Training the Multitasking Brain

Dr. Paul E. Dux, PhD
School of Psychology, The University of Queensland

Paul Bourke Lecture
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What are the processes involved from perceiving a stimulus up to selecting the appropriate response?

- We seem well equipped for this:
  - Billions of neurons
  - Trillions of synaptic connections
  - Massive processing power

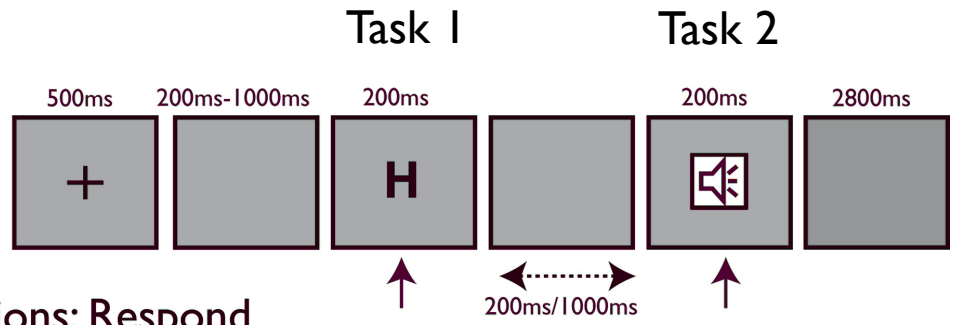
But, a lot happens in our sensory environment.....every second!

- Capacity limits are shown in multitasking scenarios
  - Talking on a mobile and driving
- Occurs for simple tasks

Why Multitasking?

- Applied settings
- Clinical settings
- Uncover the architecture of our cognitive systems

How do we study multitasking in the lab?

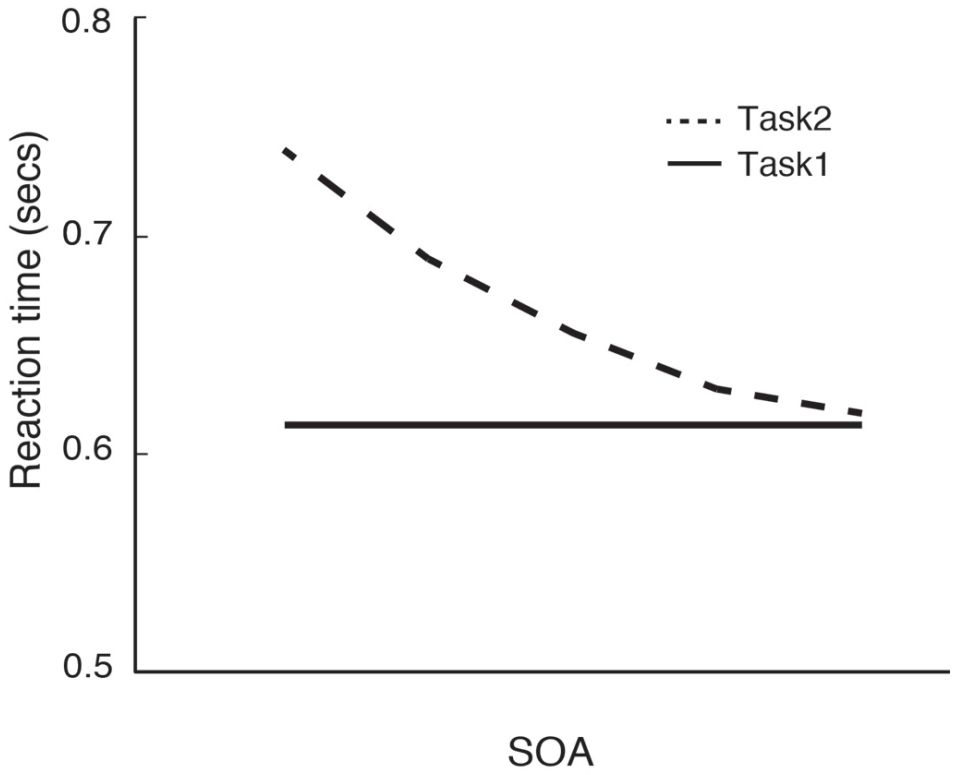


Instructions: Respond to both tasks as quickly as you can

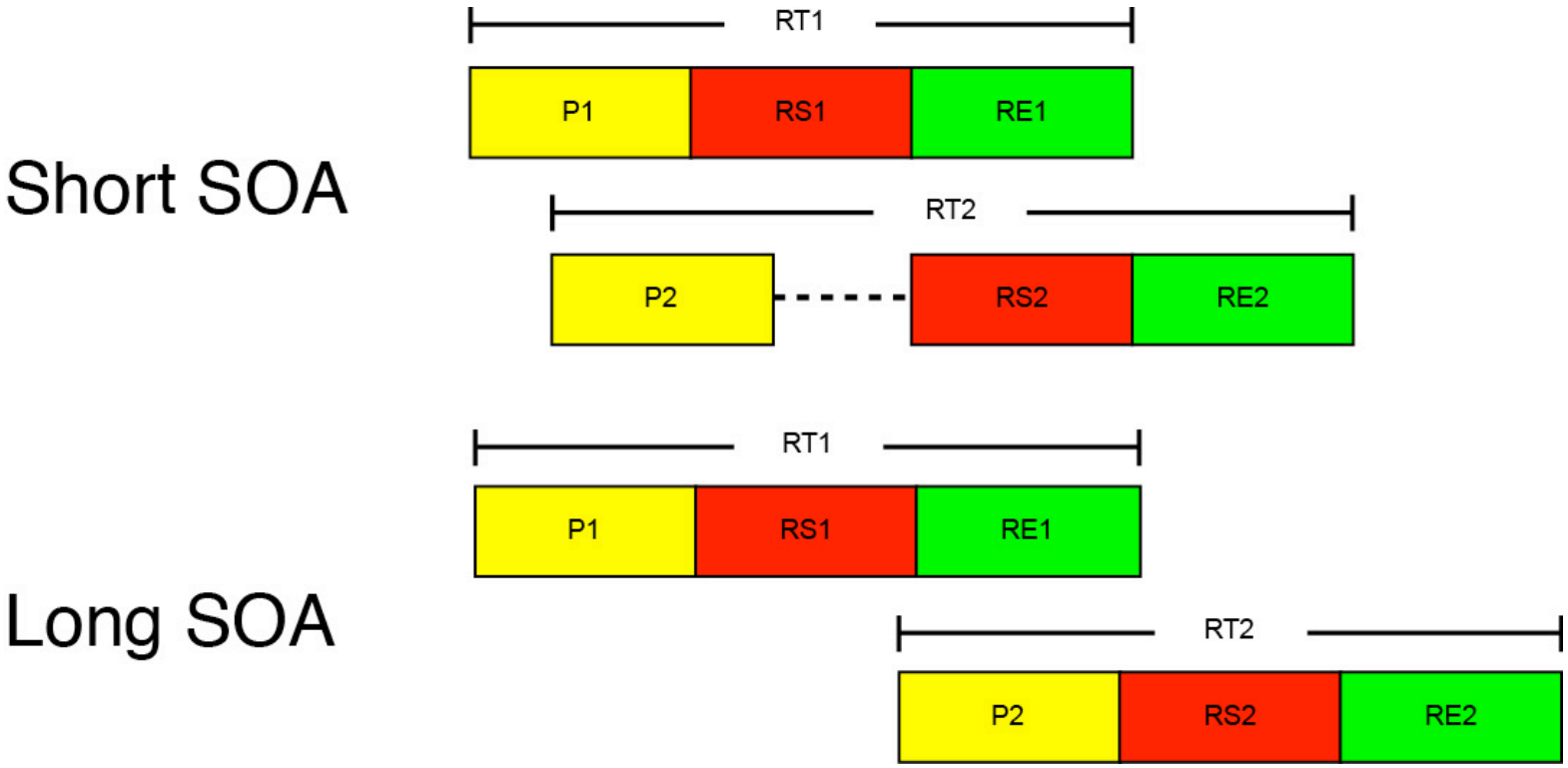
Press buttons in response to the letters H, S, A or B

Make vocal responses to sounds

Psychological Refractory Period (PRP)



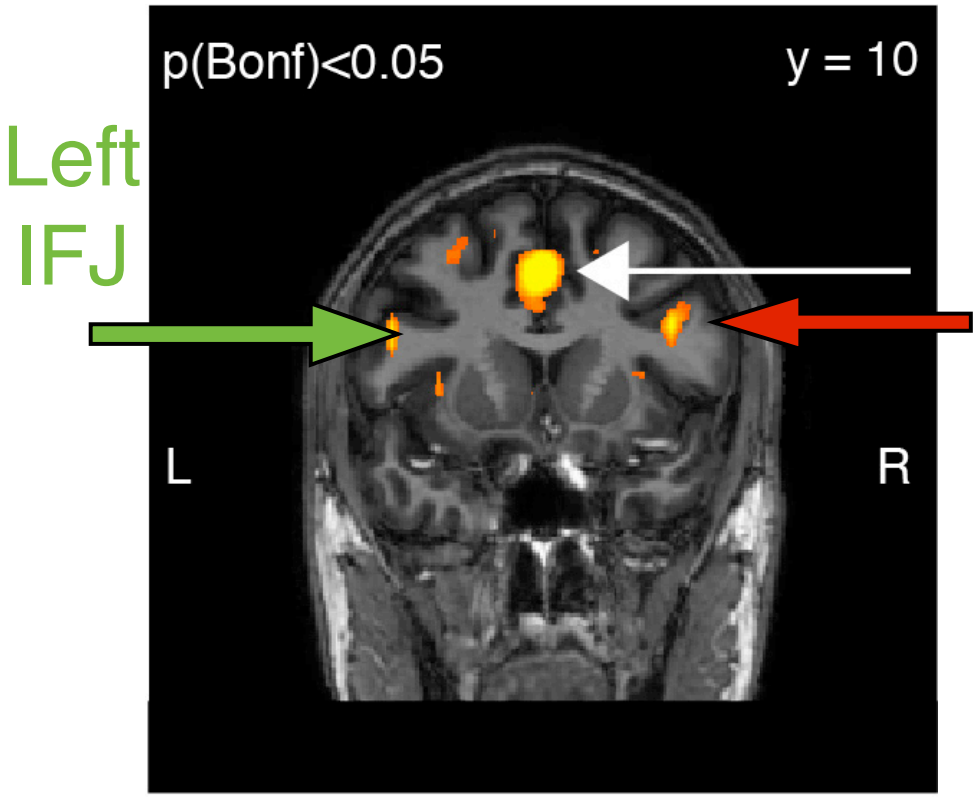
Central Bottleneck

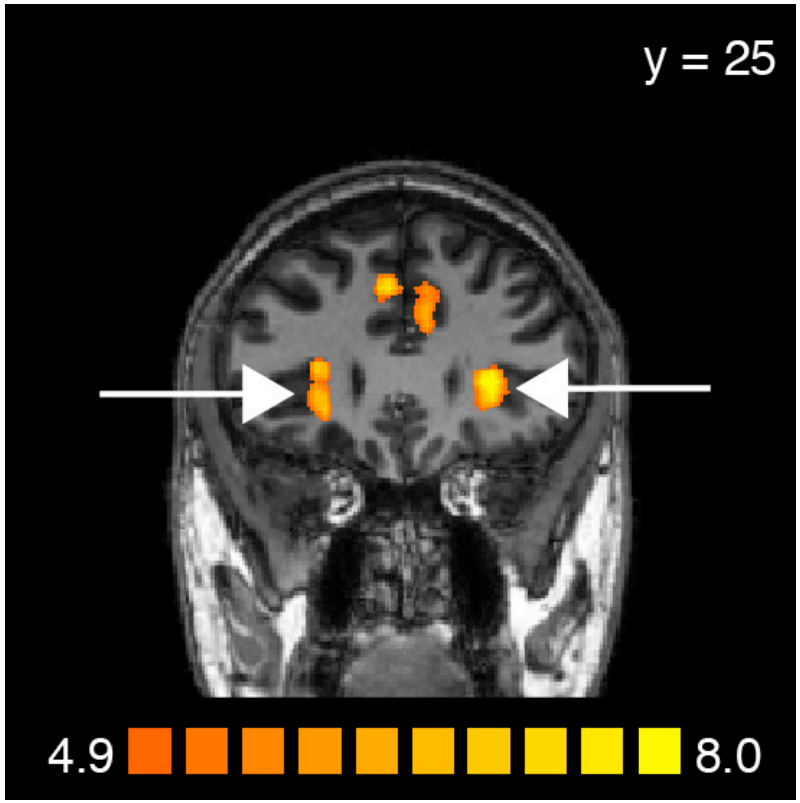


Multitasking and the Brain

- What are the neural substrates of the central bottleneck?
- Look for brain areas that:
  - Respond to tasks in different modalities
  - Are sensitive to both memory encoding and response-selection manipulations
  - Show temporal patterns of activity predicted by bottleneck models

