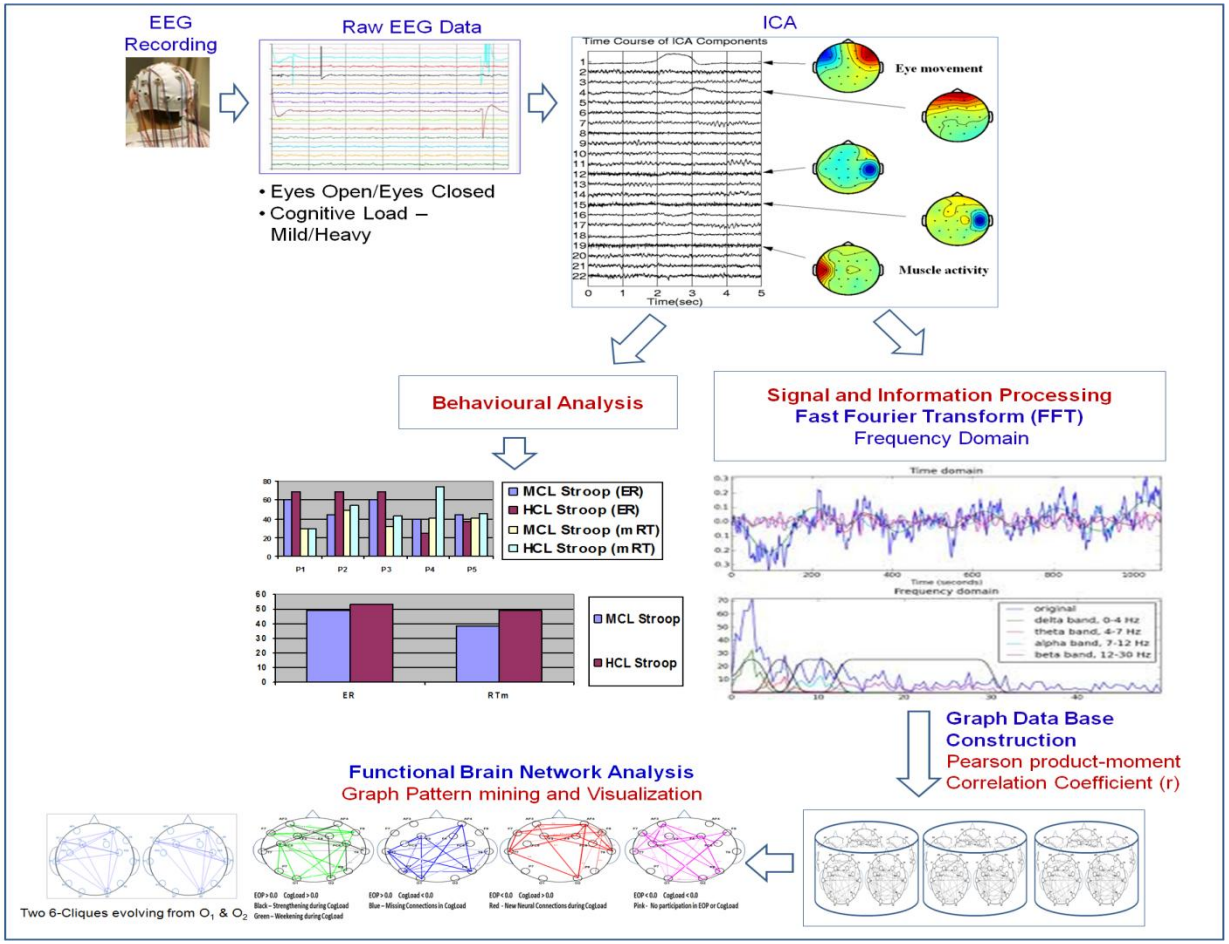
Analysis Framework



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

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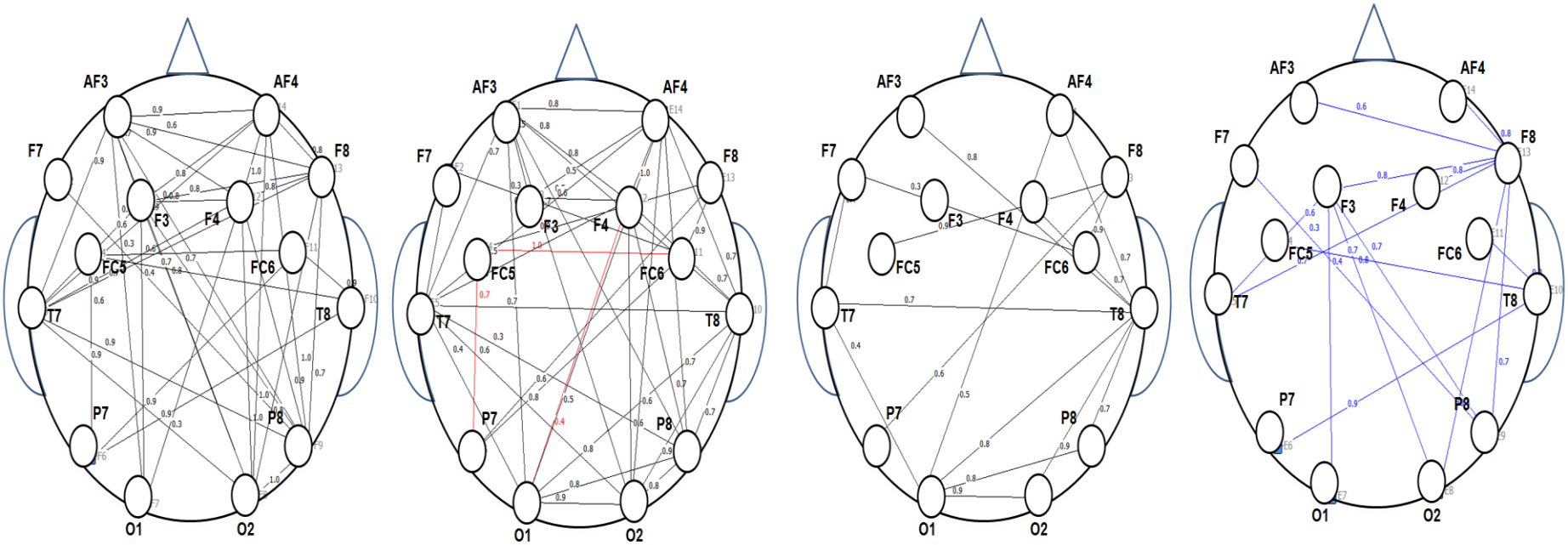
EEG Results



