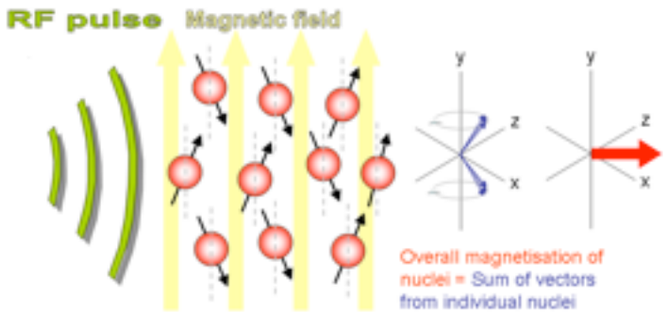
Psychophysics for fMRI

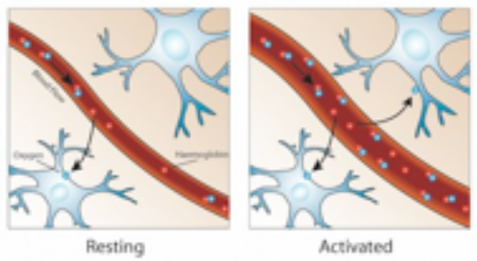
July 12, 2011

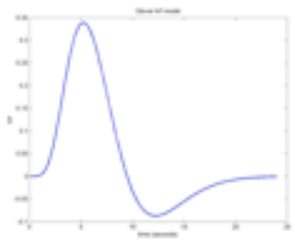
UCLA Neuroimaging Summer Course

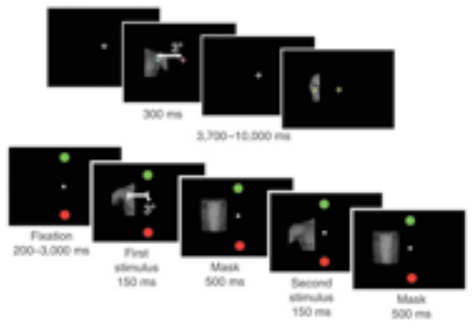
“functional MRI is difficult”

Savoy, RL (2005). Experimental design in brain activation MRI: Cautionary tales, Brain Res Bull 67, 361.





