# 從視覺記憶到腦波測謊:
# 淺談認知神經科學的基礎研究與實際應用

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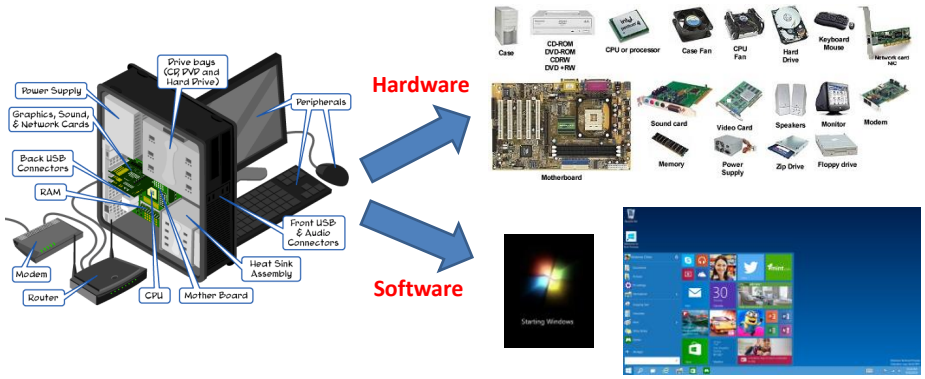
## Cognitive vs. Biological Science

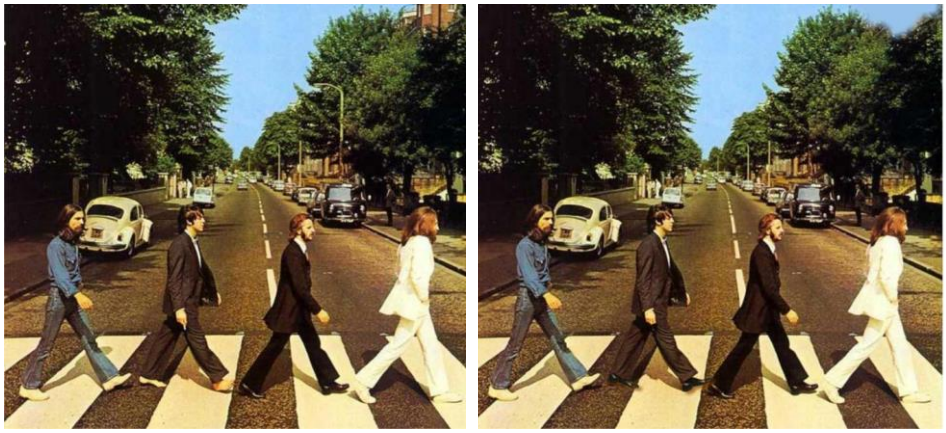


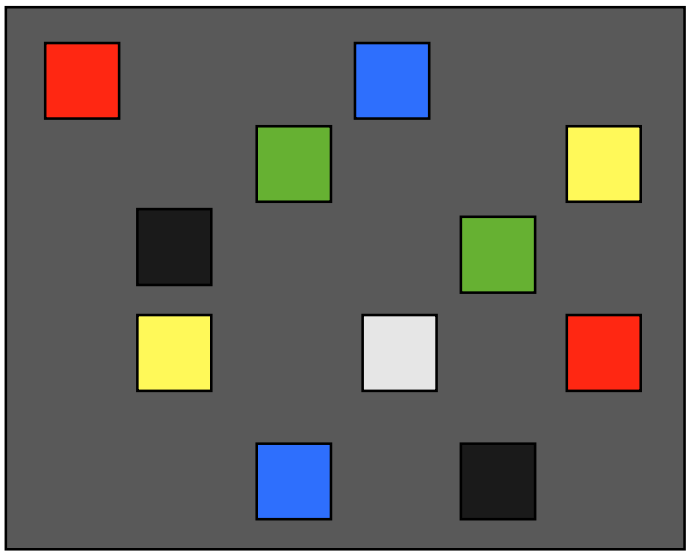

- Studying either hardware (neuroscience) or software (cognition) alone will not succeed
- The emergence of “Cognitive Neuroscience”

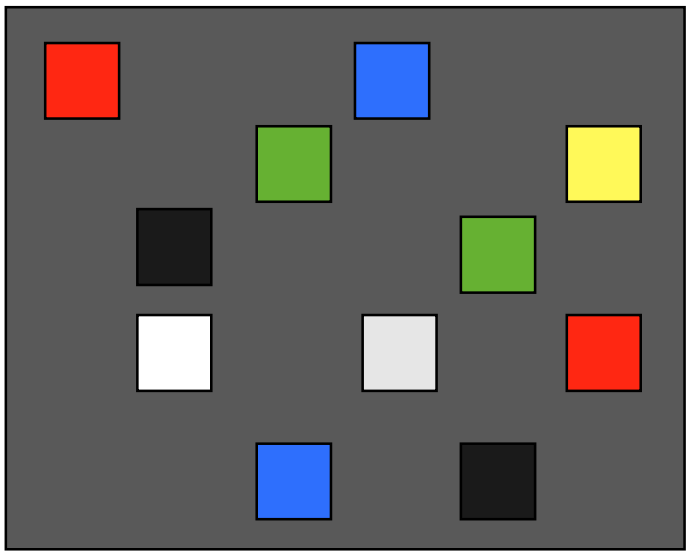
# Visual working memory?

- Types of visual memory
  - Iconic: milliseconds, rich in details
  - Short-term (working memory): seconds to minutes
  - Long-term: hours to years
- Retain gist information across multiple visual disruptions
  - Blinks or occlusions
  - Eye movements and saccadic suppression
- Good news: correlates well with fluid intelligence
- Bad news: our VWM is not as good as we think (not even close)

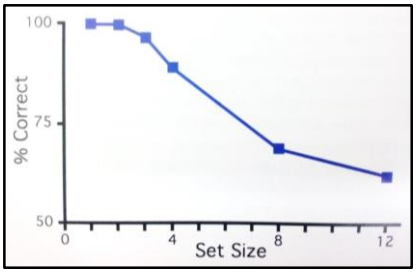
Donald Hoffman:
http://www.cogsci.uci.edu/~ddhoff/cbvenice.html