Multitasking and the Brain



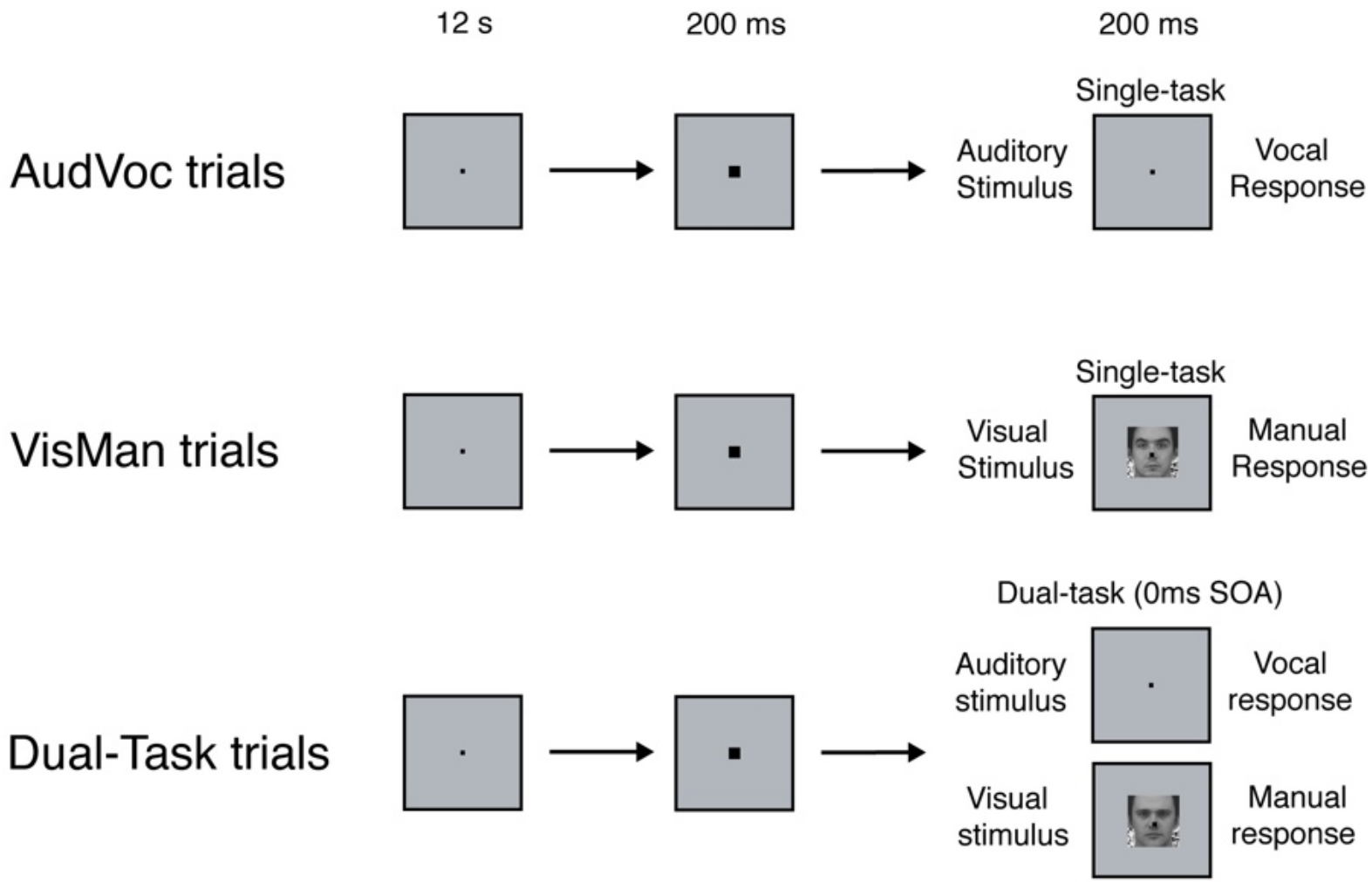


Dux et al., 2006, *Neuron;* Tombu et al., 2011, *PNAS*

Training and Multitasking

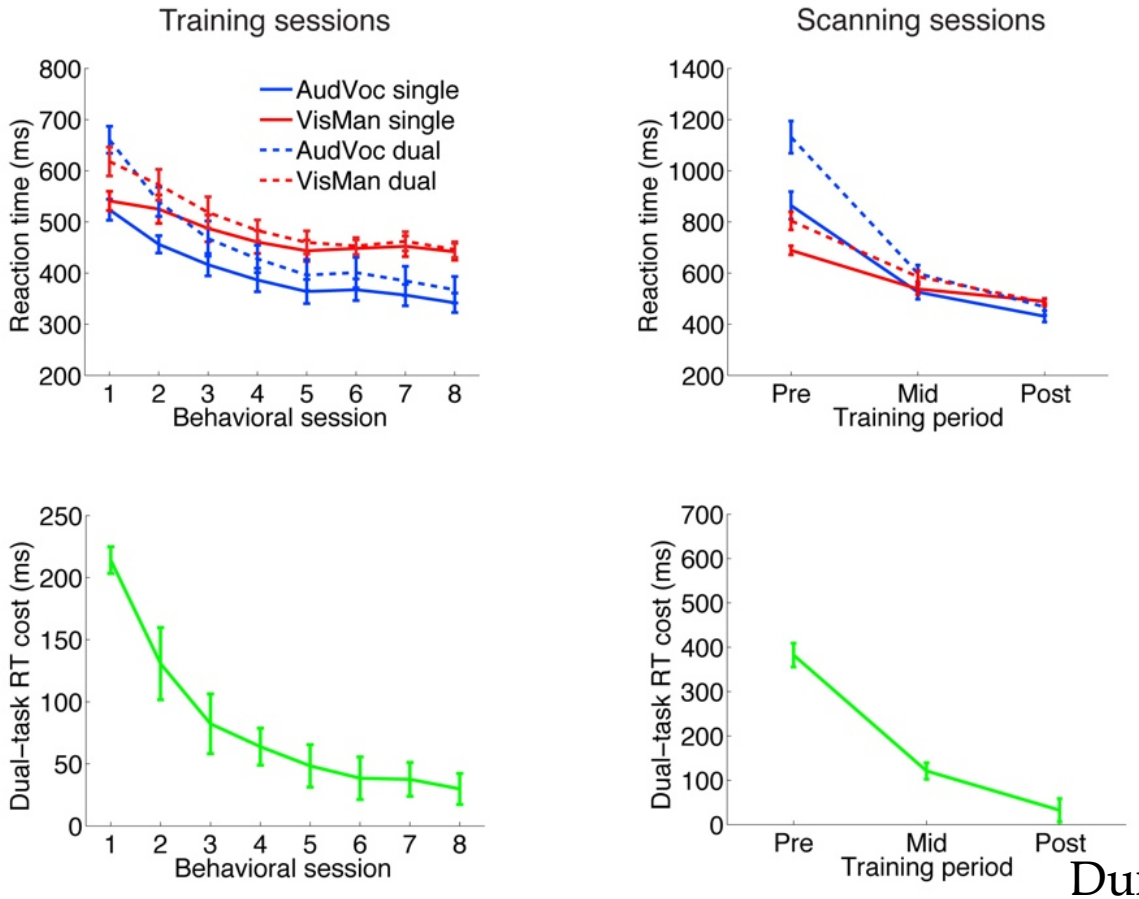
- Multitasking costs are not immutable and can be reduced with training
- Relevance in clinical and applied settings
- Can help elucidate the mechanisms that give rise to multitasking costs

How does training change the brain to allow efficient multitasking?



Dux et al., 2009, *Neuron*

Training and Multitasking



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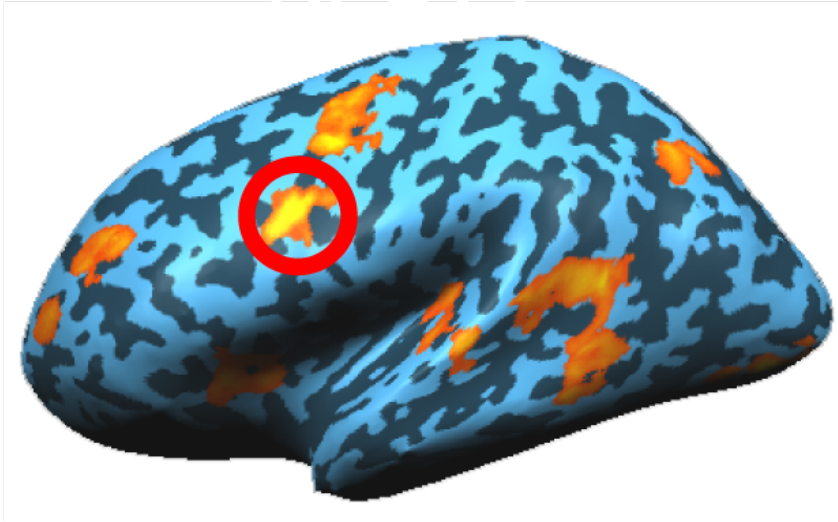
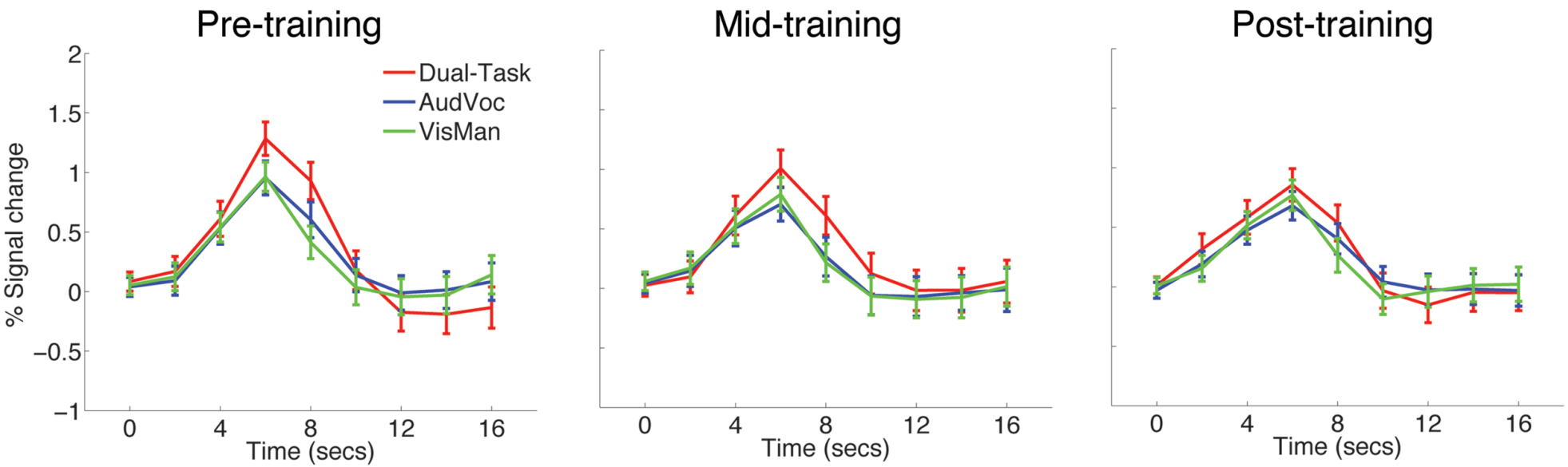