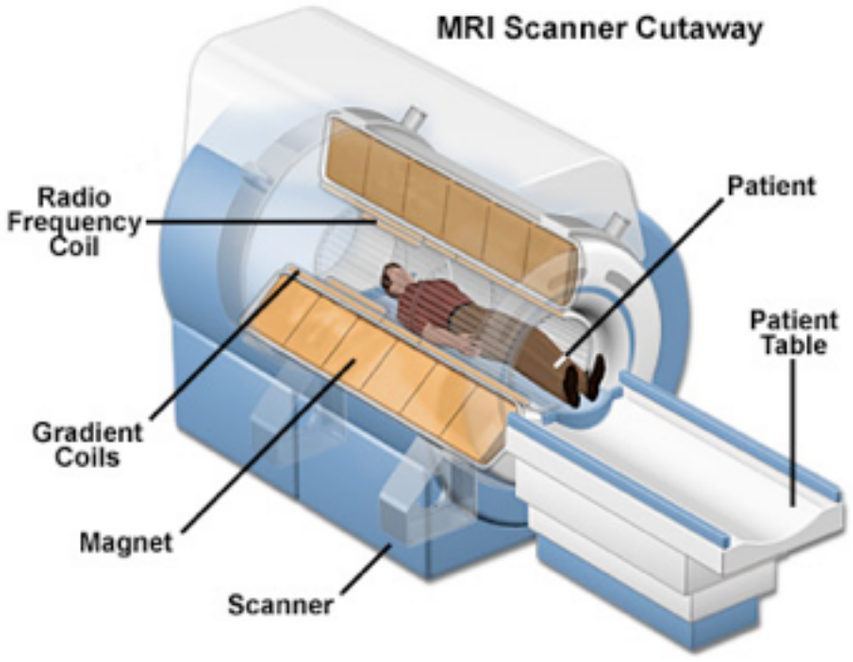




Biophysical Signal

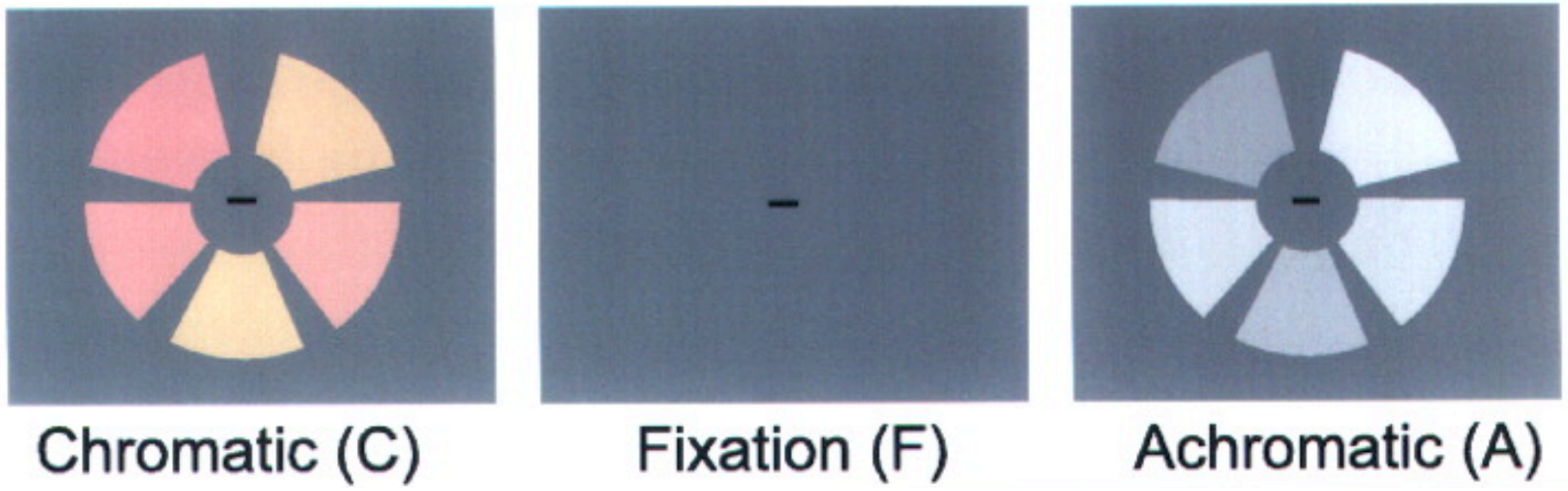
BOLD Effect

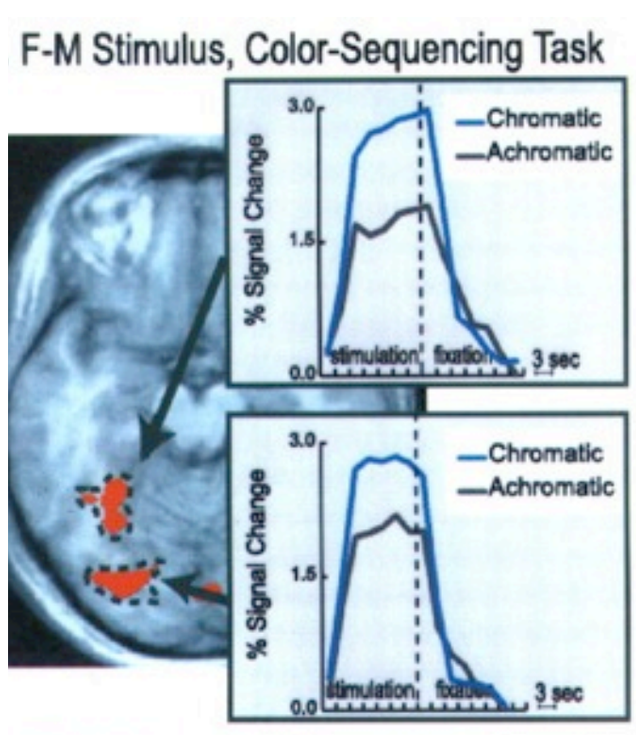