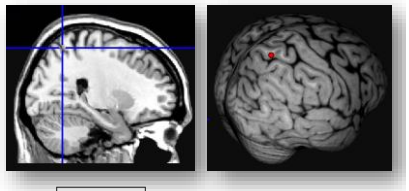


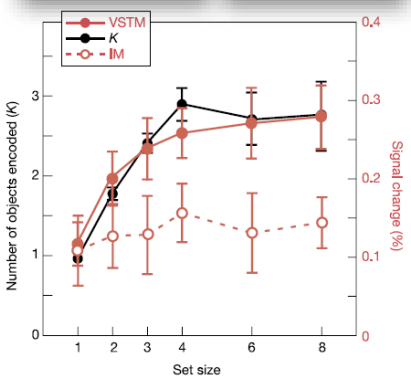




# Posterior Parietal Cortex (PPC)



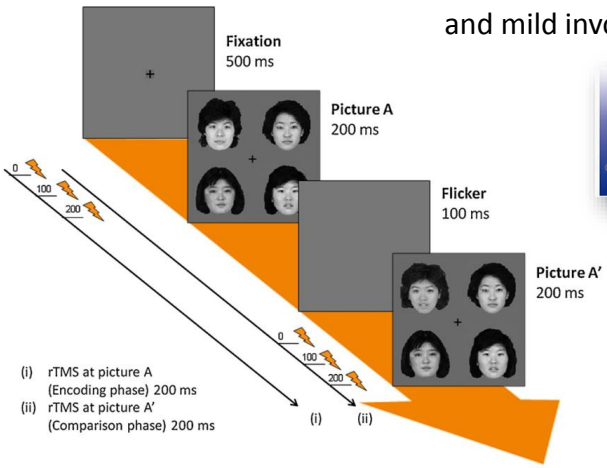



- Average capacity: 3 to 4 items
- Studies report increased activity in right PPC
  - **fMRI**: Todd & Marois (2004, 2005)
  - **fMRI:** Beck, Rees, Frith, & Lavie (2001)
  - **ERP:** Fernandez-Duque et al., (2003)

Todd & Marois (2004) *Nature 428*:751-754

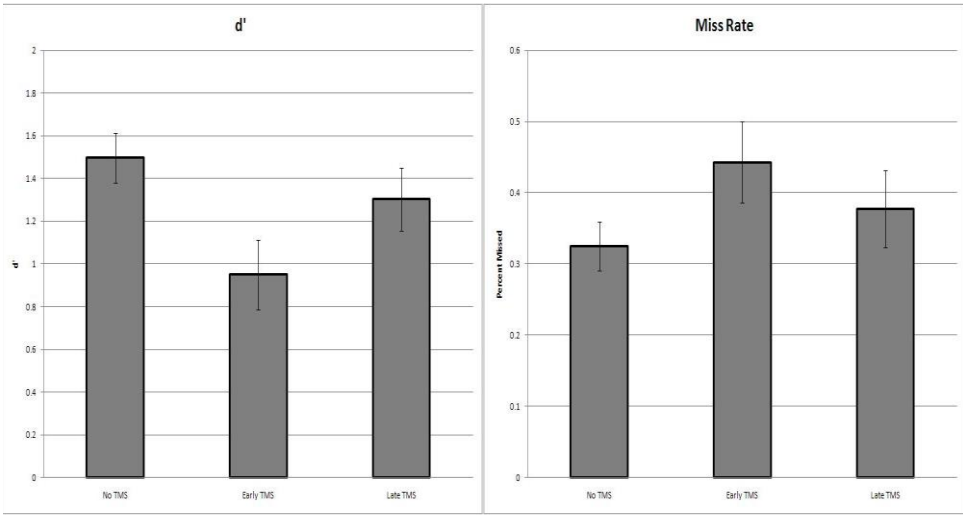
# Timing of PPC involvement: TMS Study

- Online TMS (early vs. late)
- PPC has critical involvement early, and mild involvement late




Tseng et al. (2010) *Neuropsychologia* 48:1063-1070

# Results



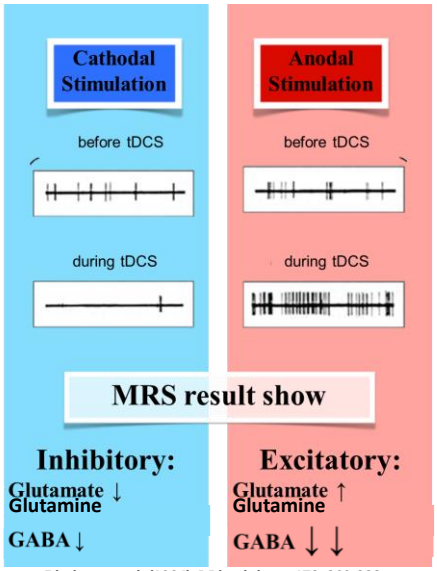

Tseng et al. (2010) *Neuropsychologia* 48:1063-1070

# Interim Conclusion

- rPPC is causally involved in VWM, especially *early* during encoding & maintenance
- It is also involved in the *late* stage (retrieval & comparison), though to a lesser extent
- TMS-induced disruption to right PPC activity impairs VWM

# tDCS

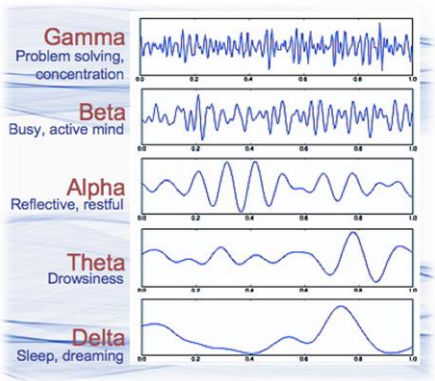
- **Transcranial Direct Current Stimulation**
  - Non-invasive
  - Anodal vs. Cathodal
  - Alters neural excitability
    - Acts on neuron's resting membrane potential (depolarize / hyperpolarize)
    - Increases / decrease spontaneous cell firing
    - No direct action potential

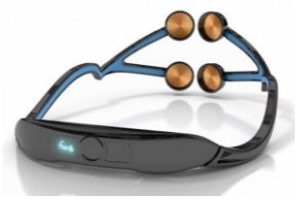



Bindman et al. (1964) *J Physiology 172, 369-382*

# tDCS, tACS, tRNS

- Causal evidence
  - tDCS
- Pinpoint specific frequency
  - tACS
  - tRNS (random)
  - Oscillatory tDCS



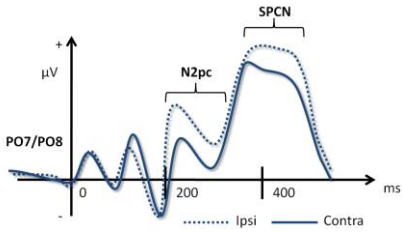



# Improving VWM

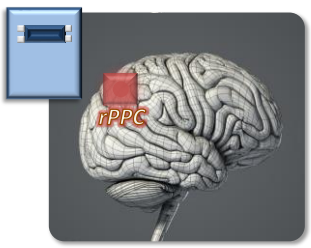
- Using anodal tDCS to increase rPPC activity

- Electrophysiological indexes
  - N2pc: visual attention
  - CDA/SPCN: memory maintenance

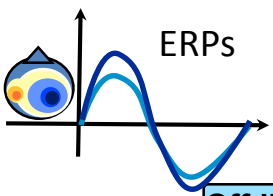
Vogel and Machizawa (2004, 2005)

