HOW TESTING THE LIMITS OF UNCONSCIOUS LEARNING CAN ASSIST IN EVALUATING THEORIES OF CONSCIOUSNESS

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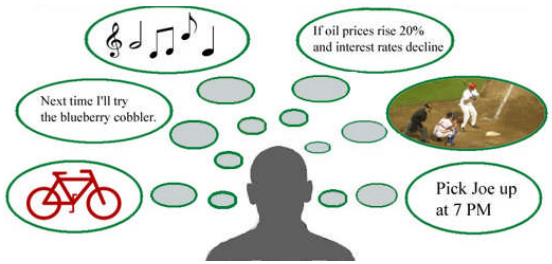
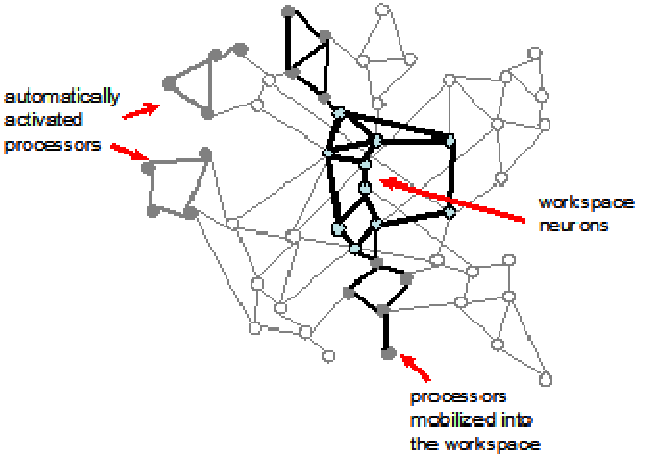
Theories of Consciousness

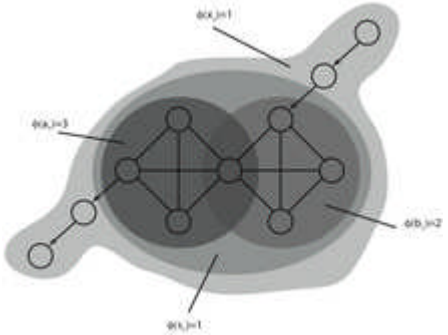
Multiple Drafts



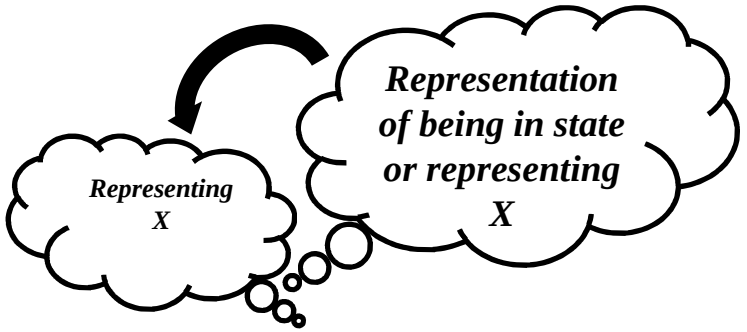
Global Workspace Theory



Integrated Information Theory



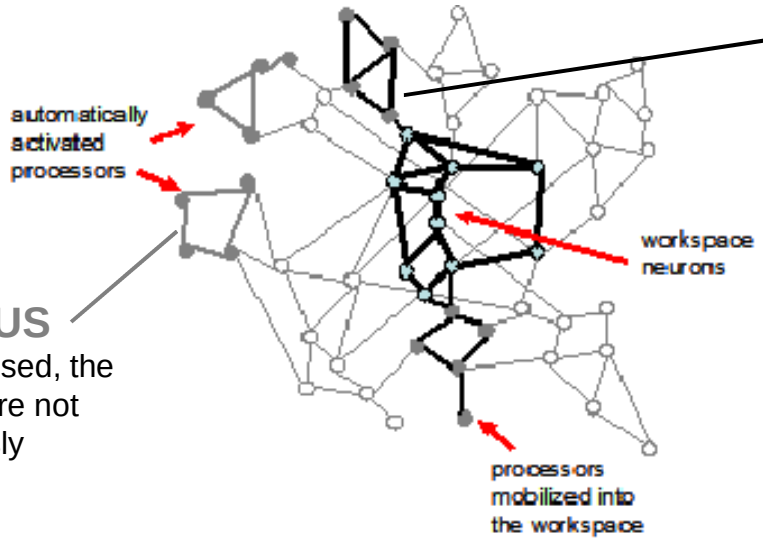
Higher Order Theories



Seeking a Test of Global Workspace Theory

Perceptions

Sight, sound, taste and touch are first processed in small localised areas of the brain



CONSCIOUS

When signals are broadcast to a wider network of neurons across much of the cortex – **the global workspace** – we become conscious of the sensation

NON-CONSCIOUS

When signals remain localised, the associated sensations are not perceived consciously

- An implication - learning dependent on the broadcast to a wider network should not occur without conscious awareness
- Specifically, *'consciousness is needed to integrate multiple sensory inputs' (Baars, 2002)*
- Unconscious 'cross-modal binding' should not be possible

Background

Unconscious Associations within a Single Modality

- Pessiglione et al., (2008) – Subliminal Instrumental Conditioning
- Duss et al., (2011) – Subliminal Face-Profession Pairs
- Reber & Henke, (2012) – Subliminal Word Pairs
- Atas et al., (2013) – Subliminal Sequence Learning

Unconscious Cross-modal Priming

- Kouider & Dupoux (2001) – Failed to find cross-modal priming visual to auditory
- Lamy et al. (2008) – Found cross-modal priming auditory to visual (using PDP).