Dux et al., 2009, *Neuron*

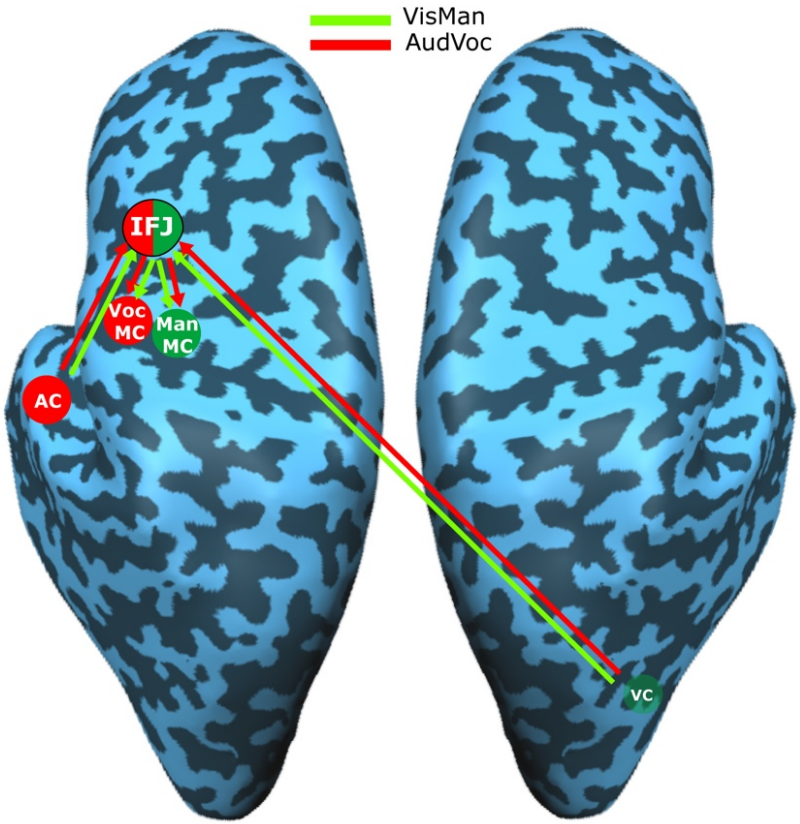
Left IFJ tracks improvements in multitasking performance with training

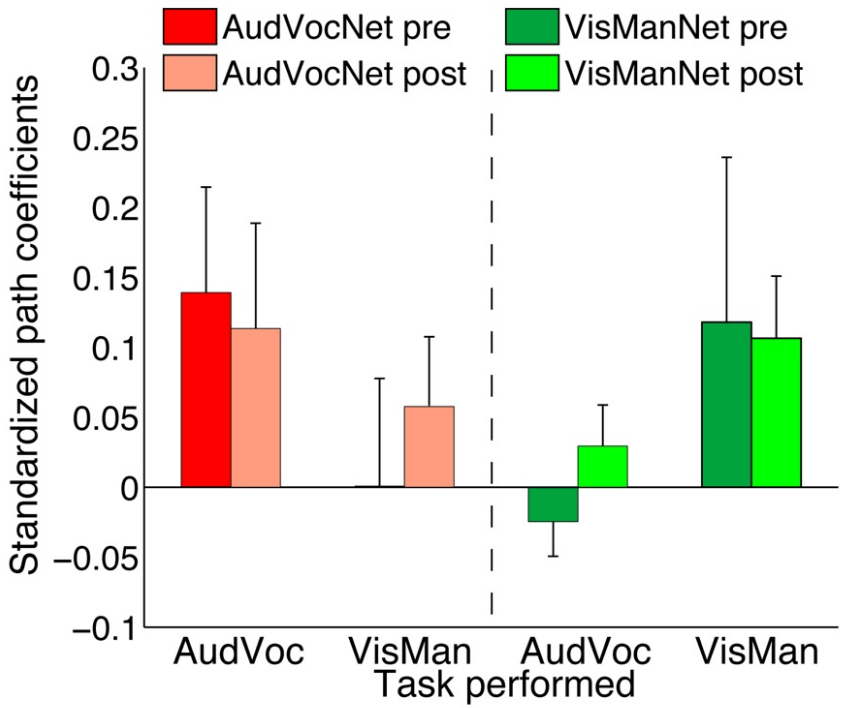
What does training do?

- Training and macro-network changes
- Training and micro-network changes
- Increased efficiency of central processing

Dux et al., 2009, *Neuron*

Training and Macro-Network Changes





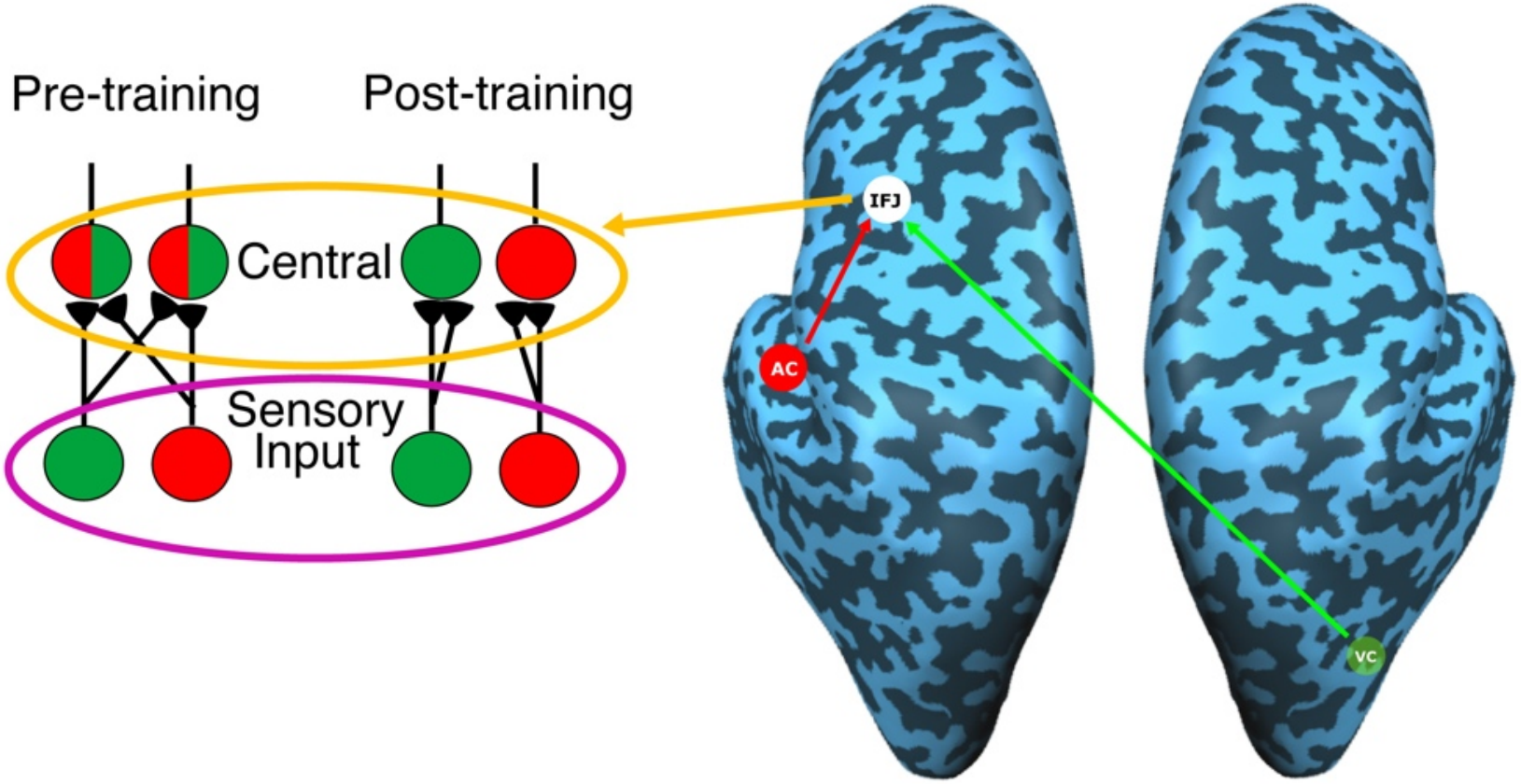
Dux et al., 2009, *Neuron*

Training and Multitasking

- ~~Training and Macro-Network Changes~~
- Training and Micro-Network Changes
- Increased Efficiency of Central Processing