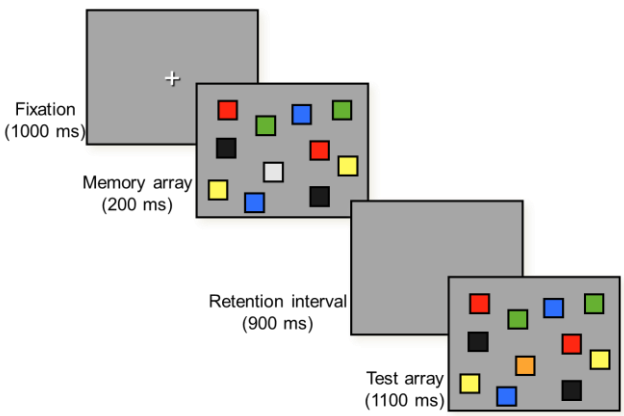



# Procedures




Anodal tDCS



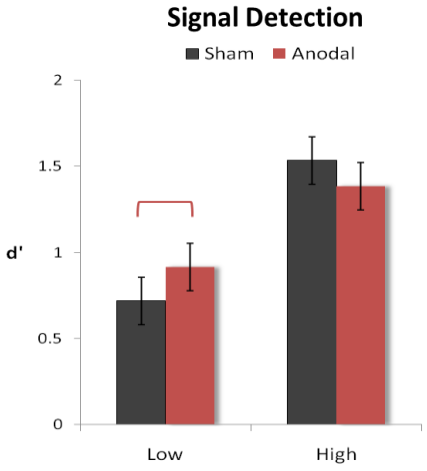



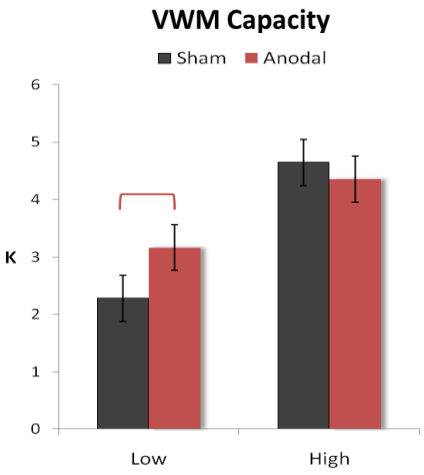

**Practice**
30 trials

**Off-line tDCS**
1.5 mA for 15 mins
4x4 cm$^2$ electrode pad
Anodal: rPPC (P4)
Cathodal: left cheek

**Formal Session**
288 trials (50% change trials)

# Behavioral Results

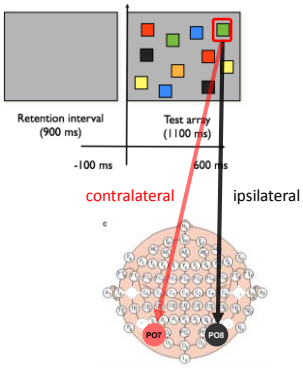


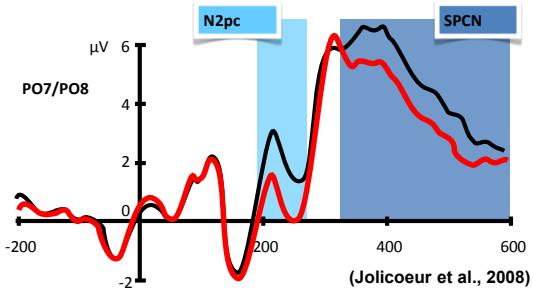




Tseng et al., (2012). *J Neurosci*

# ERP Components

**N2pc (N2 posterior contralateral): visual attention**

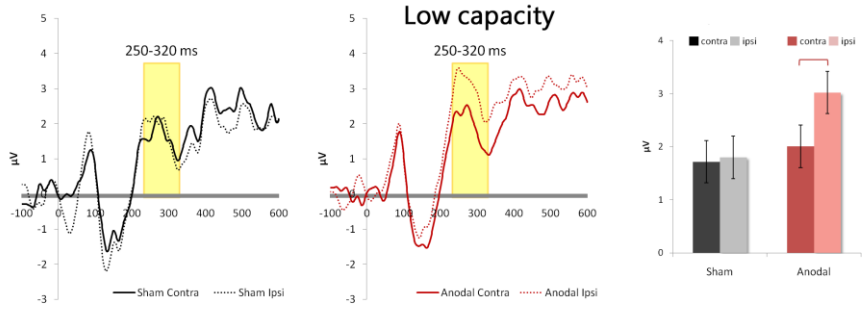


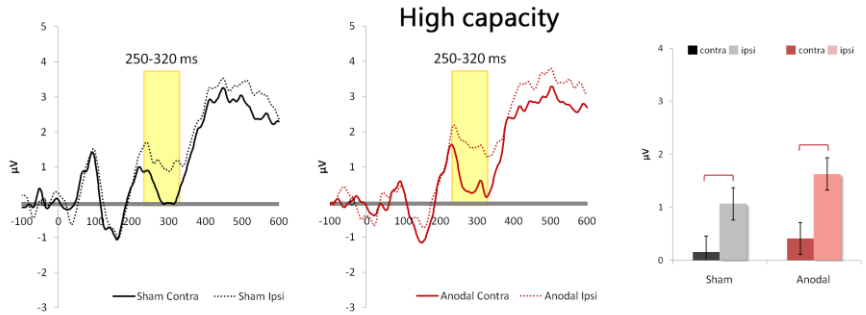



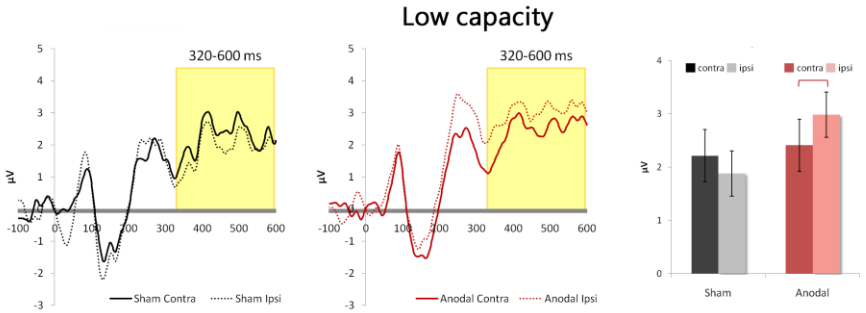

(Jolicoeur et al., 2008)

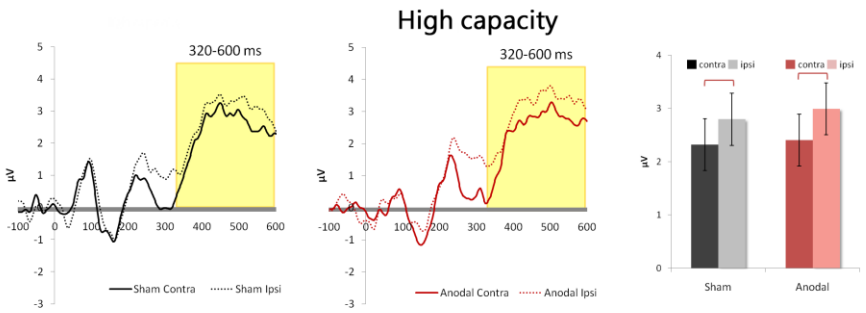
**SPCN (Sustained parietal contralateral negativity): visual working memory maintenance**