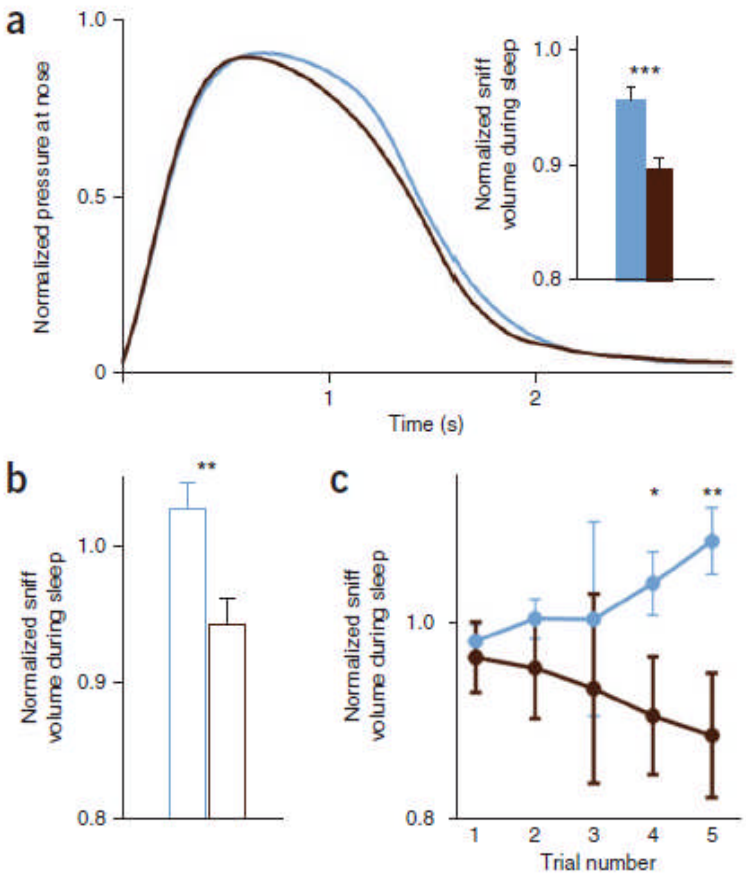
'Unconscious' Cross-modal Associative Learning

- Arzi et al. (2012) – Cross-modal associative learning during sleep

Background

Arzi et al. (2012) - Cross-modal associative learning during sleep

- Tones paired with either pleasant or unpleasant odours during sleep
- Sniff volume evaluated across trials
- Tones paired with pleasant smells result in greater sniff volume both while asleep and on waking.



Is this a challenge to GWT?

No, because sleep does not preclude conscious 'contents' which are known to be present in both REM and NON-REM stages (Tagliazucchi, Behrens & Laufs, 2013) .

Experimental Approach

A Linguistic Paradigm

- Strong existing representations should facilitate association
- Task remains the same whether auditory or visual

Reaction-time as dependent variable

- Previous work (e.g. Atas et al. 2013, Henke et al. 2003) had shown greater sensitivity in reaction times than classifications.

A trial-by-trial test of awareness

- Avoids issues of drifting thresholds and variable attention
- Permits use of optimal subjective threshold for each participant

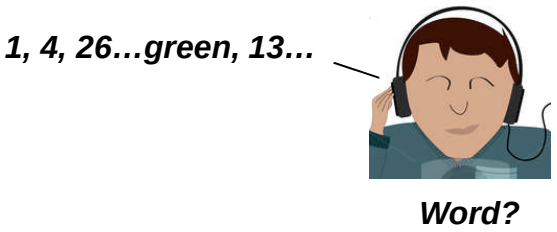
Adopted an initial Three Study Sequence

- Auditory modality, visual modality, cross-modal
- Informative irrespective of cross-modal success.

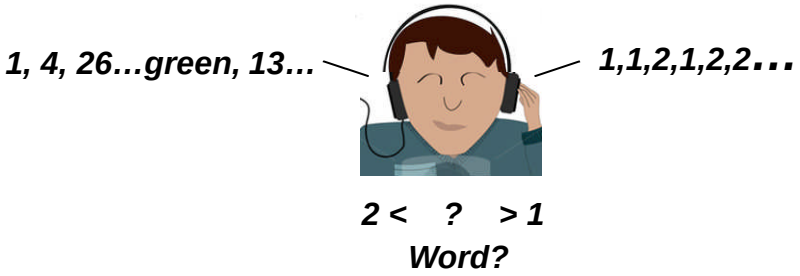
Experiment 1: Auditory Modality

Pre-test stages

- Find auditory threshold in right ear (Report the non-number word)



- Introduce attentional task in left ear (Press left for 1, and right for 2)



- Train the classification of professions (e.g. Pianist, Banker, Composer)

Experiment 1: Auditory Modality

32 Test Trials – three stages per trial

- Two name-profession pairs presented below threshold (one creative profession, one uncreative profession) while doing the attentional task