a) Eyes opened (b) Cognitive load with strengthened connections (Red) (c) New neural connections during cognition (d) Missing connections during cognition (Blue)

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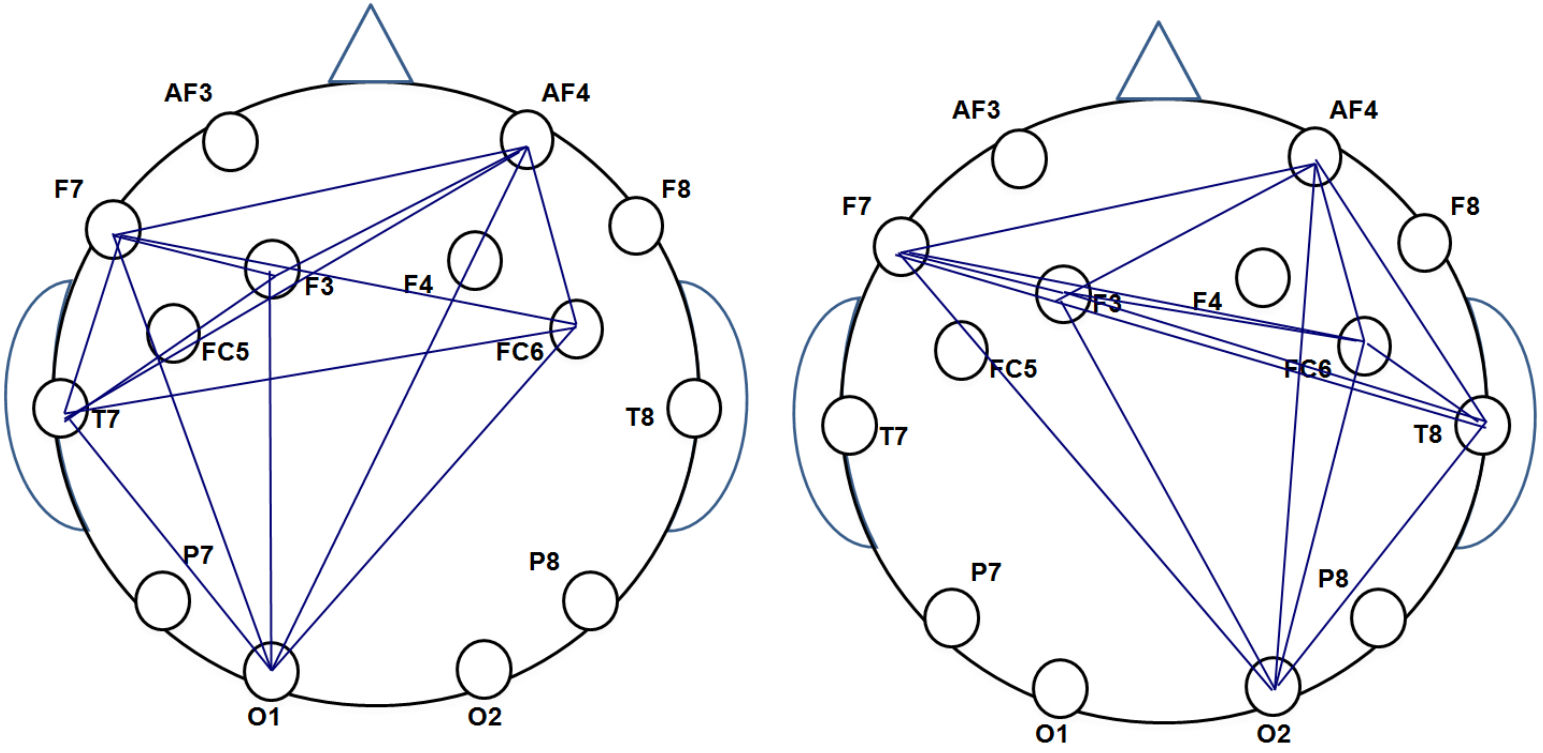
More EEG Results