**(a.k.a. Contralateral Delayed Activity)**

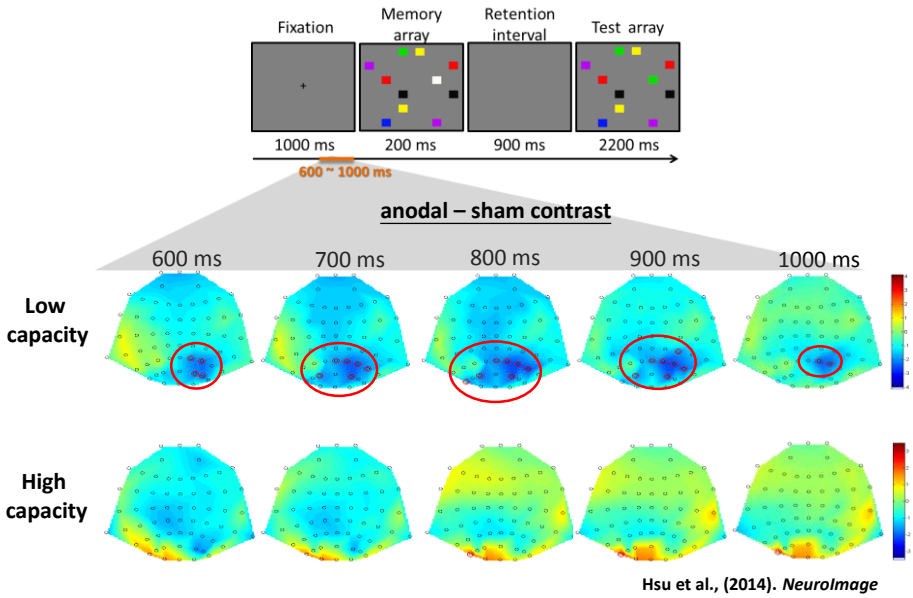

Low capacity
250-320 ms
250-320 ms
μV
Sham Contra
Sham Ipsi
Anodal Contra
Anodal Ipsi
contra ipsi
contra ipsi
Sham
Anodal


High capacity
250-320 ms
250-320 ms
μV
Sham Contra
Sham Ipsi
Anodal Contra
Anodal Ipsi
contra ipsi
contra ipsi
Sham
Anodal


Low capacity
320-600 ms
320-600 ms
μV
Sham Contra
Sham Ipsi
Anodal Contra
Anodal Ipsi
contra ipsi
contra ipsi
Sham
Anodal


High capacity
320-600 ms
320-600 ms
μV
Sham Contra
Sham Ipsi
Anodal Contra
Anodal Ipsi
contra ipsi
contra ipsi
Sham
Anodal

# Difference map of prestimulus alpha




Hsu et al., (2014). *NeuroImage*

# Interim Conclusion II

- High-performers didn't need much help

  (though there's definitely still room for improvement)
- Anodal tDCS over rPPC improves VWM in low-performers
- Behavioral effect matched results from ERP and EEG data (N2pc, SPCN, alpha power)

# Clinical Applications?

- Variant of VWM task: feature binding

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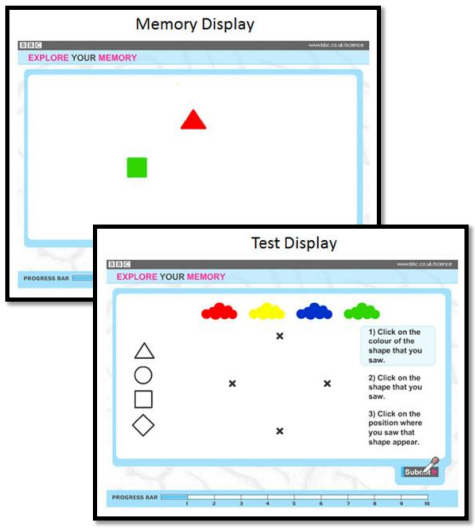
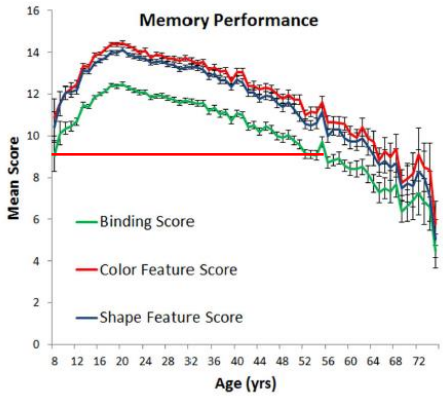


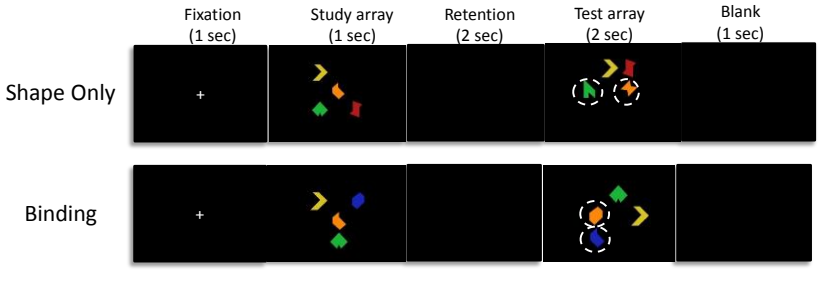

**Brockmole & Logie, 2013**

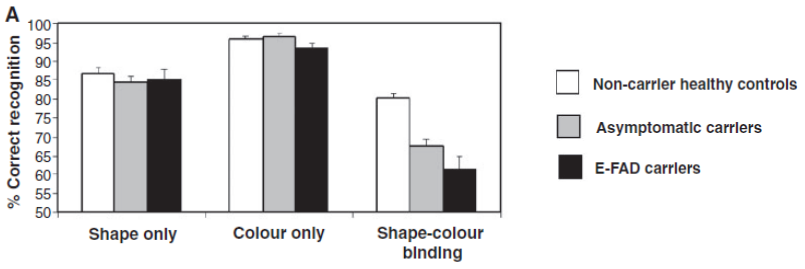
# VWM – Early Diagnosis

- Behavioral detection of early-onset familial Alzheimer's Disease (E-FAD) carriers
  - Inherited from one parent
  - Onset around late 30's and 40's
  - 1 to 5% of all Alzheimer cases