Experimental Manipulation

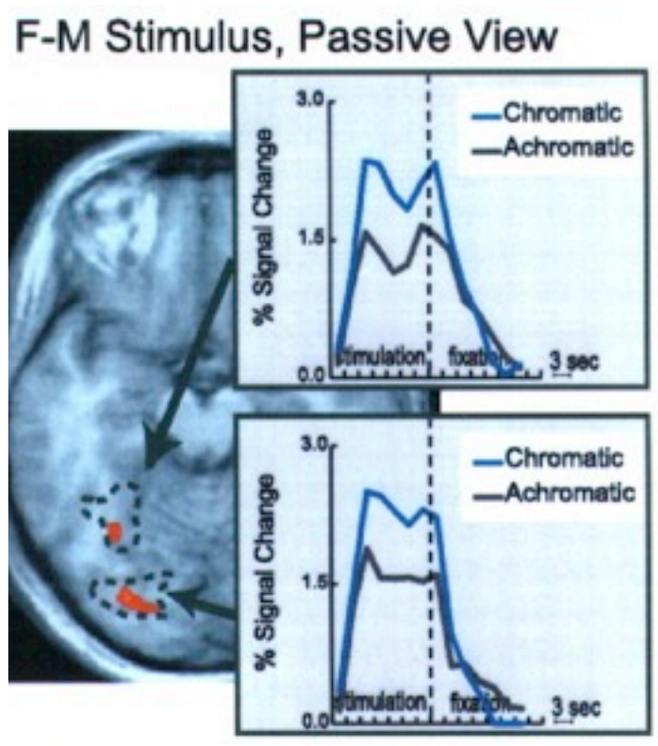


Farnsworth-Munsell Hue Test & Achromatopsia
Farnsworth (1957)