Two 6-Cliques evolving from O1 and O2

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Interpretations

1. Global cognitive load appears to be measurable.
2. Individual processes interact to create that global load state irrespective of individual brain variation (e.g. structure).
3. Likely sites for measuring degree of load identified.
4. As cognitive load increases, performance decreases.

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Caveats

Small sample size (especially for behavioural analyses)

Gender bias (6 x males, 2 x females)

Outliers (esp. P1 and P8)

Language background (monolingual vs bilingual English speakers)

Cultural variations

“Mild” cognitive load tasks might not have been mild!

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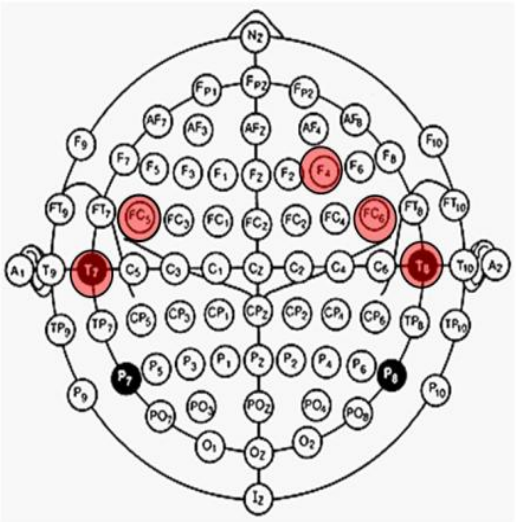
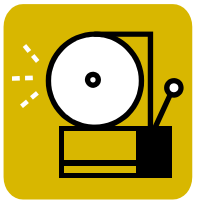
Future Research

Visual distraction



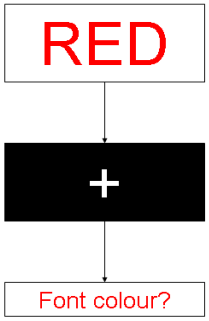


Audio distraction

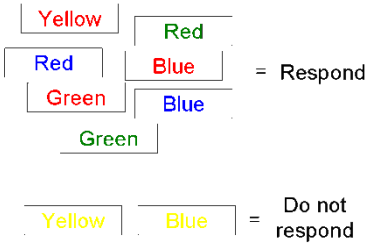
RED

RED

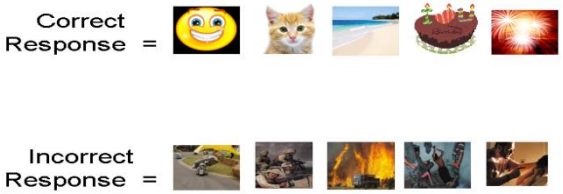
Classic Stroop task



1-back Stroop task



Go/No-go 1-back Stroop task



Punishment/reward

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ICCS 2013

9th International Conference on Cognitive Science
27 - 30th August 2013
Kuching, Sarawak, Malaysia

http://www.iccs2013.org/

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Thank you ☺

Questions?