| | Healthy controls ($n=30$) | | Asymptomatic carriers ($n=30$) | | E-FAD carriers ($n=22$) | | One-way ANOVA | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $F(P)$ | Post hoc tests ($P$-value) | | |
| | Mean (SD) | Range | Mean (SD) | Range | Mean (SD) | Range | | Asymptomatic Carriers versus Healthy Controls | Asymptomatic Carriers versus E-FAD | Healthy controls versus E-FAD |
| Age[a,b] | 40.9 (9.3) | (24–58) | 35.6 (6.6) | (23–46) | 45.2 (4.8) | (32–52) | 11.2 (0.000) | 0.018 | 0.001 | 0.12 |
| Years of education | 9.5 (3.2) | (4–16) | 9.3 (4.4) | (1–20) | 8.5 (4.2) | (1–18) | 0.5 (0.60) | 1 | 1 | 0.98 |
| Mini-Mental State Examination[b,c] | 29.4 (1.3) | (24–30) | 29.2 (1.3) | (25–30) | 25.5 (3.7) | (18–30) | 23.76 (0.000) | 1 | 0.000 | 0.000 |
| Paired Associates Learning[b,c] | 13.1 (3.5) | (6–19) | 12.1 (4.0) | (5–20) | 7.4 (3.5) | (3–16) | 15.84 (0.000) | 1 | 0.000 | 0.000 |
| Verbal Fluency (Letters-FAS)[b,c] | 12.4 (3.6) | (6–19) | 11.5 (5.8) | (2–29) | 8.4 (3.6) | (3–16) | 5.217 (0.007) | 1 | 0.04 | 0.007 |
| Verbal Fluency (Animals)[b,c] | 20.5 (4.1) | (12–28) | 18.6 (5.3) | (9–32) | 14.1 (3.6) | (9–21) | 13.27 (0.000) | 0.33 | 0.002 | 0.000 |
| REY-Copy[c] | 27.5 (4.7) | (19–34) | 24.2 (7.0) | (4–34) | 21.1 (7.8) | (3–31) | 6.11 (0.003) | 0.15 | 0.32 | 0.003 |
| REY-Recall[b,c] | 16.3 (6.1) | (4–26) | 13.2 (6.6) | (3–26) | 4.0 (4.3) | (0–19) | 28.85 (0.000) | 0.17 | 0.000 | 0.000 |
| Trail Making Test[b,c] | 61.7 (26.5) | (17–138) | 73.7 (52.2) | (31–290) | 114.76 (61.08) | (39–275) | 9.66 (0.000) | 1 | 0.004 | 0.000 |
| Wisconsin Card Sorting Test Categories[b,c] | 3.5 (1.5) | (1–6) | 3.3 (1.5) | (0–6) | 1.6 (1.0) | (0–3) | 13.29 (0.000) | 1 | 0.000 | 0.000 |
| Wisconsin Card Sorting Test Concept[b,c] | 11.7 (7.0) | (6–31) | 11.4 (7.4) | (2–37) | 21.7 (17.5) | (6–46) | 6.91 (0.002) | 1 | 0.004 | 0.005 |

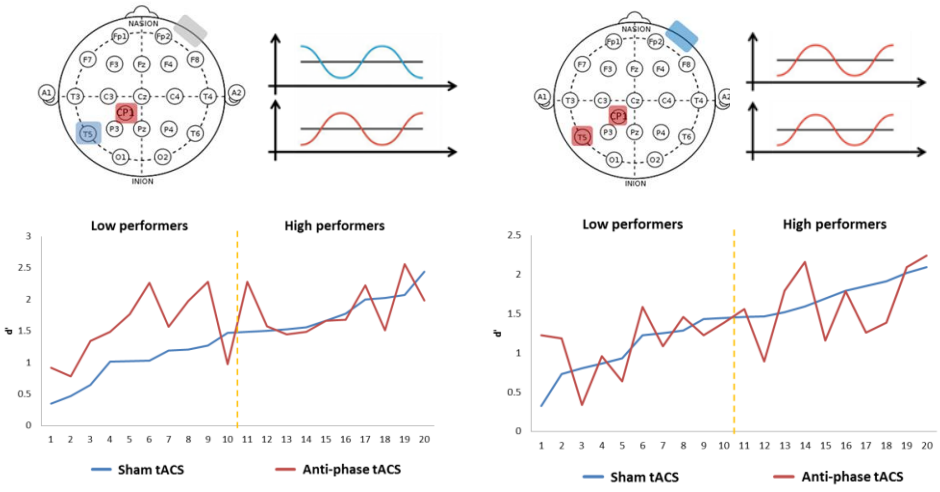
# VWM – Early Diagnosis



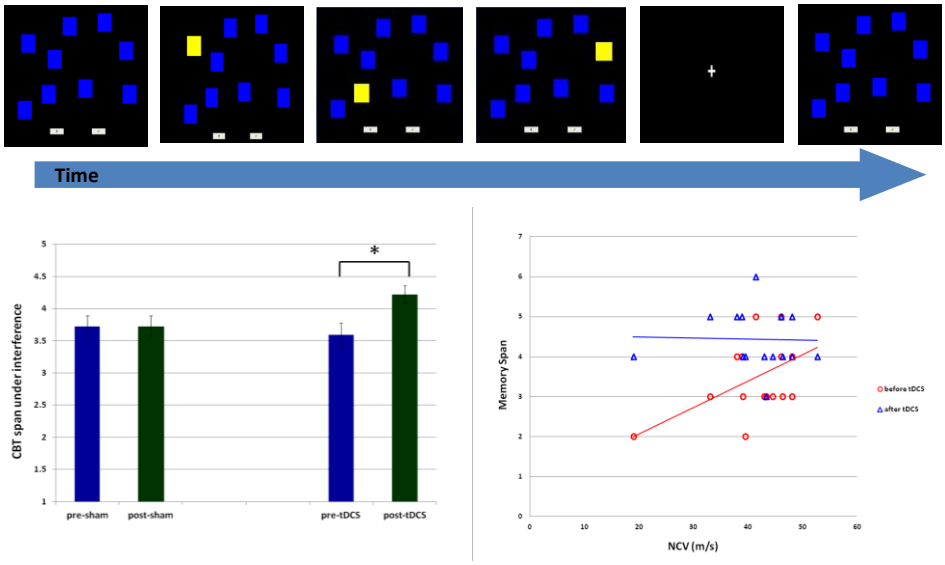

Parra et al., (2010) *Brain*

# 40 Hz in-phase vs. anti-phase gamma




Tseng et al., (2016) *Sci Rep*

# MCI Patients




Wu et al., (2016) *Front in Hum Neurosci*

# Conclusions

- Visuospatial WM involves PPC, mostly during encoding but also retrieval & comparison
- Anodal tDCS boosts visuospatial WM in low-performers, with EEG & ERP evidence (e.g., N2pc, SPCN/CDA, alpha power)
- 40 Hz gamma tACS can improve nonspatial binding VWM in low-performers
- tDCS results seem promising for MCI patients


**Memory-load activities during the preparation and execution of truth-based lies**

Philip Tseng

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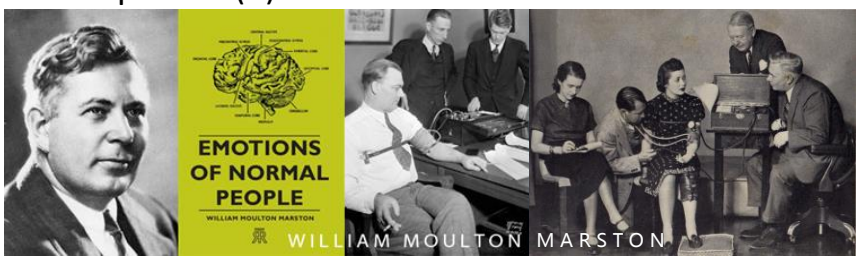
# History of Lie Detection