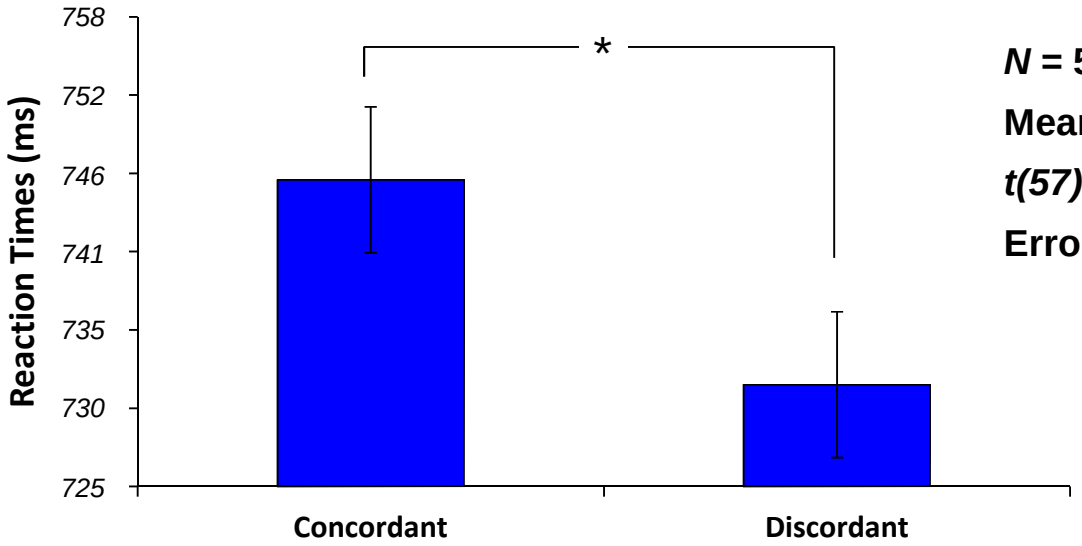
- Asked to report whether any non-number words had been heard

- Timed classification of profession – primed by a name (above threshold)

Experiment 1: Auditory Modality

Pre-processing and exclusions (Identical for all 3 experiments)

- Trials were excluded if:
  - a ‘subliminal’ word was identified
  - the classification judgement was wrong
  - the RT was < 200ms or > 2SD from mean
- Participants were excluded if:
  - they perceived ‘subliminal’ words on > 25% of trials
  - their reaction time difference was identified as an outlier by SPSS



***N* = 58**

Mean Difference = 14 ms

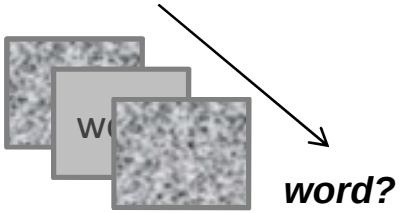
t(57) = 2.81, p = .007, dz = 0.37

Error bars = +/- 1 SEM diff.

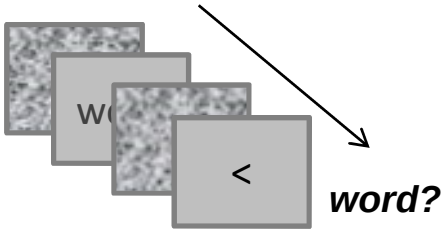
Experiment 2: Visual Modality

Pre-test Stages

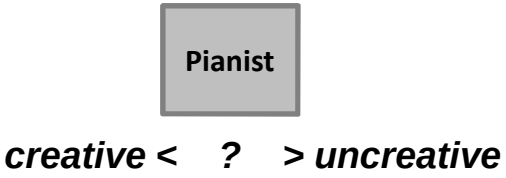
- Find visual threshold for low contrast words
  (Report any word seen)



- Introduce attentional task)
  (Press left arrow or right arrow as seen)



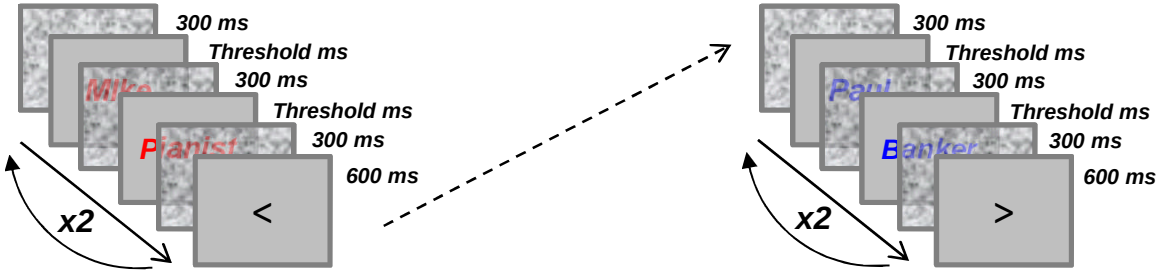
- Train the classification of professions
  (Press left for uncreative, right creative)



Experiment 2: Visual Modality

32 Test Trials – three stages per trial

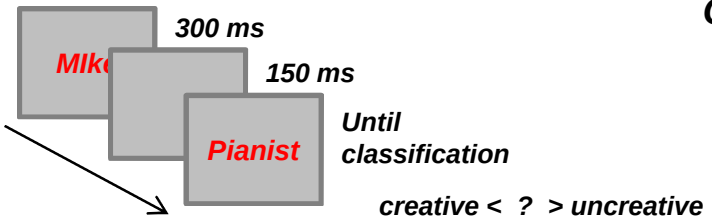
- Two name-profession pairs presented below threshold (one creative profession, one uncreative profession) while doing the attentional task



- Asked to report whether any words had been seen

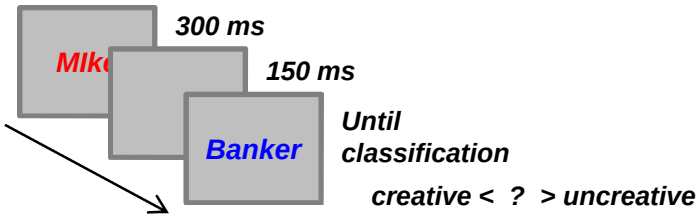
- Perform timed classification of profession – primed by a name