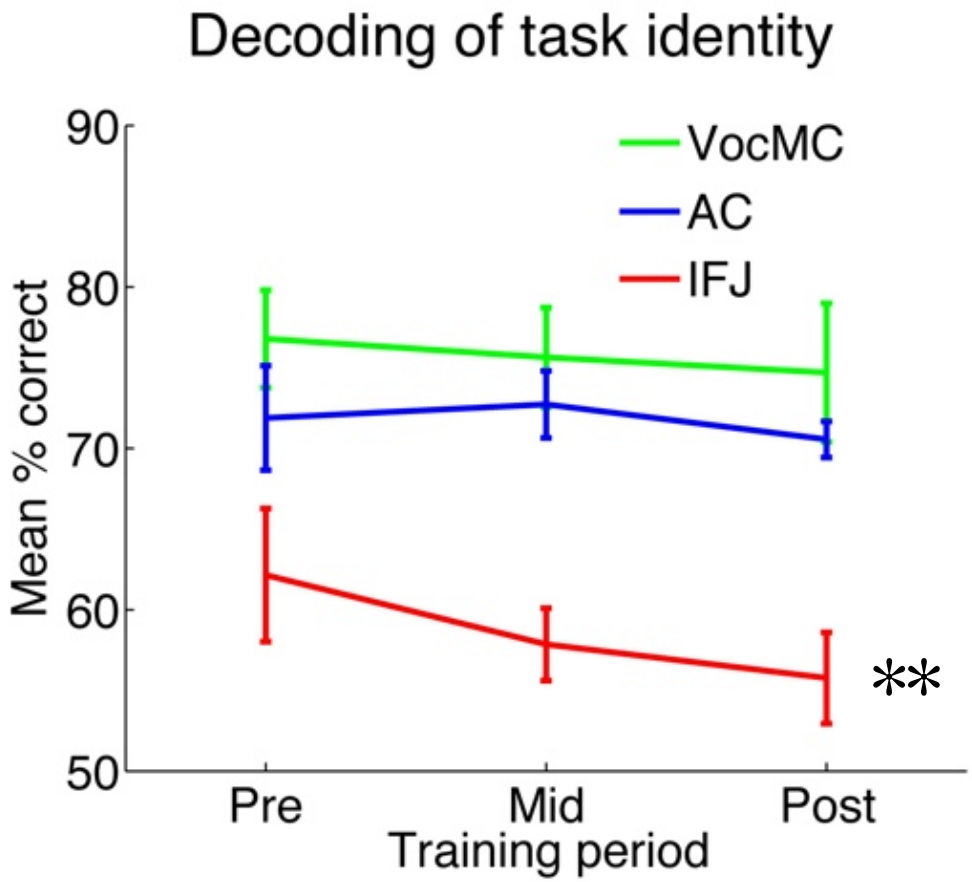
Dux et al., 2009, *Neuron*

Training and Micro-Network Changes



Dux et al., 2009, *Neuron*

Training and Micro-Network Changes



Dux et al., 2009, *Neuron*

Training and Multitasking

- ~~Training and Macro-Network Changes~~
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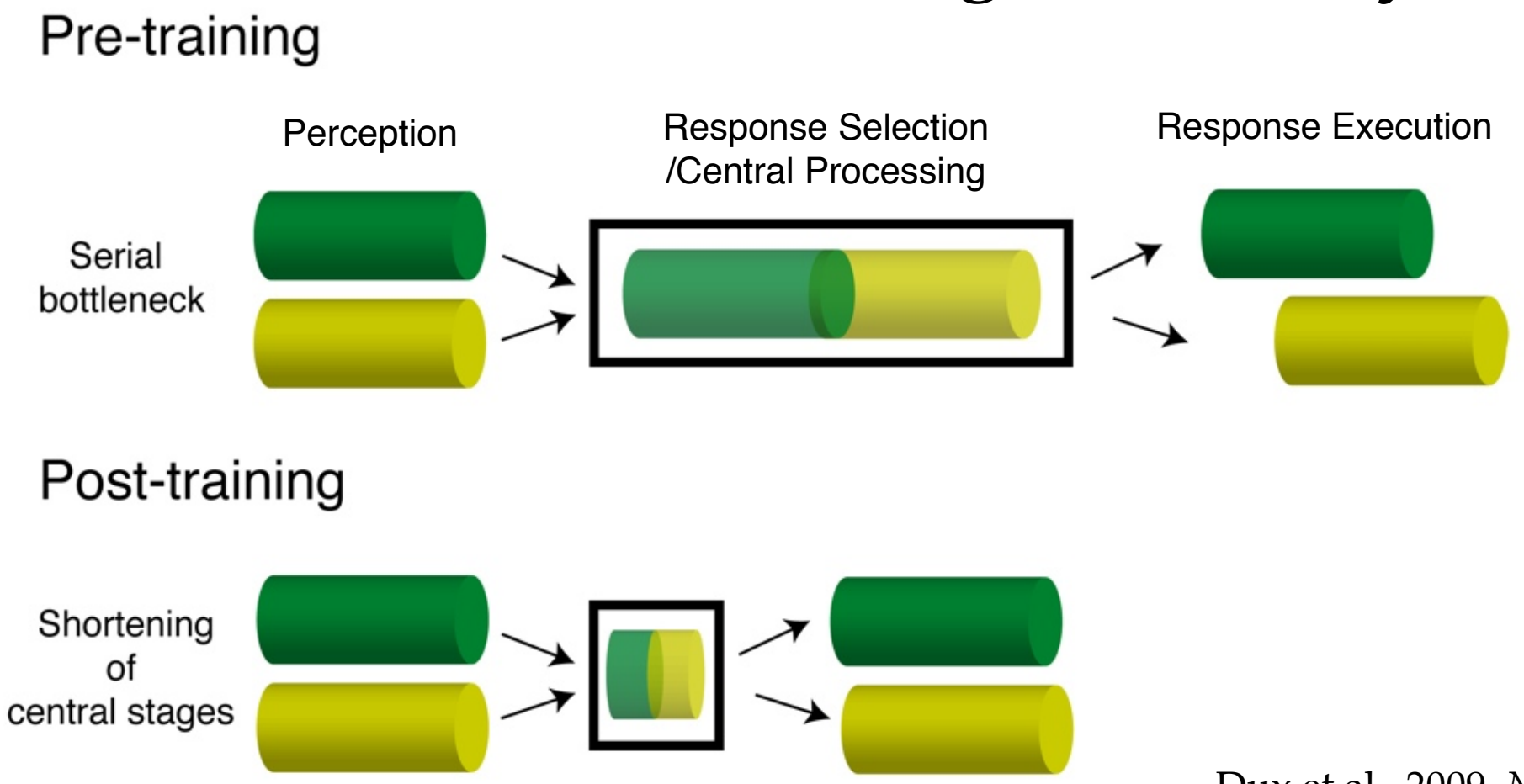
Increased Processing Efficiency



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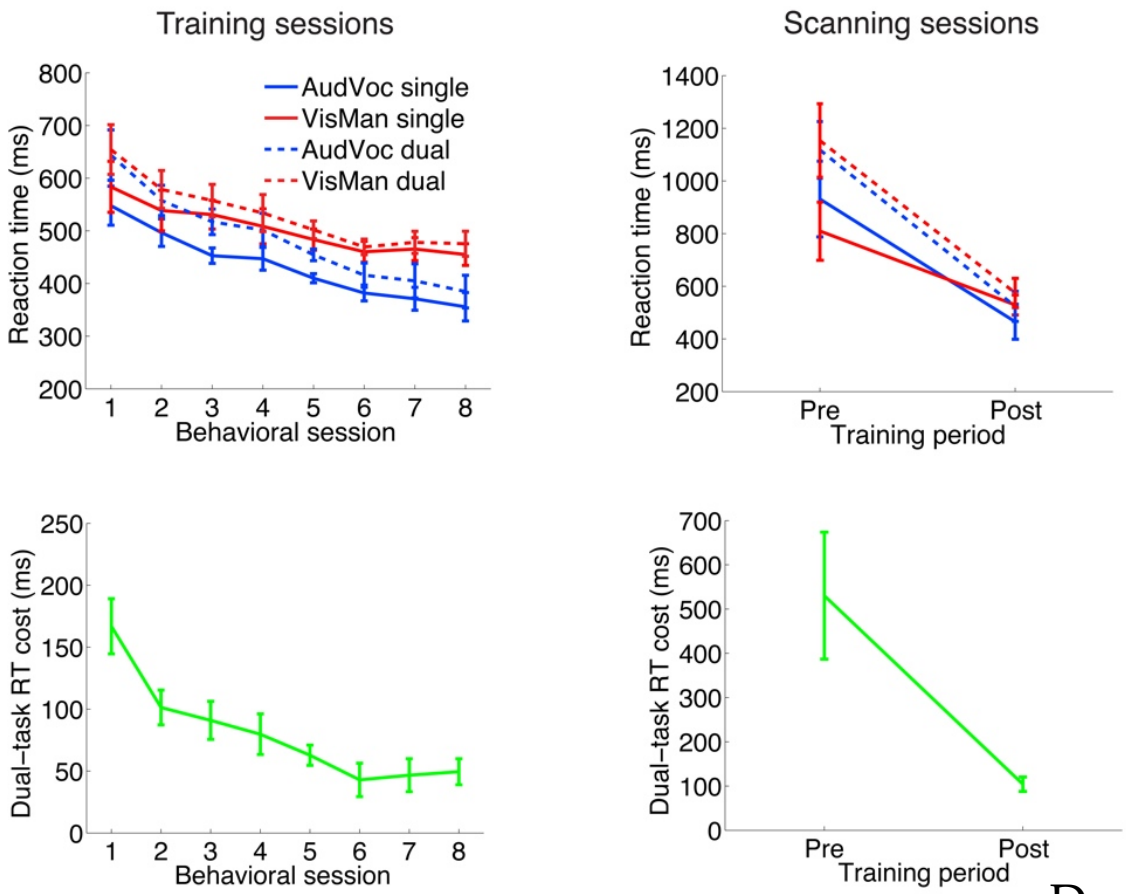
Increased Processing Efficiency



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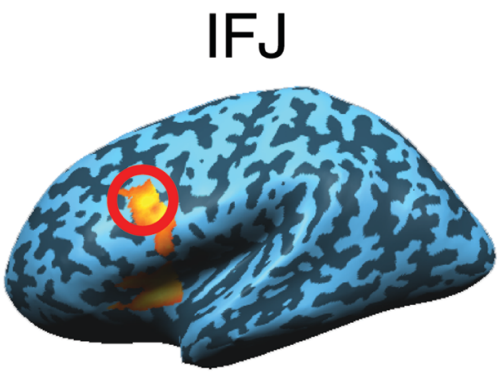

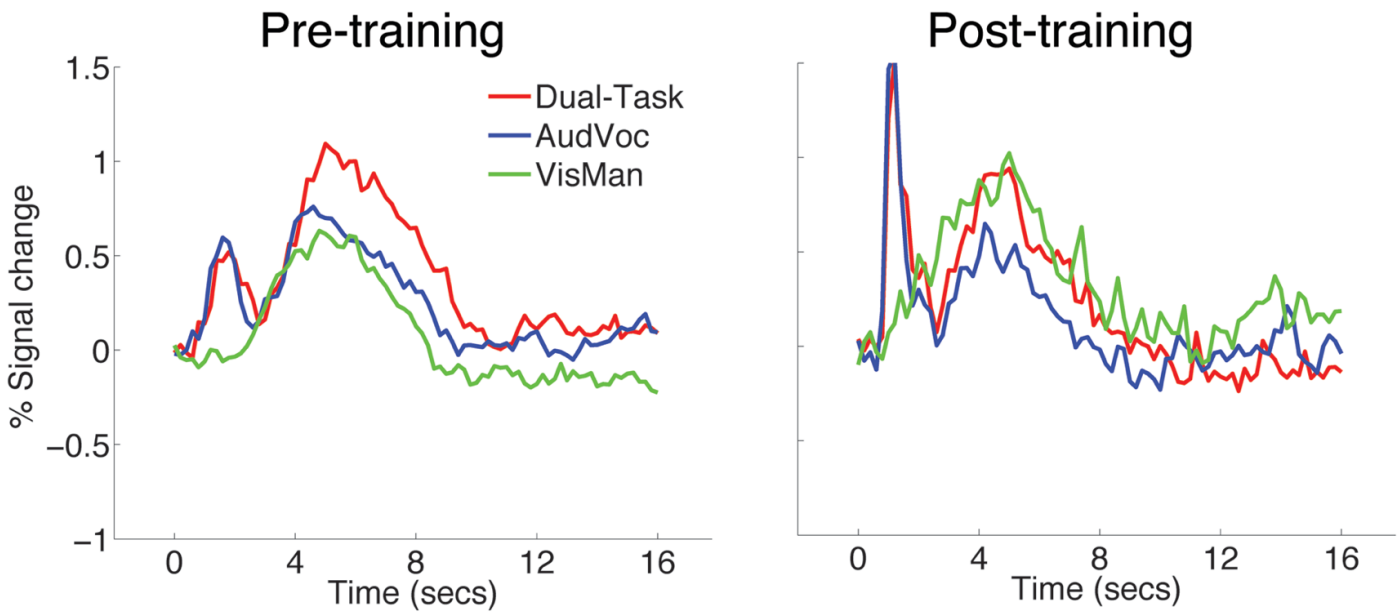

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Training and Multitasking

- ~~Training and Macro-Network Changes~~
- Training and Micro-Network Changes ✓
- Increased Efficiency of Central Processing ✓

Dux et al., 2009, *Neuron*

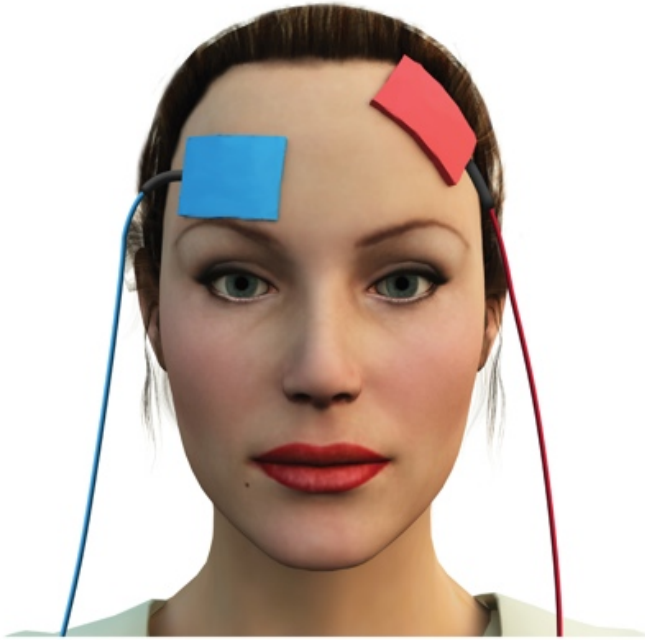
Is left IFJ processing required for sensory-motor training benefits to occur?