- Ancient China:
  - Suspect chews dry rice; assumes stress slows down saliva flow and cause dry mouth (high tongue-rice concentration)
- Ancient India:
  - Suspect goes inside a dark tent and pull a donkey's tail (that has been blackened), with the cover story that if the donkey brayed, the guilt is confirmed.
  - Whoever left the tent with clean hands, the priests would know he/she has not pulled the donkey tail out of fear

# William Moulton Marston

- Observed a link b/w emotion and blood pressure
  - when his wife, Elizabeth, (also a psychologist) "got mad or excited, her blood pressure seemed to climb"
- Used blood pressure as a tool to detect lie-telling
- Creator of the DISC theory of Personality:
  - Dominance (D), Influence (I), Steadiness (S), and Compliance (C)



# Objective Measures

- Need for a better test that measures information, not nervousness
- Guilty Knowledge Test: tests for automatic recognition of things from long-term memory
- The Stroop test can be considered as a form of GKT

## 叫色作業 **(Stroop Effect)**

好　　綠

朋　　黃

友　　紅

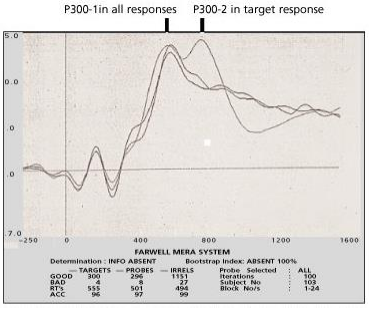
# Objective Measures

- Need for a better test that measures information, not nervousness
- Guilty Knowledge Test: tests for automatic recognition of things from long-term memory
- The Stroop test can be considered as a form of GKT

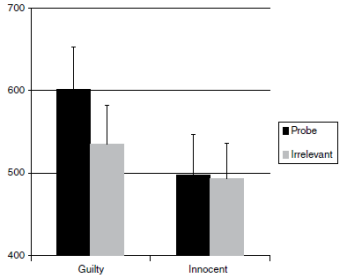
Синий Фиолетовый Красный
Зеленый Фиолетовый Зеленый

- But how do you distinguish between a naïve Russian speaker vs. a Russian spy?

# GKT in ERP and RT




Farwell & Donchin, 1991




Verschuere et al., 2015

# Back to our Russian spy friend






# Famouse MERMER Case

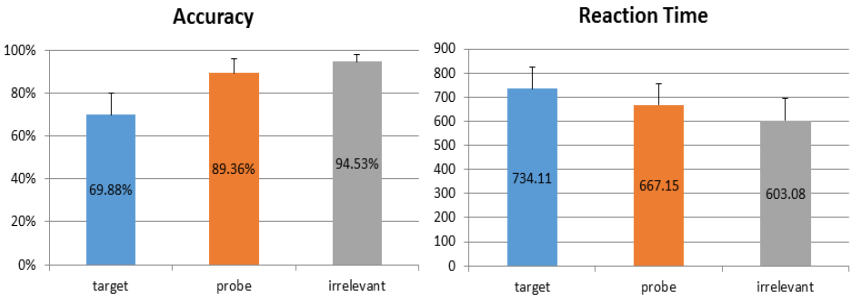
- JB Grinder, a suspect of Julie Helton's death in 1984
- Grinder gave multiple conflicting accounts, but police needed "hard" evidence
- In 1999, Missouri Police and FBI asked Larry Farwell to help, the inventor of P300-MERMER
- Used key words that only the murder would know: weapon, killing method, victim's injuries, the rope used to bind her hands, where her body was left, items he left at the scene, items he stole from her…etc
- GKT positive, and Grinder pled guilty of killing Helton as well as 3 other women

Harrington v. State, 2001

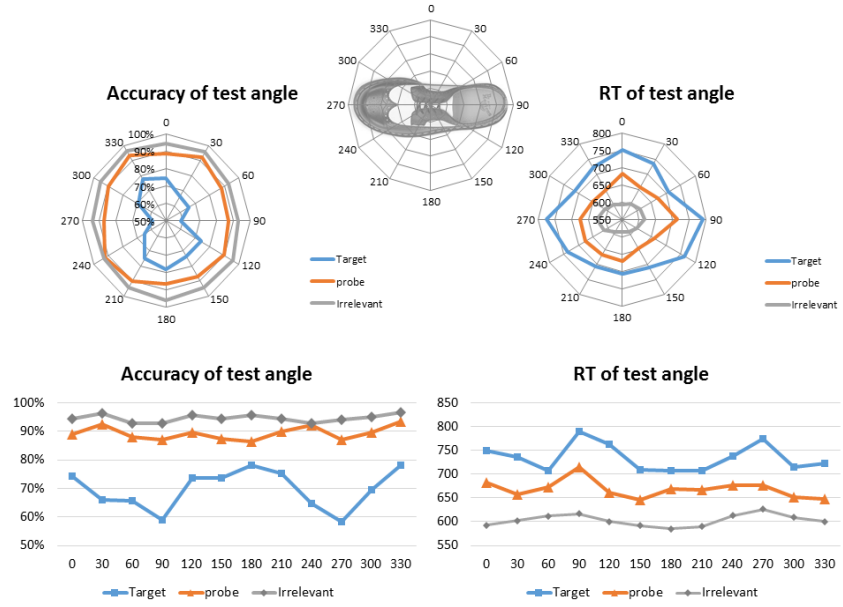
# Does angle matter?


- Manipulated deviation angles between encode & test images
- $0^o$ to $330^o$ in 11 steps