Concordant with subliminal



OR

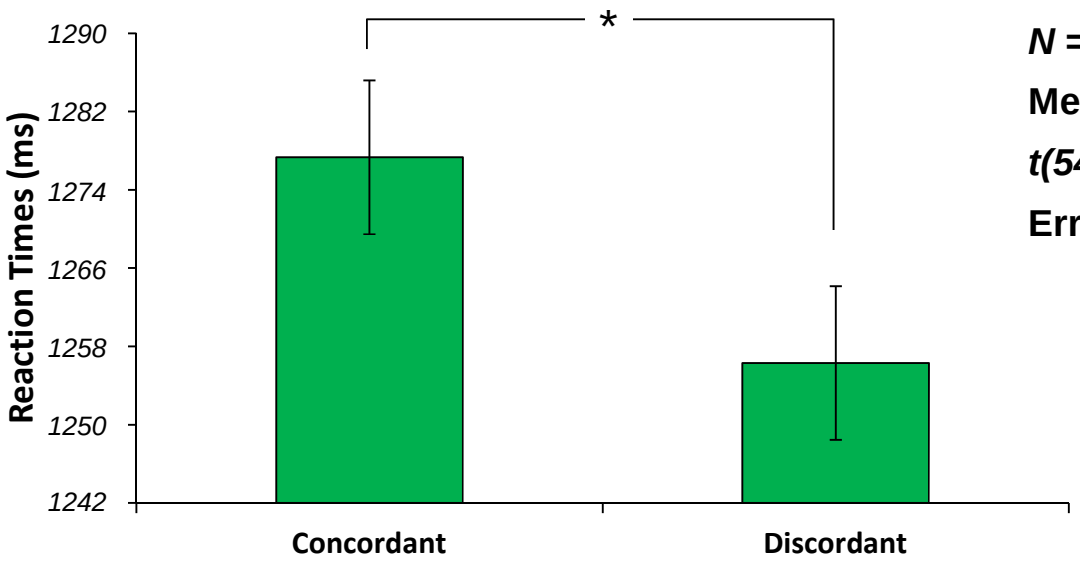
Discordant with subliminal



Experiment 2: Visual Modality

Pre-processing and exclusions (Identical to Experiment 1)

- Trials were excluded if:
  - a ‘subliminal’ word was identified
  - the classification judgement was wrong
  - the RT was < 200ms or > 2SD from mean
- Participants were excluded if:
  - they perceived ‘subliminal’ words on > 25% of trials
  - their reaction time difference was identified as an outlier by SPSS



***N* = 55**

Mean Difference = 21 ms

t(54) = 2.68, p = .010, dz = .36

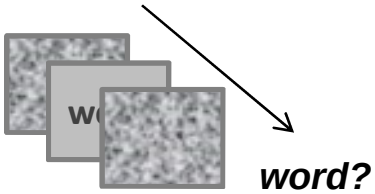
Error bars = +/- 1 SEM diff

Experiment 3: Linguistic Cross-Modal

Pre-test stages

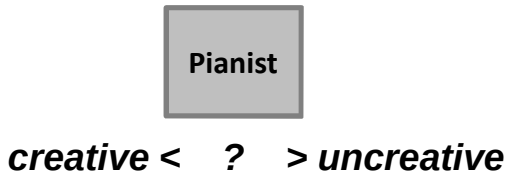
- Find auditory threshold
  (Report the non-number word)

- Find visual threshold
  (Report any word seen)



- Combine visual and auditory with attentional task (left or right arrow)

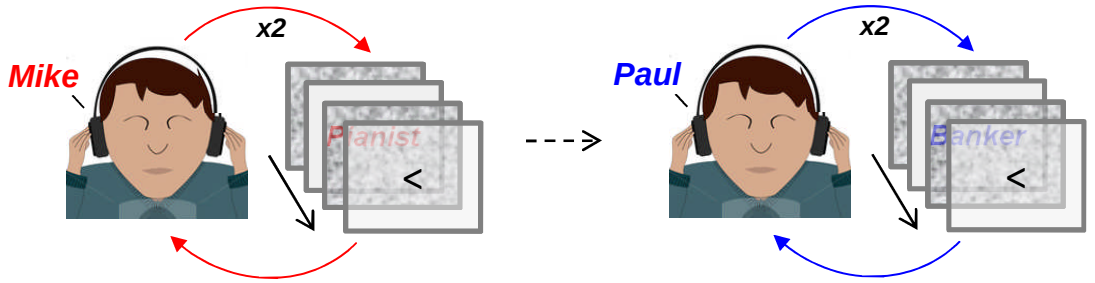
- Train the classification of professions visually
  (e.g. Pianist, Banker, Composer)