Filmer et al., *in prep*

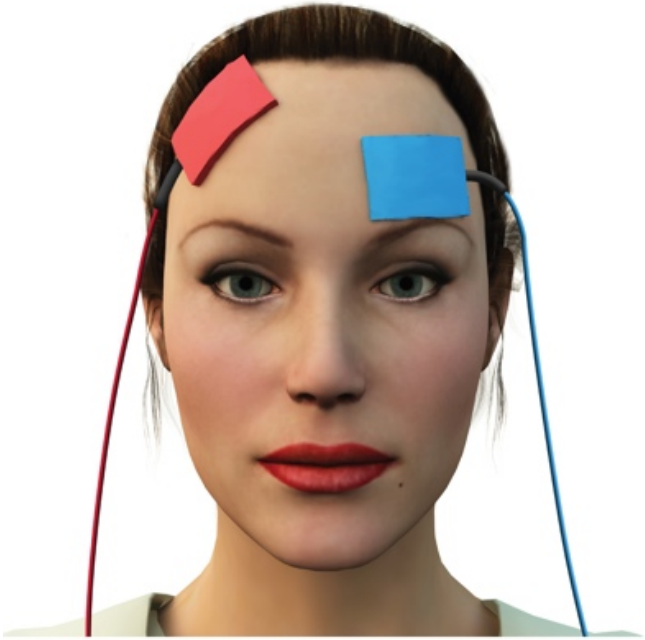
Stimulated IFJ, using transcranial direct current stimulation (tDCS), and measured participants response to training

Filmer et al., *in prep*

Left IFJ (F3) n = 18



Right IFJ (F4) n = 18



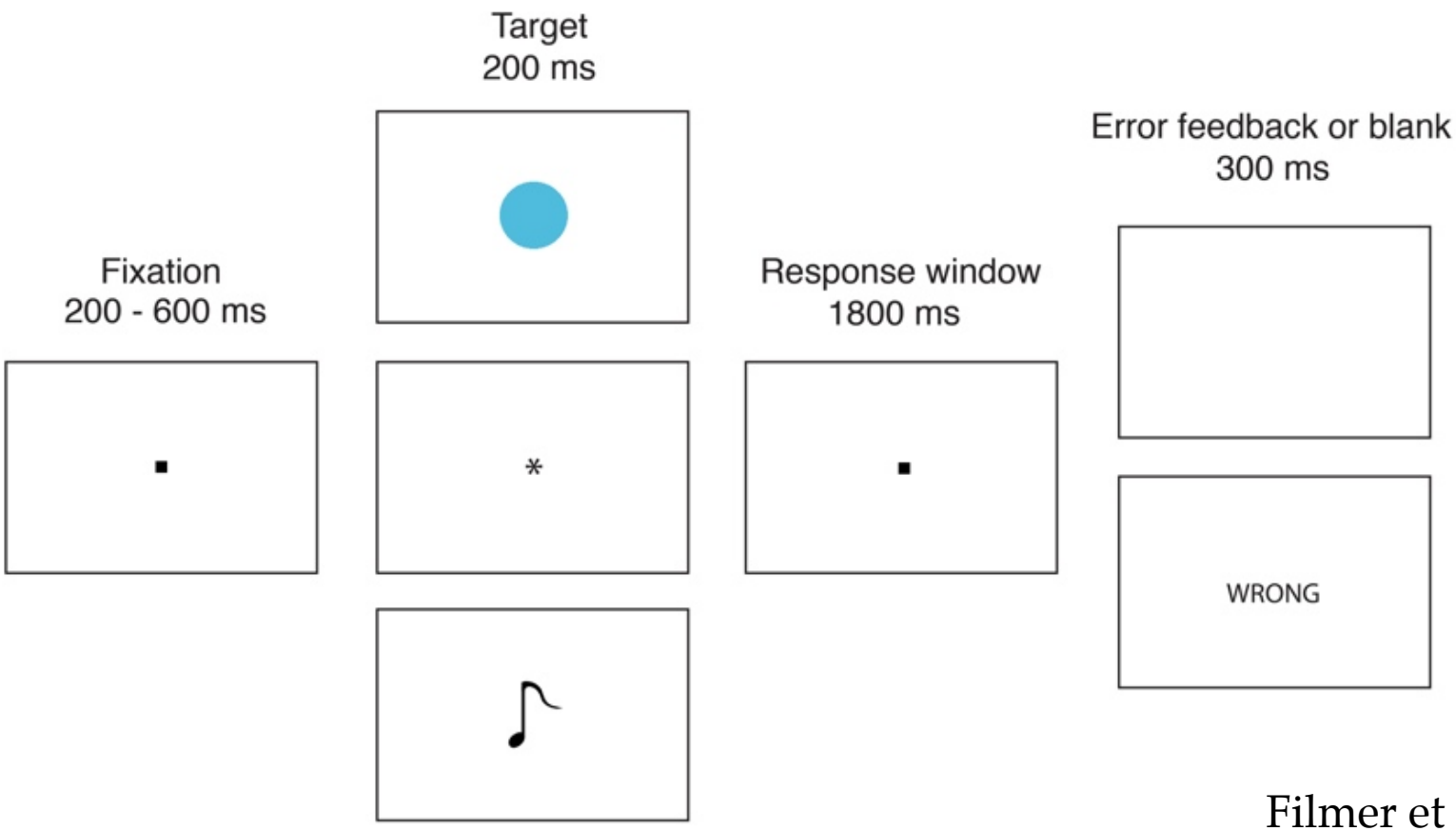
Filmer et al., *in prep*

tDCS of IFJ

- Two groups completed:
- Cathode (inhibitory), Anode (excitatory) and Sham sessions
- 2AFC vs. 6AFC blocks in each session
- 3 different time points: pre, immediately after tDCS, 20 mins after tDCS