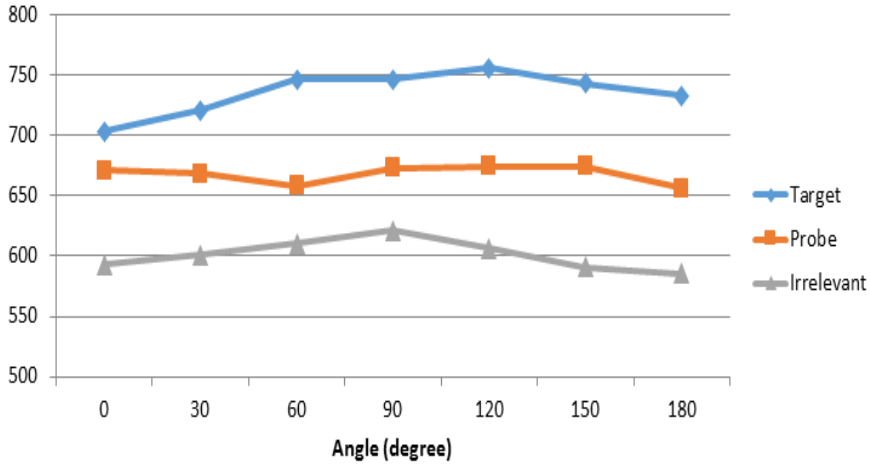
# Results



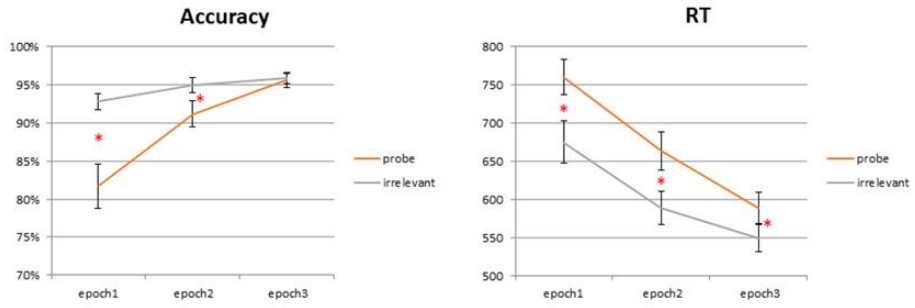
# Presentation angle




# Deviation in encode vs. test angle



# GKT efficacy over time




# Interim Conclusion

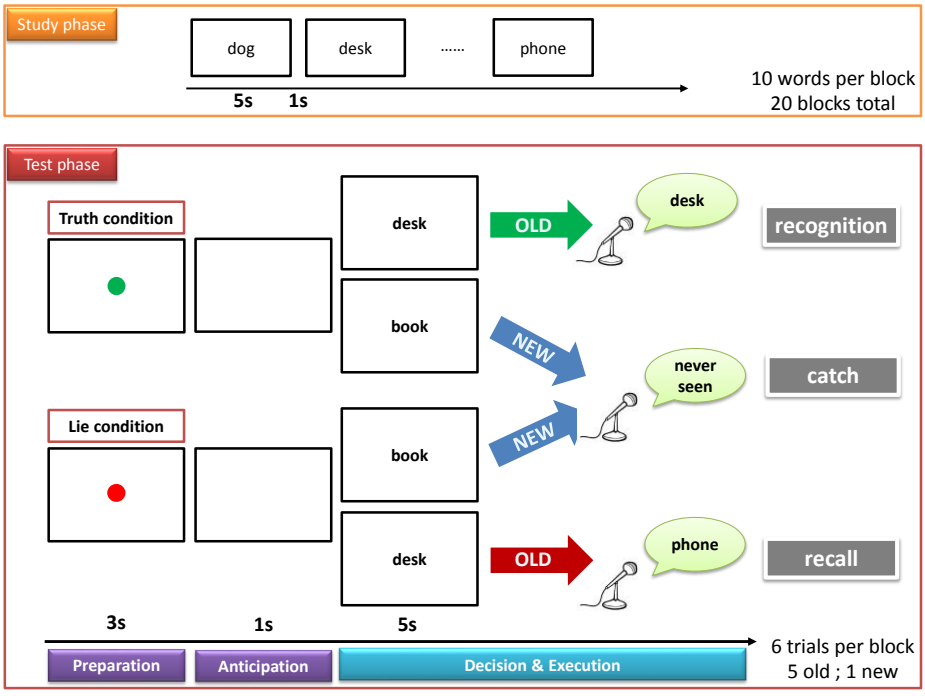
- Differences in encode-test angle does NOT seem to matter in our image set
  - This is achieved with 30 min practice with Probes, not to mention a suspect's own items
- Presentation angle matters, but does not impact GKT performance
- People get better over time (and multiple exposure to Probes), yet GKT effect remained robust after 750 trials

# What's next?

- During an interrogation, it's common for the suspects to lie using truth-based stories (Leins et al., 2013)
  - This is GKT-resistant
- But, maintaining false links between multiple memory accounts (though truthful) is effortful
  - Especially when they have to stay logically consistent and coherent (Walczyk et al., 2013)
  - This is essentially a working memory (WM) exercise

# Aim

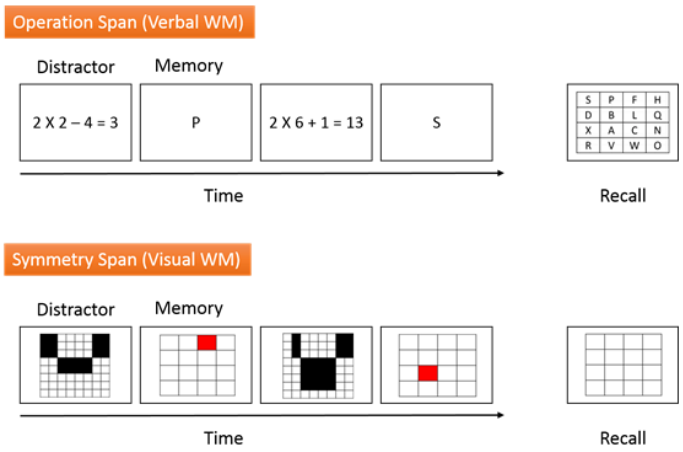
- Here we investigate the role of WM in producing truth-based lies
- A task that (hopefully) has certain similar characteristics as an interrogation



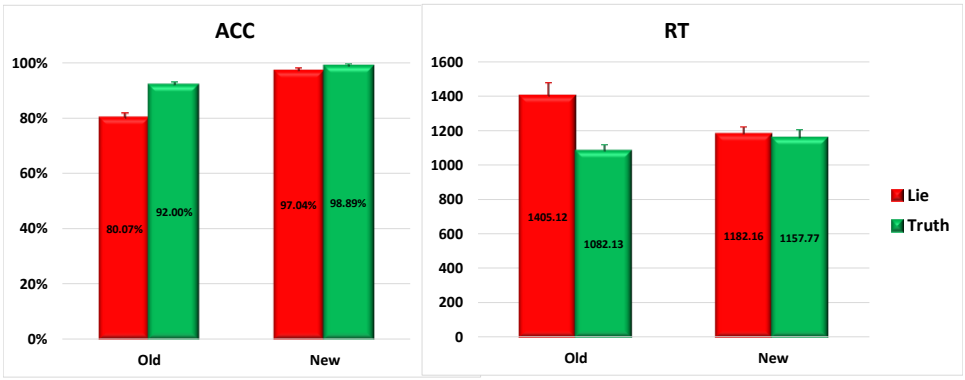

# Aim

- Here we investigate the role of WM in producing truth-based lies
- A task that (hopefully) has certain similar characteristics as an interrogation
  - Vocal responses
  - Maintain truthful items for potential deceptive use
  - Participants can mentally prepare ahead of time
  - But answers are dependent on the question