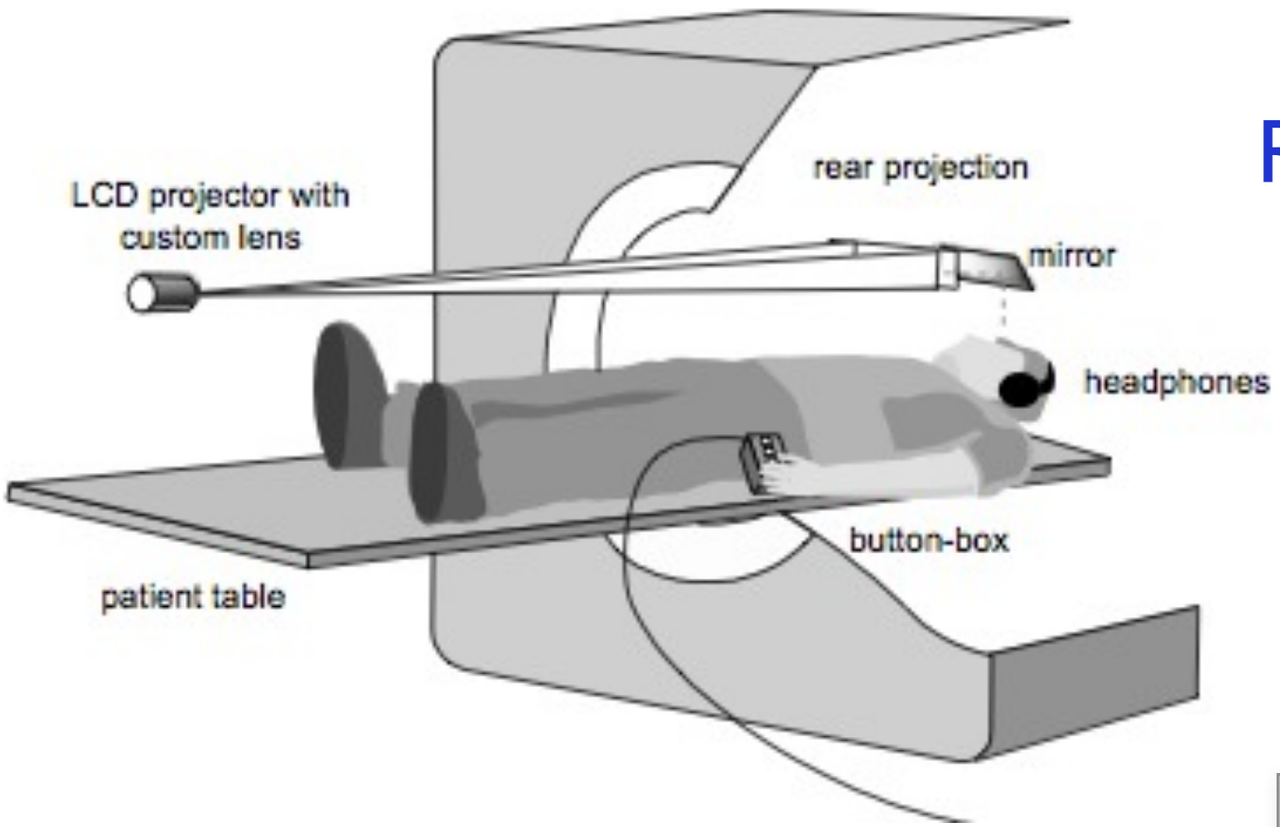
Beauchamp et al., 1999, Cerebral Cortex







Challenge in fMRI



Unique Sensory Conditions

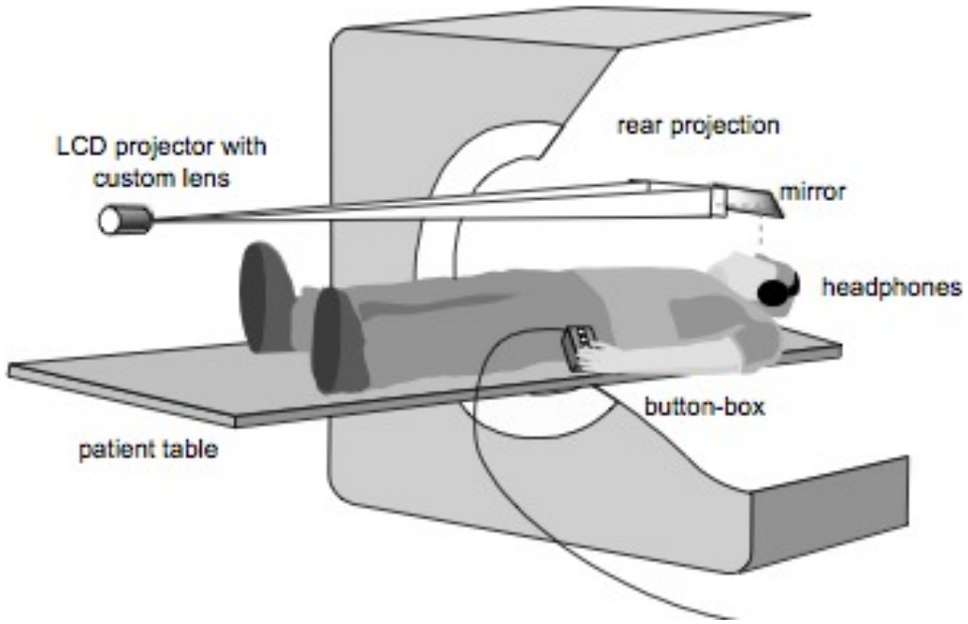
Response Collection & Motion

MRI Unique State Factors

Meaningful and
Detectable Neural Signal

"psychophysics" of fMRI

VISUAL STIMULATION



Projection Systems

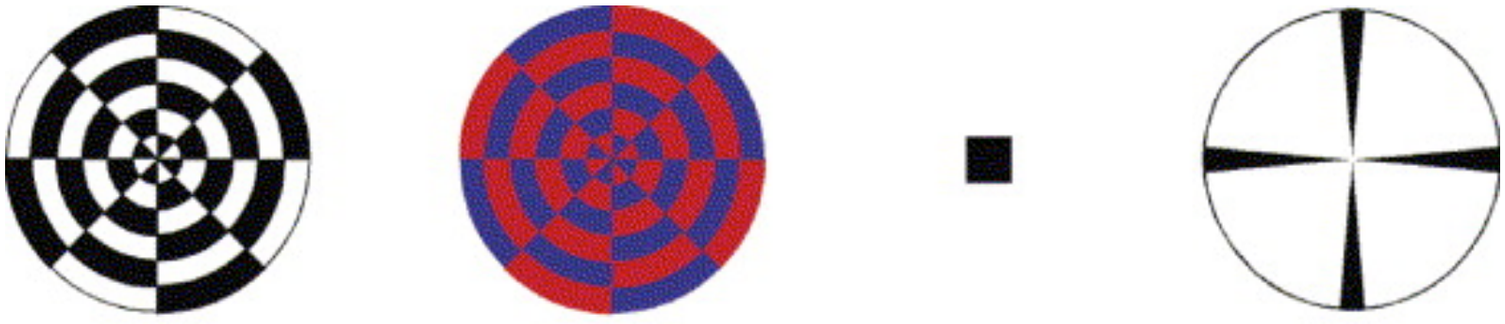
Cambridge Research Systems

Resonance Technologies Inc

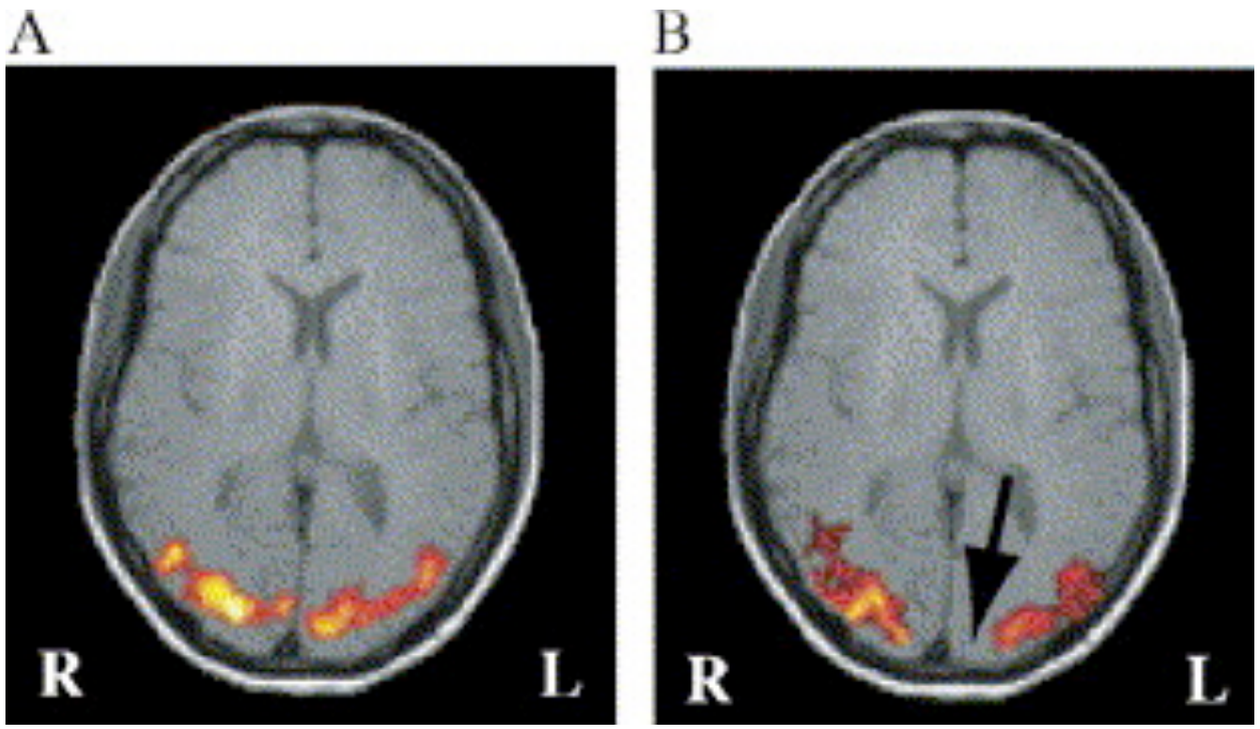
VISUAL STIMULATION

Specifications	Cambridge Research Systems	Resonance Technologies	Optoma Pico Projector