Experiment 3: Linguistic Cross-Modal

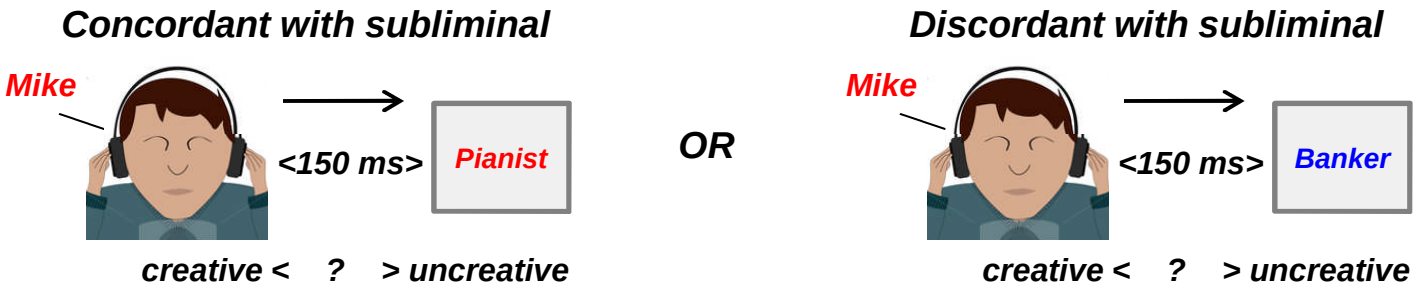
32 Test Trials – three stages per trial

- Two name-profession pairs presented below threshold – name presented audially followed by profession visually



- Asked to report whether any words were either seen or heard

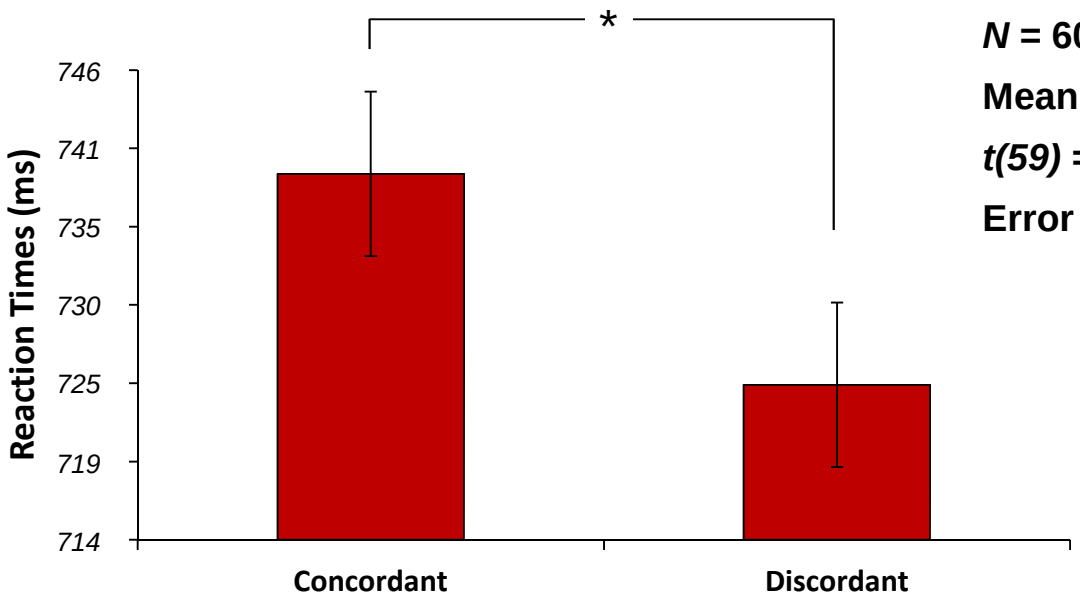
- Timed classification of profession – primed by a name (above threshold)



Experiment 3: Linguistic Cross-Modal

Pre-processing and exclusions (Identical to Experiments 1 & 2)

- Trials were excluded if:
  - a ‘subliminal’ word was identified
  - the classification judgement was wrong
  - the RT was < 200ms or > 2SD from mean
- Participants were excluded if:
  - they perceived ‘subliminal’ words on > 25% of trials
  - their reaction time difference was identified as an outlier by SPSS