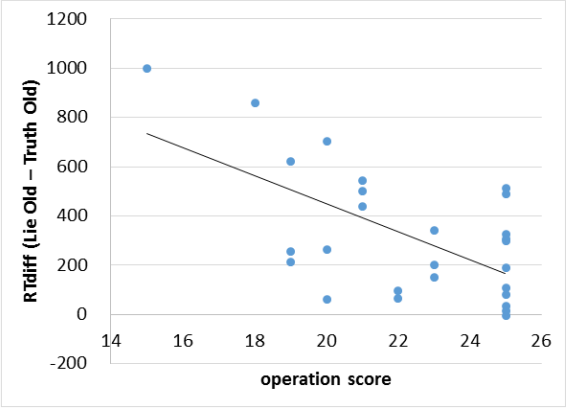
# Working Memory Span



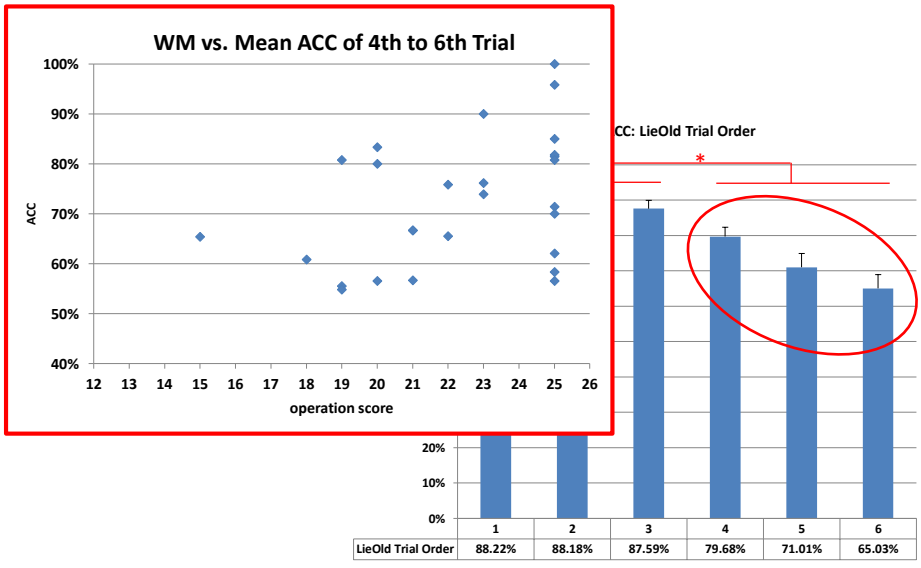

# Behavioral Results



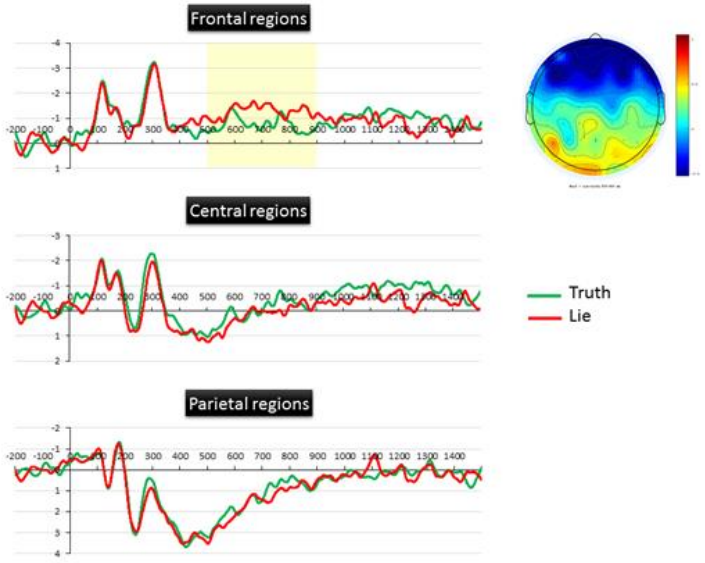
# Correlation b/w WM and RT cost (LieOld - TruthOld)



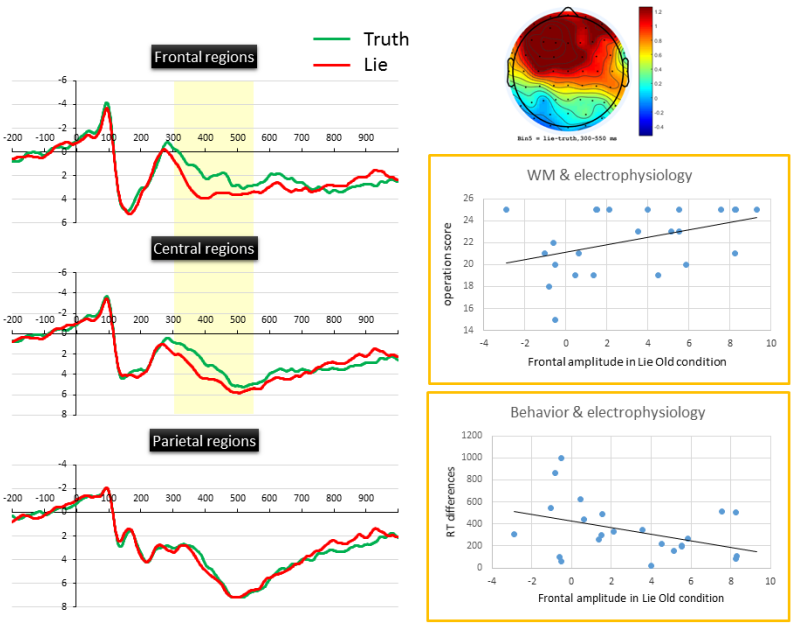

# ACC: WM Exhaustion



# ERP: Preparation

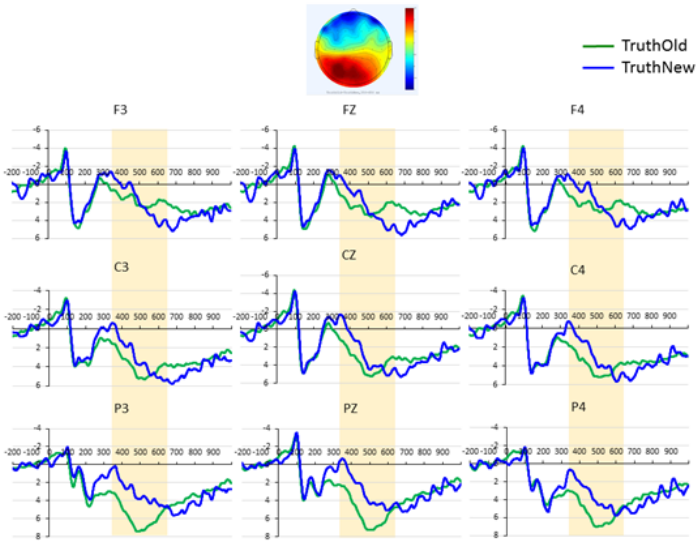



# ERP: Execution



# ERP: Familiarity

TruthOld vs TruthNew




# Conclusion

- Overall, lie trials have higher RT and lower ACC
- People with better WM (Ospan)
  - Can lie faster
  - Can maintain better accuracy (though still lower) in latter trials when available choices are exhausted
- ERP Results
  - Execution stage: positive-going differences in frontal region, in the 300-550 ms window
  - This frontal amplitude is:
    - positively correlated with verbal WM
    - and negatively correlated with RT-cost of lying

# Thank you for your attention!

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