Max Resolution	1280x1024	800 x 600	1280 x 800
Contrast Ratio	400:1	NA	2000:1
Displayable Colors	NA	NA	100% NTSC Color Gamut
Field of View	24-45 degree horizontal	30 degree horizontal	Varies (5” to 66” diag proj size)
Refresh Rate	60 Hz	up to 85Hz	60 Hz
Eye-Tracking	Yes (250 Hz)	Yes (??)	No

VISUAL STIMULATION



1 2 3 4



Goggles (Res Tech) vs. Projection

Engström et al., (2005) MRI, 23 (5). 695-699

VISUAL STIMULATION

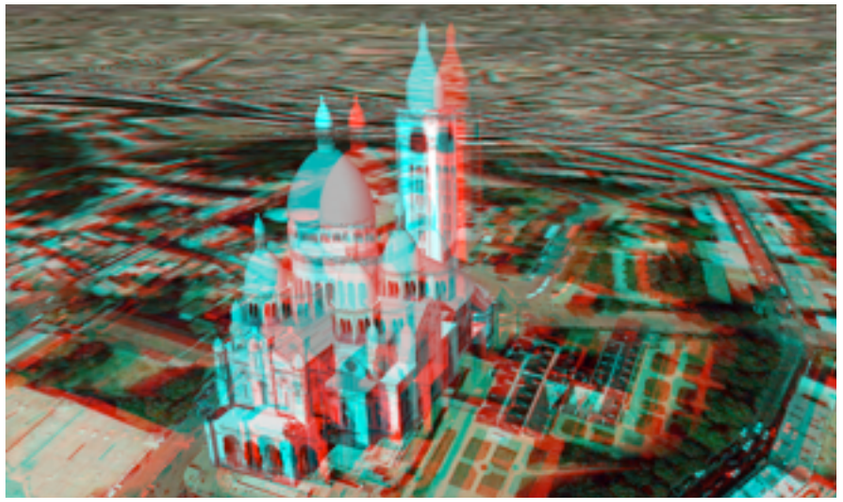
"...the image quality of the goggle system is not nearly as good as that of the flat panel display. The resolution is lower (800x600), the **color rendering is much poorer**, the **gamma curves are odd**, and there are some **ghosting artifacts due to the analog signals**.

The **goggles are a tight fit** in the head coils. To get them in, first position the subject with the coil slid back out of the way. Then, position the goggles in the coil and slide the coil and goggles together over the subject's face. Note that for some subjects with large heads, the goggles might not fit comfortably in the 32-channel coil."