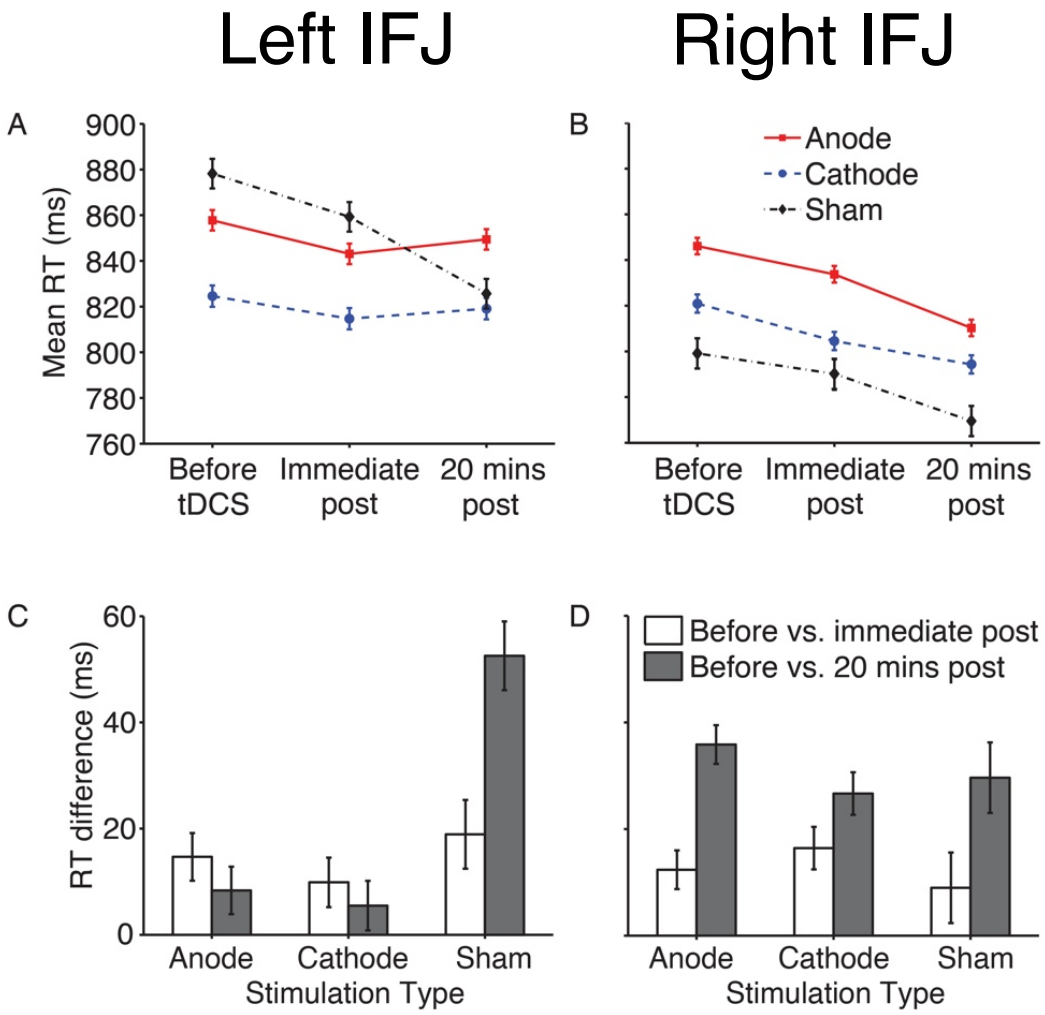
Filmer et al., *in prep*

tDCS of IFJ



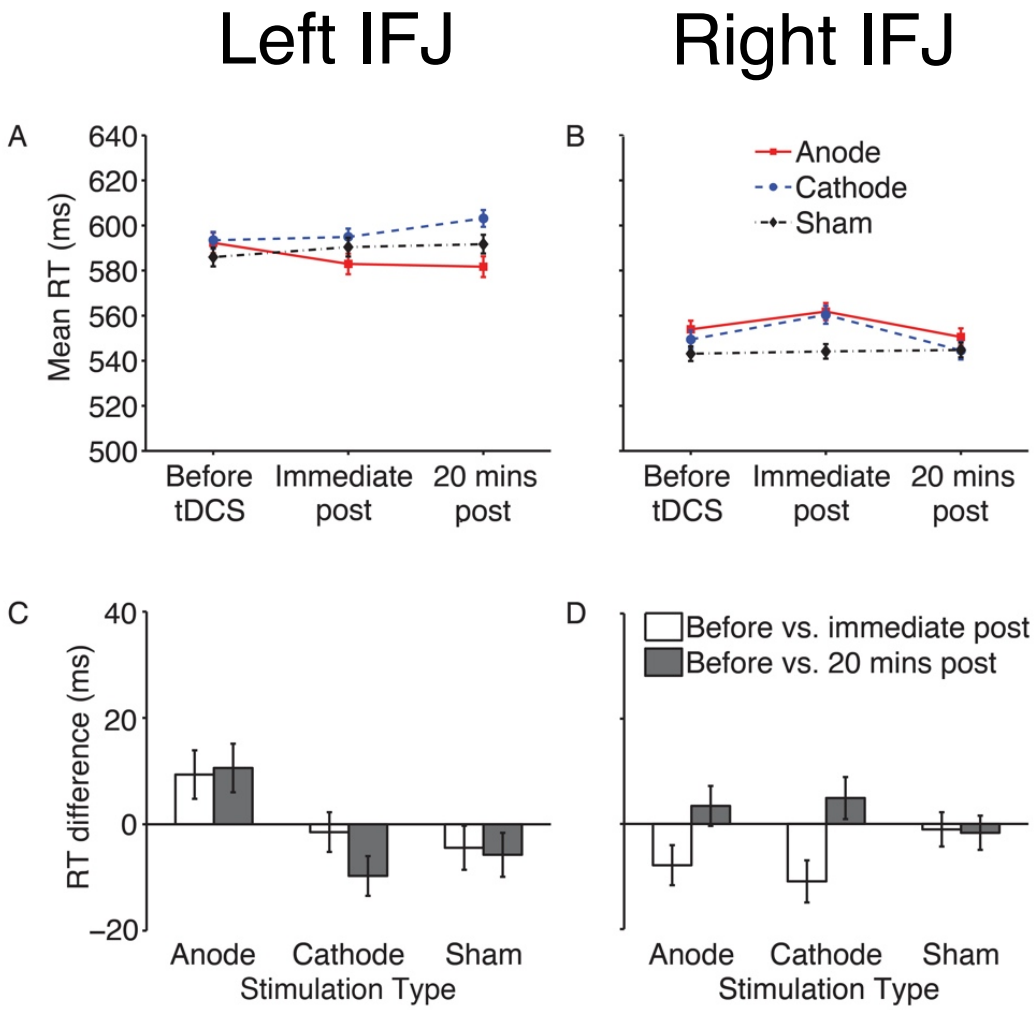
Filmer et al., *in prep*

6AFC



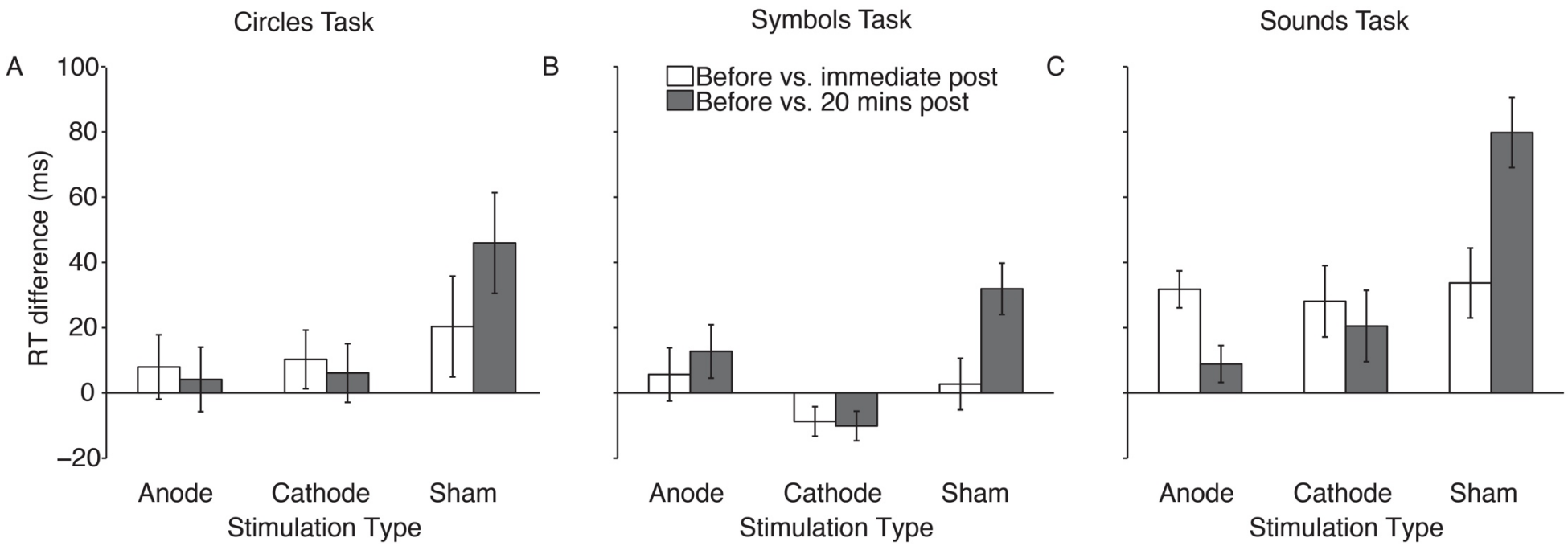
Filmer et al., *in prep*

2AFC



Filmer et al., *in prep*

Left IFJ across tasks



Filmer et al., *in prep*

Interim Conclusions

- Left IFJ appears to be involved in response-selection pre- and post-training
- Stimulation of Left IFJ with tDCS prevents response-selection training effects
- Convergent evidence from different techniques

Shifting Gears....

- Training on a task makes you better at that task
- Are there general training benefits?

General Training Benefits?

- Does brain training work?
  - Working memory training
- $5 Billion question.....(2015)
  - In 2008, US brain training industry was worth ~285 million
- Has been suggested to:
  - Improve attention, memory and intelligence
  - Treat a range of psychiatric and neurological conditions

"Cognitive exercise is like physical exercise: anyone can benefit, regardless of age, gender, profession, or educational background…..**Product X** has helped people remember names and faces, prepare for sports competitions, study for academic tests, and even learn new instruments and languages. It's also helped those recovering from disease- and accident-related brain injuries."

General Training Benefits?

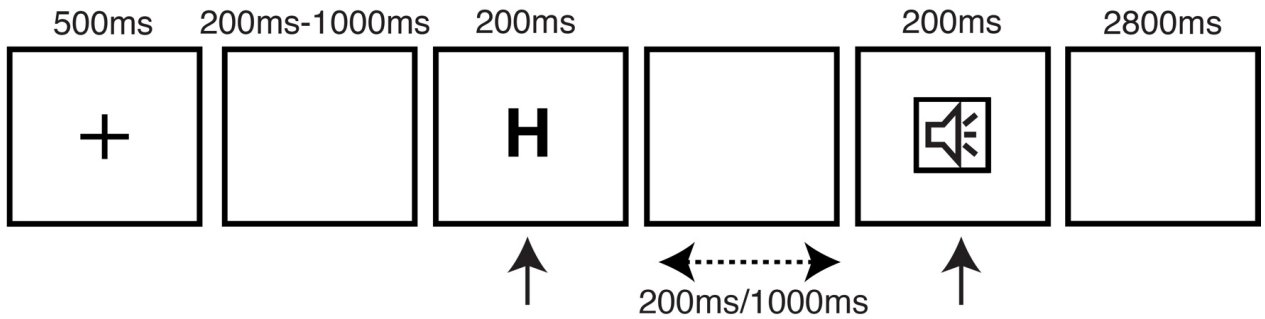
- Jury is still out....
- Highly cited study (Jaeggi et al., 2008) linking brain training and IQ was recently not replicated (Redick et al., 2013)
- Owen et al. in a large sample (>10000) found no evidence of a generalised brain training benefit

General Training and Multitasking

- How does cognitive training influence specific cognitive processes?
- Does it have different effects at different levels on information processing?

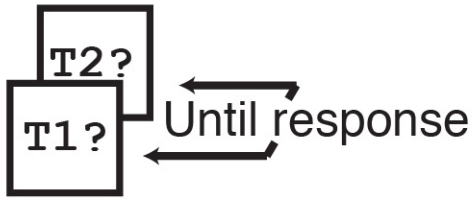
Garner et al., *Under Review*

PRP Task

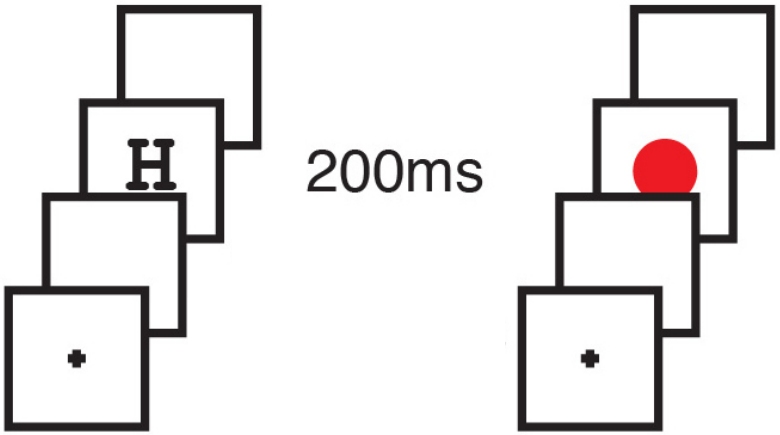


Press buttons in response to the letters H, S, A or B

Make vocal response to 1 of 4 sounds

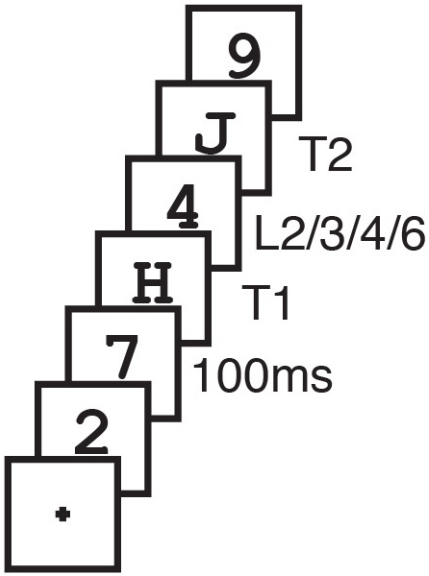


Until response



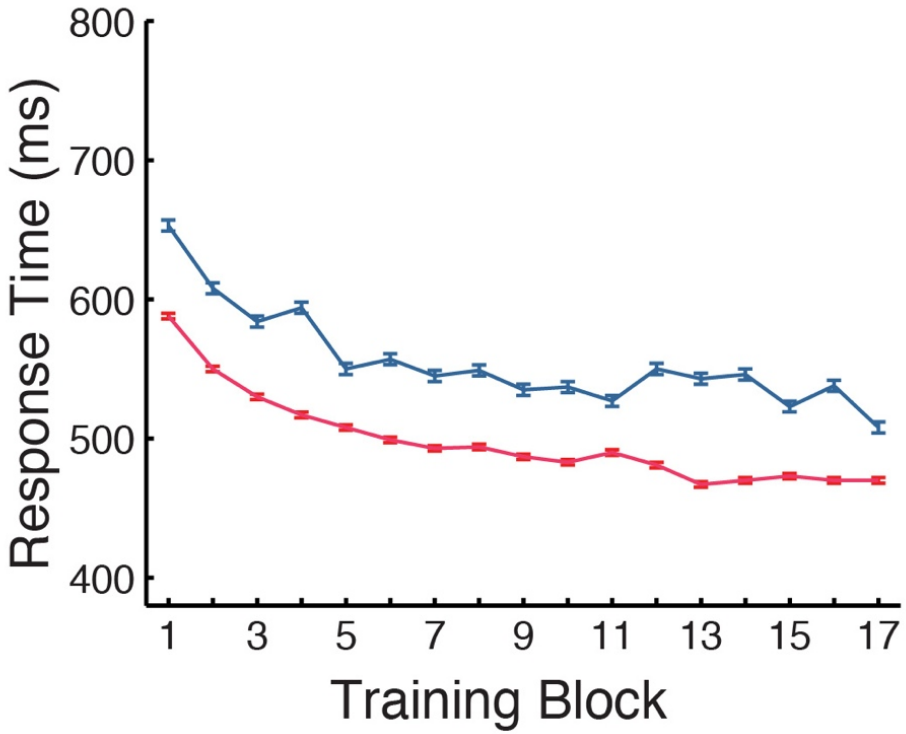
Relevant Training Irrelevant Training

4080 training trials

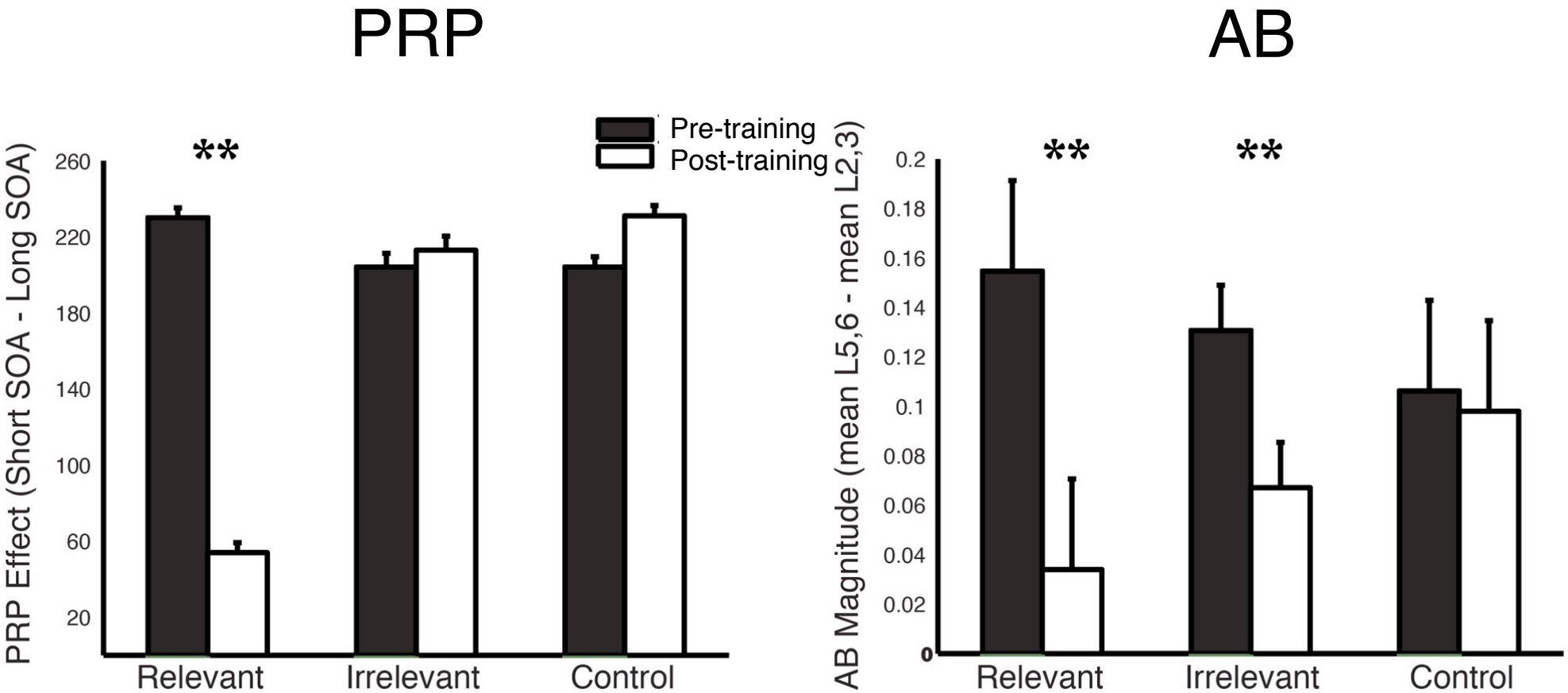


AB Task

Garner et al., *Under Review*



Garner et al., *Under Review*



Garner et al., *Under Review*

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General Training Benefits?