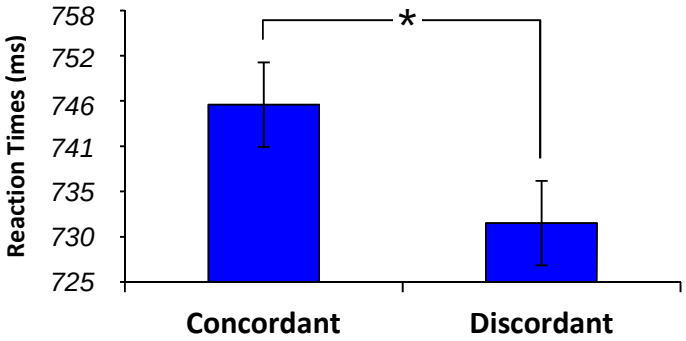
***N* = 60**

Mean Difference = 14 ms

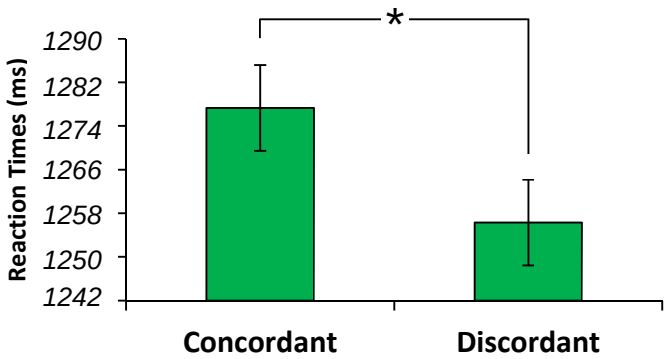
t(59) = 2.56, p = .013, dz = .33

Error bars = +/- 1 SEM diff

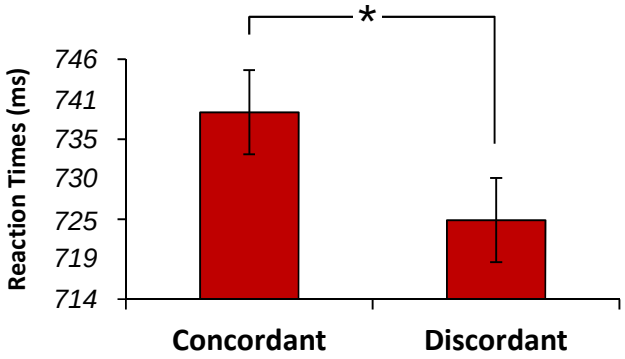
Results Summary



Auditory
N = 58
Mean Difference 14 ms
dz = .37



Visual
N = 55
Mean Difference 21 ms
dz = .36



Cross-Modal
N = 60
Mean Difference 14 ms
dz = .33

KEY QUESTIONS

- **Might these findings be limited to linguistic stimuli where there is a pre-learnt association between the visual and phonetic representations?**
- **If we can do this unconsciously, is there a conscious advantage? Would we observe a stronger association if the task was performed above the conscious threshold?**

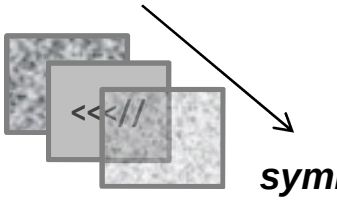
Experiment 4: Non-linguistic Cross-Modal

Pre-test stages

- Find auditory threshold
  (Report if last two tones the same)

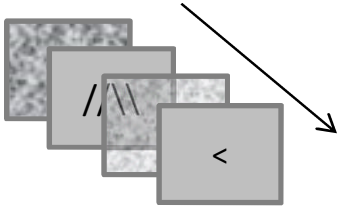
Same?

- Find visual threshold
  (Report if sequence is symmetrical)



symmetrical?

- Combine visual and auditory with
  attentional task (left or right arrow)



Hear or see anything?

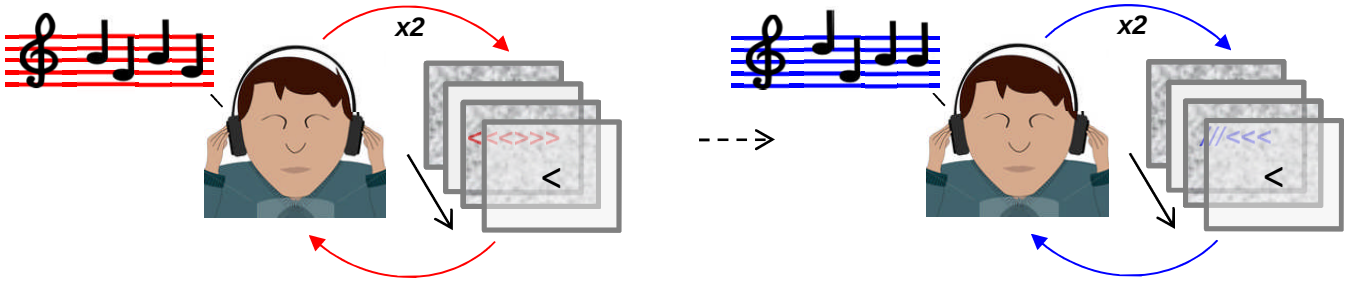
- Train the classification of symbol sequences visually
  e.g. **////\\\\>>>>** or **<<<<<>>>>>**

symmetrical < ? > non-symmetrical

Experiment 4: Non-linguistic Cross-Modal

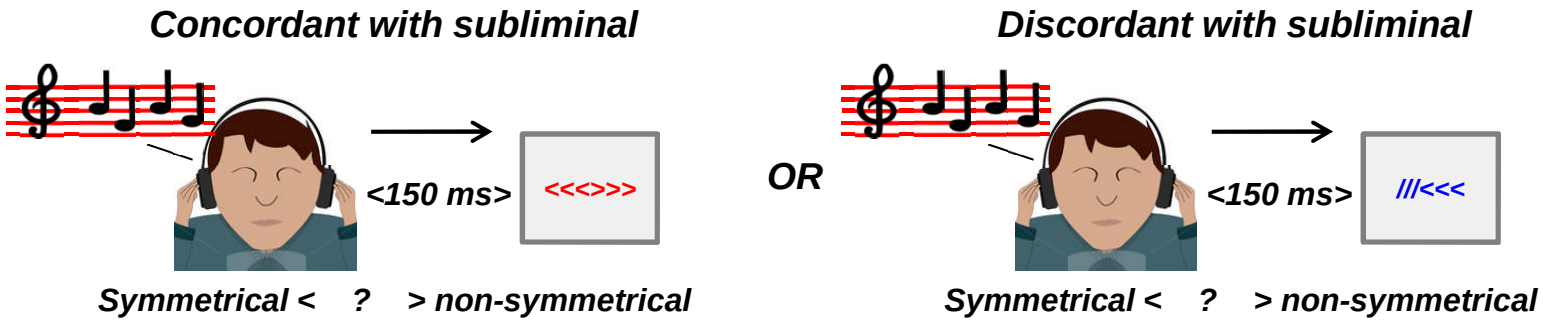
32 Test Trials – three stages per trial

- Two tone-symbol sequence pairs presented below threshold – tone sequence audially followed by symbol sequence visually