- Different effects of training at different levels of information processing
  - AB, perceptual encoding limit - general training benefit
  - PRP, decision making limit - no general training benefit
- Question very much still open!

Garner et al., *Under Review*

"Everyday" Training Benefits?

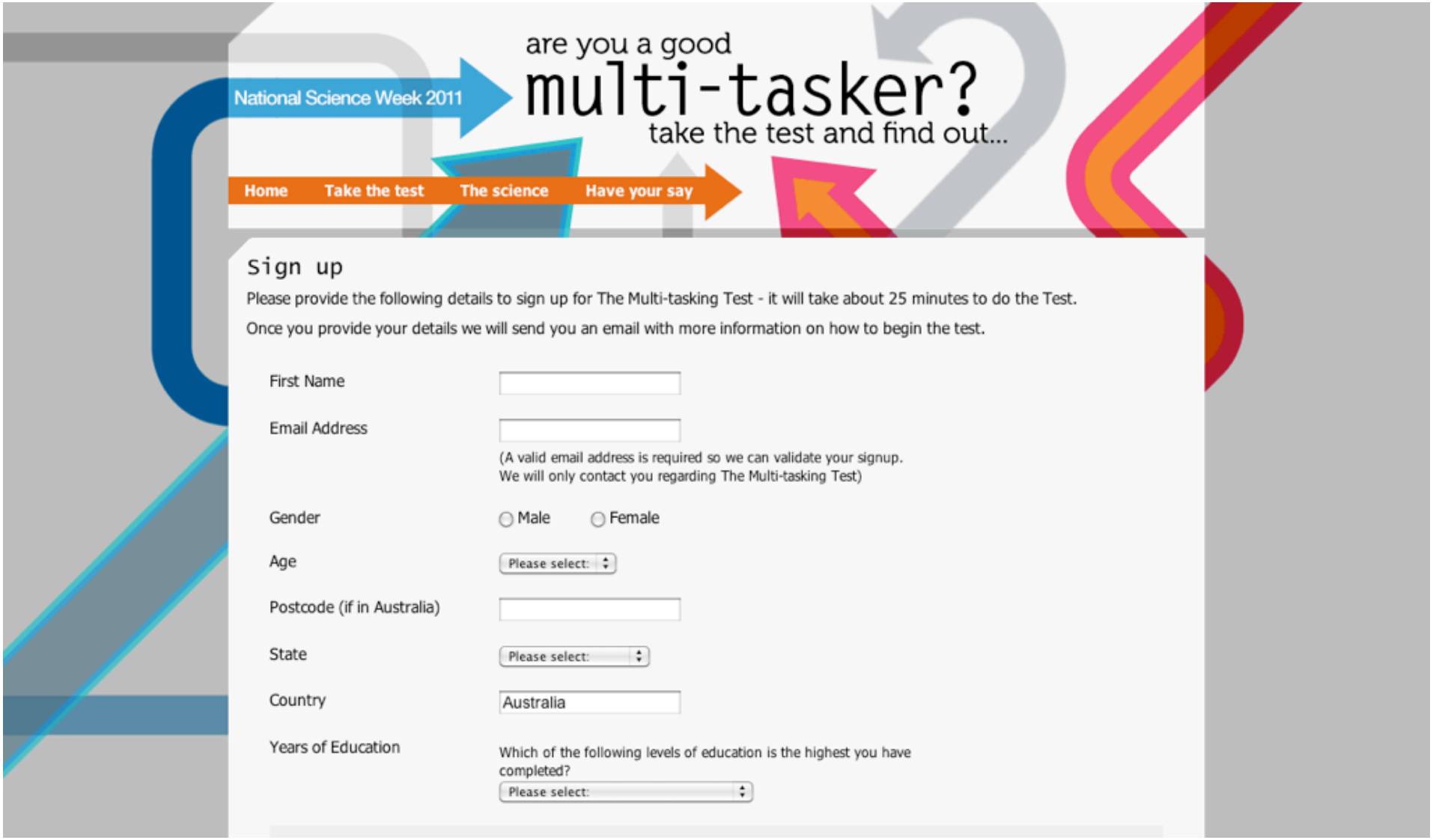
- Studies so far are all lab based
- What about our everyday behaviour?
- Media-multitasking linked to attentional focus
- Ophir et al. (2009) found high-MMI are impaired in task-switching relative to low-MMI (but see Alzahabi and Becker, 2013)

Dux et al., *in prep*

“Everyday” Training Benefits?

- Does everyday multitasking behaviour influence multitasking ability?
  - Even when controlling for a range other variables
- Conducted community based project with the ABC for Science Week n =~4500

Dux et al., *in prep*



Dux et al., *in prep*

multi-tasking test

Progress Bar:

you are in section 1 of 5

Multi-tasking Habits

The following 10 questions will help researchers work out how often you multi-task different types of media, such as mobiles, print or computers. This will help them assess the impact - both positive and negative - that media multi-tasking is having on our society. Please answer the questions as accurately as possible. There are no right answers

1. On an average day, how much time do you spend TALKING FACE-TO-FACE WITH A PERSON ?

Hours : Minutes :

If you do not do this activity on the average day, please enter 0.

While you are TALKING FACE-TO-FACE WITH A PERSON, what percentage of time are you also doing each of these other activities?

Please use the sliders to indicate the percentage of time.

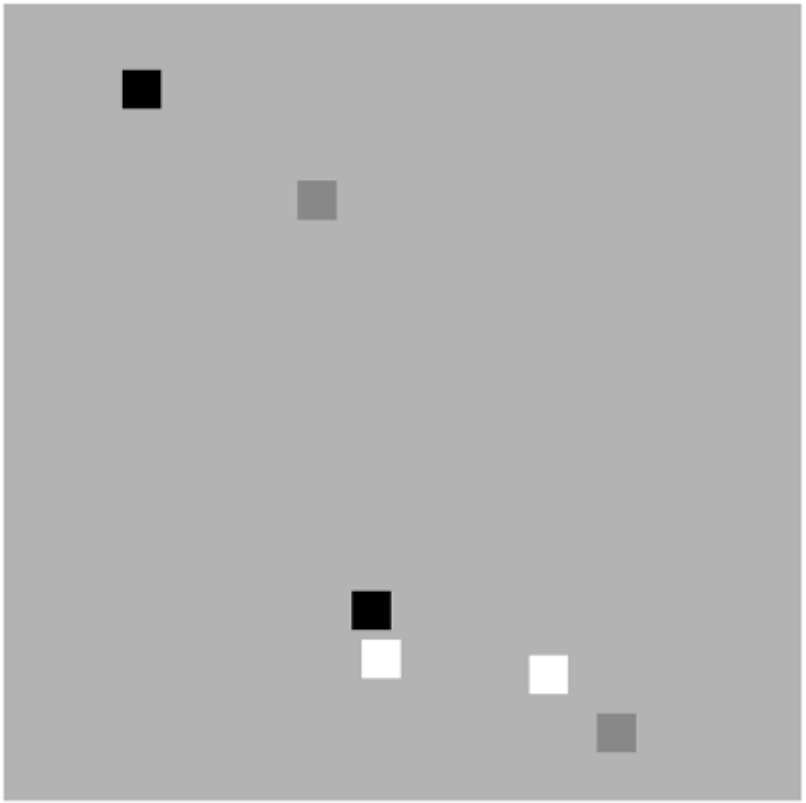
Talking face-to-face with another person	0 %
Reading print media (including print books, print newspapers, etc.)	0 %
Texting, instant messaging, or emailing	0 %
Using social sites (e.g., Facebook, Twitter, etc., except games)	0 %
Using non-social text-oriented sites (e.g., online news, blogs, eBooks)	0 %
Talking on the telephone or video chatting (e.g., Skype, iPhone video chat)	0 %
Listening to music	0 %
Doing document writing/homework/studying	0 %
Watching TV or Movies (online and off-line) or YouTube	0 %
Playing video games or online games	0 %
Doing housework	0 %

next >>

Dux et al., *in prep*

Changing Squares

Test 1 of 16



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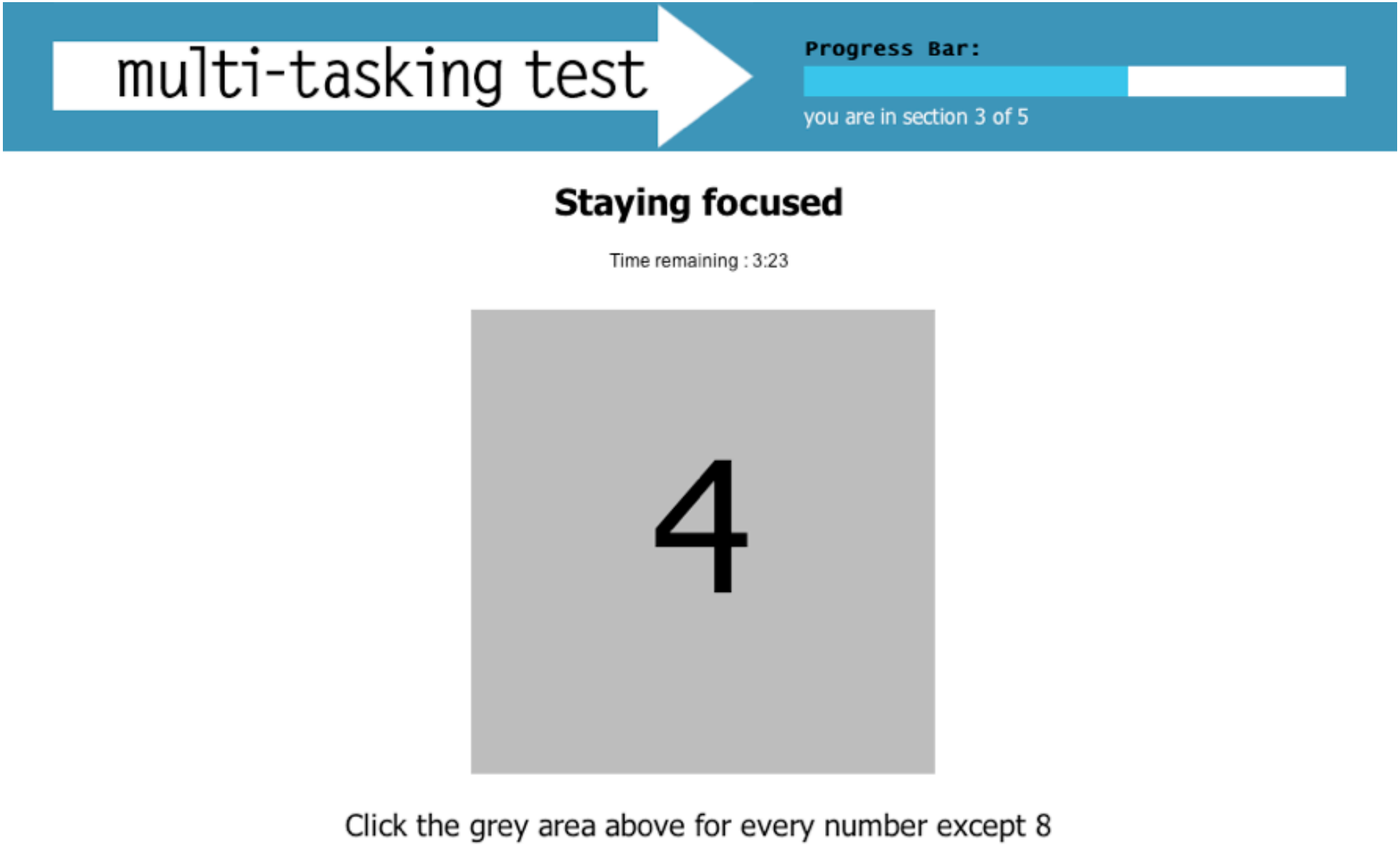