- Asked to report whether any tones were heard or symbols seen

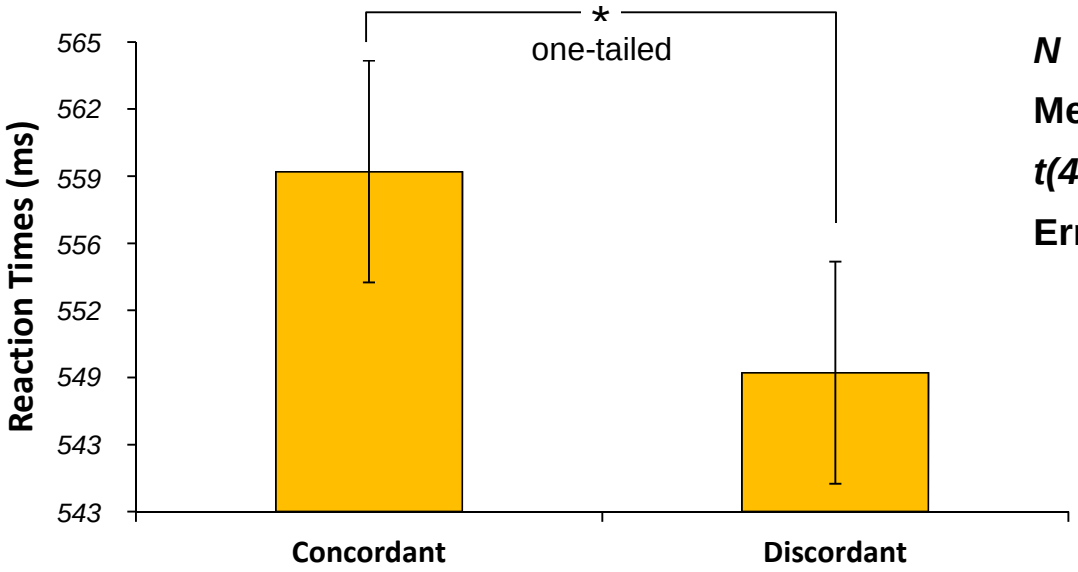
- Timed classification of symbol sequence – primed by tones sequence



Experiment 4: Non-linguistic Cross-Modal

Pre-processing and exclusions (Identical to Experiments 1-3)

- Trials were excluded if:
  - a 'subliminal' stimulus was identified
  - the classification judgement was wrong
  - the RT was < 200ms or > 2SD from mean
- Participants were excluded if:
  - they perceived 'subliminal' stimuli on > 25% of trials
  - their reaction time difference was identified as an outlier by SPSS



***N* = 49**

Mean Difference = 9 ms

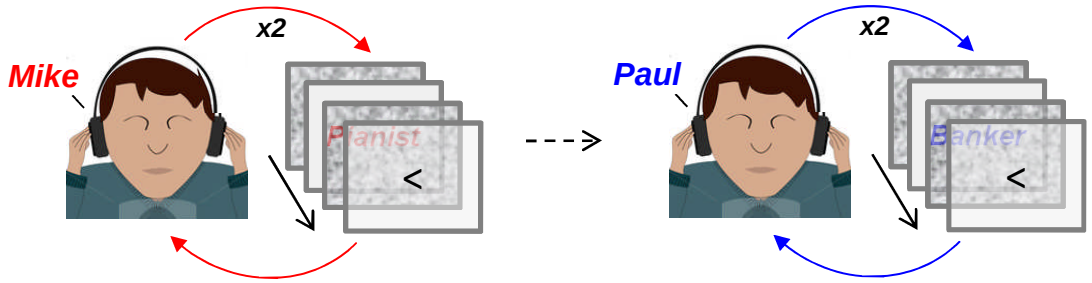
t(48) = 1.81, p = .076, dz = .26

Error bars = +/- 1 SEM diff

Experiment 5: Conscious Cross-modal

Conscious version of the unconscious linguistic cross-modal study

- Two name-profession pairs presented **ABOVE** threshold – name presented audially followed by profession visually



- Asked to confirm they **COULD** see and hear the words

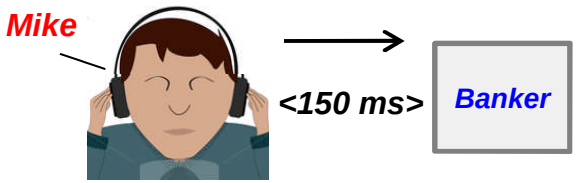
- Timed classification of profession – primed by a name (above threshold)

Concordant with subliminal

creative < ? > uncreative

OR

Discordant with subliminal

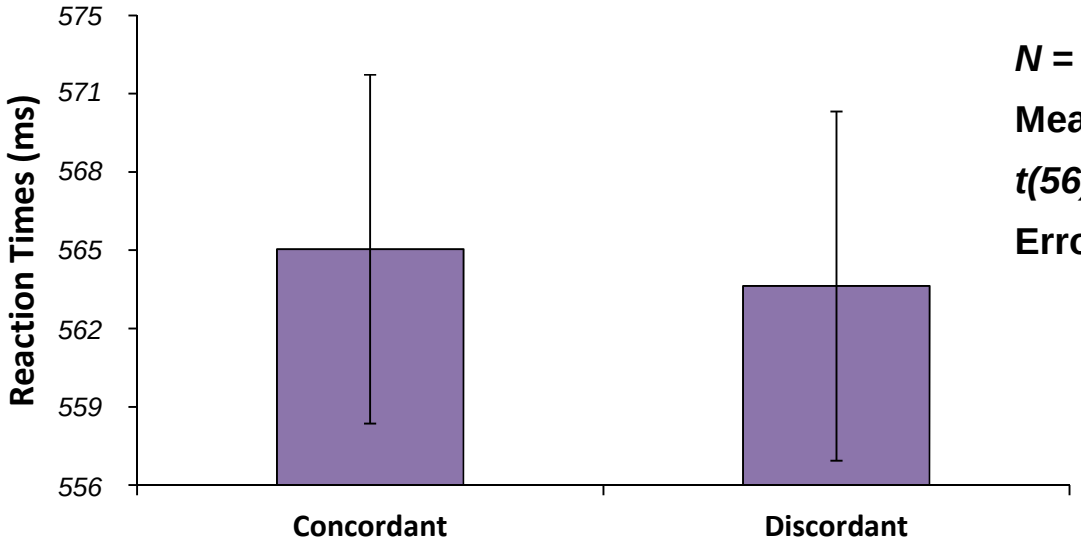


creative < ? > uncreative

Experiment 5: Conscious Cross-modal

Pre-processing and exclusions (near identical to Experiments 1-4)

- Trials were excluded if:
  - ~~a 'subliminal' word was identified~~
  - the classification judgement was wrong
  - the RT was < 200ms or > 2SD from mean
- Participants were excluded if:
  - ~~they perceived 'subliminal' words on > 25% of trials~~
  - their reaction time difference was identified as an outlier by SPSS



***N* = 57**

Mean Difference = 2 ms

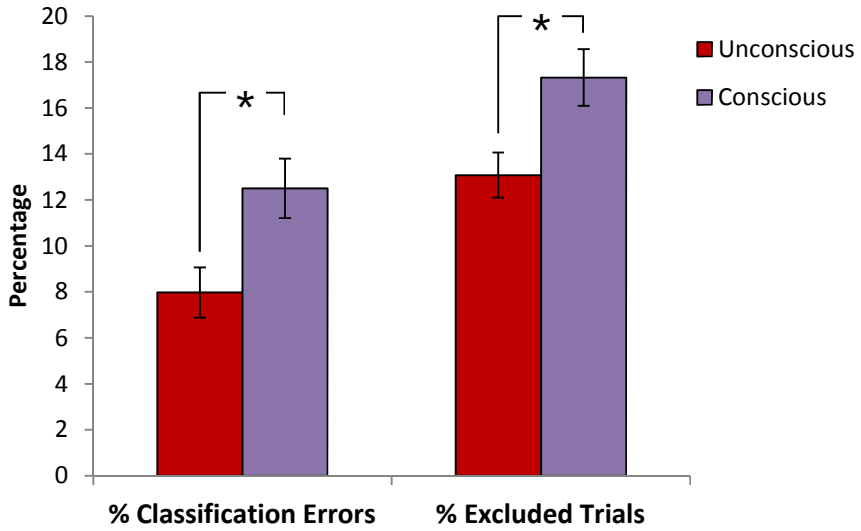
***t*(56) = 0.21, *p* = .833, *dz* = .03**

Error bars = +/- 1 SEM diff

Experiment 5: Conscious Cross-modal

Why do we not see the effect in the conscious study?

- Participants in the conscious cross-modal study make significantly more classification errors than the participants in the subliminal cross-modal study
- As a result of this there are significantly more trials excluded in the conscious vs. subliminal study, reducing the power to detect an effect
- We may need a larger number of trials to have equivalent power.
- On a positive note, this difference demonstrates that the participants are approaching the task very differently when doing it consciously.

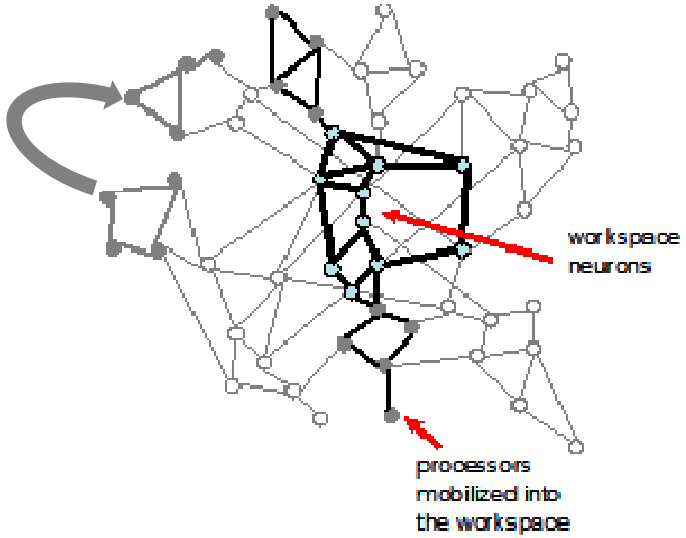


CONCLUSIONS

- **We've demonstrated unconscious associative learning both within individual modalities and cross-modally.**
- **We've demonstrated that this can be achieved even for novel stimuli without existing inter-modal relationships (non-linguisitic stimuli)**
- **We've found that this unconscious learning appears to be more effective than conscious learning in this (very limited) context**

CONCLUSIONS

- **Contrary to the Global Workspace Theory, and the Global Access Hypothesis specifically, this suggests that integration between sensory modalities can occur ‘locally’ without content entering the global workspace**



This sequence of behavioural studies exploring the extent of unconscious learning has permitted us to test and refute a central aspect of one of the most dominant theories of consciousness.

THANK YOU

Collaborators

Zoltan Dienes

Jason Samaha

Ron Chrisley

Funding and Support

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

University of Sussex
Sackler Centre for Consciousness Science