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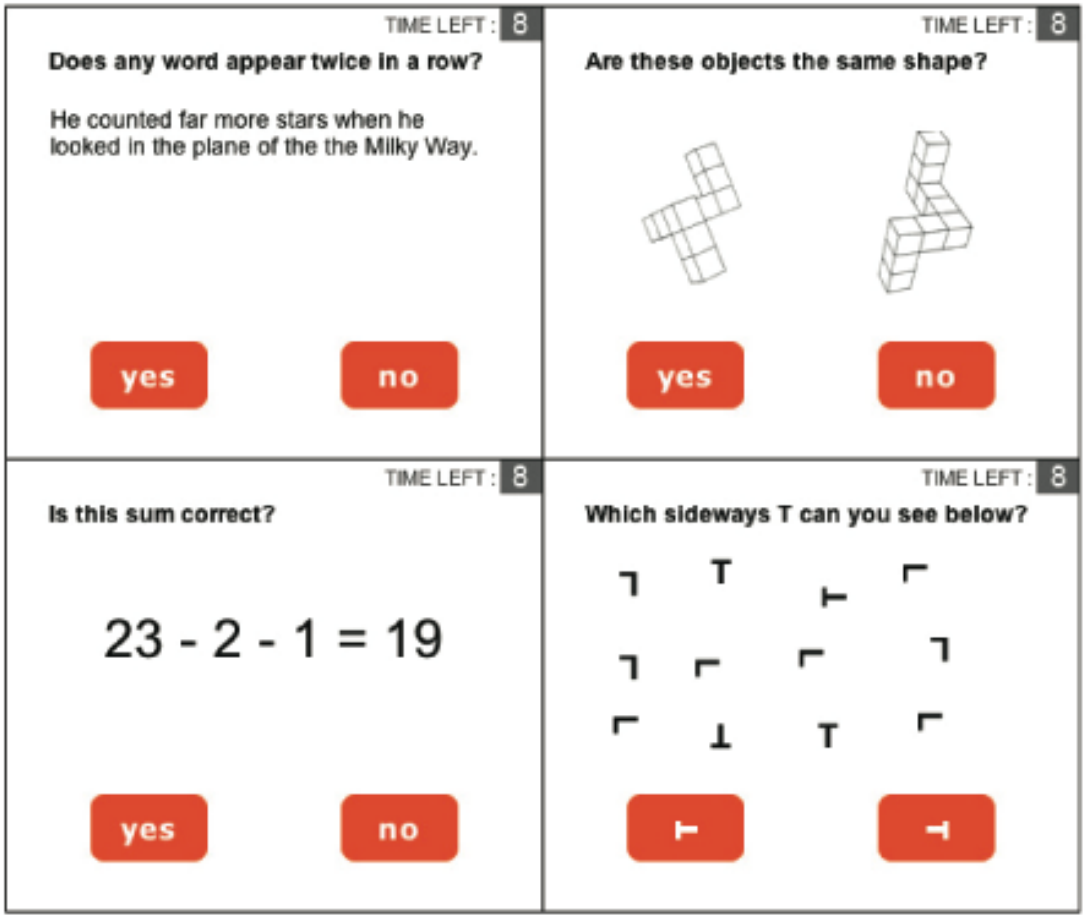

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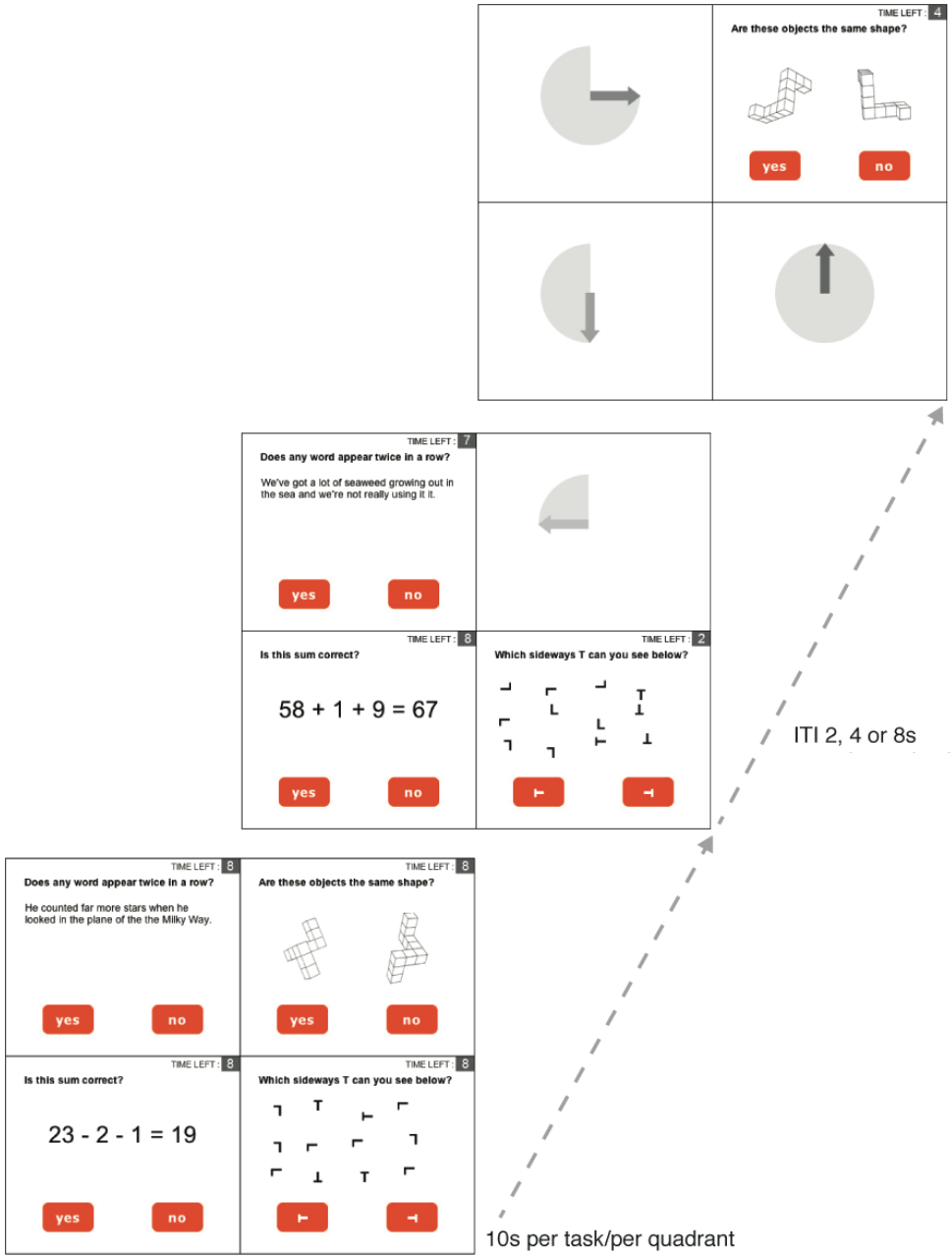

Dux et al., *in prep*

“Everyday” Training Benefits?

- Final sample ~2000, challenges of the approach
- Very rich data set

Dux et al., *in prep*

Overall Multitasking Reaction Time

	Unstandardised Coefficients		Standardised Coefficients		95% Confidence Interval for B	
Model	B	St. Error	Beta	*t*	Lower	Upper
1.						
Gender	-129.08	35.44	-0.08	-3.64**	-198.58	-59.58
Age	6.29	1.13	0.13	5.55**	4.06	8.51
Education	-10.01	10.93	-0.02	-0.92	-31.44	11.42
2.						
Gender	-130.17	35.19	-0.08	-3.73**	-199.19	-61.12
Age	5.24	1.18	0.11	4.46**	2.9	7.55
Education	-8.05	10.95	-0.02	-0.74	-29.51	13.42
STM 8	-0.65	0.75	-0.02	-0.87	-2.12	0.82
SART Com	-42.36	14.05	-0.08	-3.02**	-69.91	-14.81
SART Om	-36.65	11.13	-0.1	-3.29**	-58.48	-14.82
SART RT	0.93	0.17	0.13	5.45**	0.59	1.26
3.						
Gender	-116.2	35.4	-0.07	-3.29**	-185.84	-46.99
Age	4.18	1.22	0.09	3.42**	1.78	6.58
Education	-14.24	11.1	-0.03	-1.28	-36.02	7.53
STM 8	-0.7	0.75	-0.02	-0.94	-2.17	0.76
SART Com	-40.1	14.04	-0.08	-2.85**	-67.59	-12.52
SART Om	-35.55	11.11	-0.09	-3.2**	-57.35	-13.76
SART RT	0.93	0.17	0.13	5.5**	0.60	1.27
MMI	-1.51	0.49	-0.08	-3.1**	-2.46	-0.55

** $p < 0.005$; All models significant $Fs > 11.1$, $p < 0.001$

Each Model Significant $p<0.005$

$R = 0.21$

Dux et al., *in prep*

Overall Multitasking Accuracy

Model	Unstandardised Coefficients B	Unstandardised Coefficients St. Error	Standardised Coefficients Beta	*t*	95% Confidence Interval for B Lower	95% Confidence Interval for B Upper
1.						
Gender	-1.69	0.52	-.07	-3.2**	-2.71	-0.66
Age	-0.26	0.02	-.35	-15.49**	-0.29	-0.23
Education	2.07	0.16	.29	12.85**	1.75	2.39
2.						
Gender	-1.56	0.51	.06	-3.05**	-2.57	-0.56
Age	-0.26	0.02	-.35	-15.01**	-0.29	-0.22
Education	1.86	0.16	.26	11.69**	1.55	2.17
STM 8	0.04	0.01	.07	3.37**	0.02	0.06
SART Com	-1.05	0.2	-.13	-5.14**	-1.45	-0.65
SART Om	-0.14	0.16	-.02	-.84	-0.45	0.18
SART RT	-0.02	0.01	-.16	-6.95**	-0.02	-0.01
3.						
Gender	-1.37	.51	-.06	-2.66**	-2.38	-0.36
Age	-0.27	.02	-.37	-15.27**	-0.31	-0.24
Education	1.77	.16	.25	10.97**	1.46	2.09
STM 8	0.04	.1	.07	3.3**	0.01	0.06
SART Com	-1.01	.2	-.13	-4.97**	-1.42	-0.61
SART Om	-0.12	.16	-.02	-.75	-0.44	0.2
SART RT	-0.017	.01	-.16	-6.93**	-0.02	-0.01
MMI	-0.02	.01	-.07	-3**	-0.04	-0.01

** $p < 0.005$; All models significant $Fs > 53.3$, $p < 0.001$

Each Model Significant $p<0.005$

$R = 0.423$

Dux et al., *in prep*

“Everyday” Training Benefits?

- Everyday media-multitasking influences general multitasking performance
- High MMI correlates with faster RTs, but poorer accuracy
- Strategic effect?
- General training effect

Dux et al., *in prep*

Conclusions

- Left IFJ is key central bottleneck region
- Left IFJ plays a definitive role in sensory-motor training benefits
- General training can have different effects at different levels of information processing
- Everyday multitasking behaviour influences multitasking performance

Acknowledgements

- René Marois
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- Frank Tong
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- Jason Mattingley
- Hannah Filmer
- Robert Colvin
- Rebecca King
- Kelly Garner
- The ABC
- The ARC