* or with additional hardware present, like EEG caps *

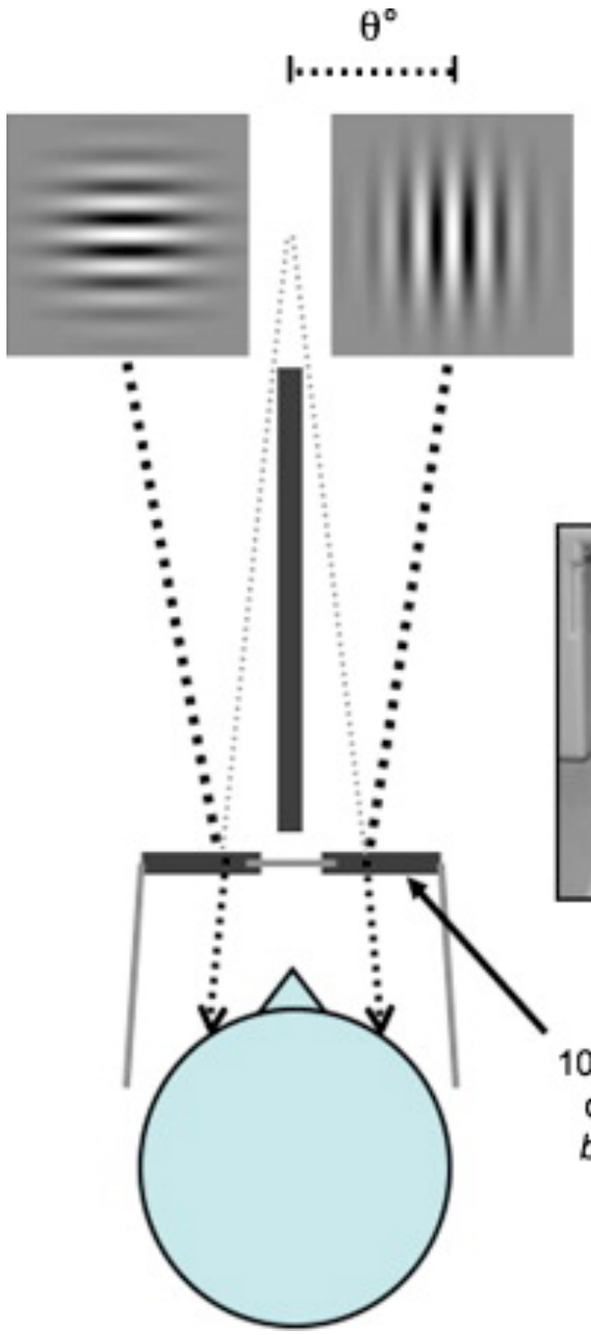
http://cniweb.stanford.edu/wiki/MR_Hardware

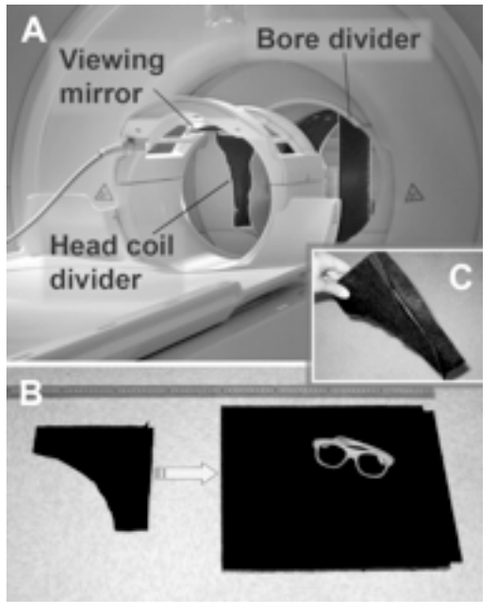
VISUAL STIMULATION



Stereoscopic presentation is implemented in both goggle systems.

Schurger, (2009) J Neuro Methods, 177 (1). 199-202





VISUAL STIMULATION

Renshaw and his tachistoscope

Temporal resolution either projections system is > 10 ms
(50-60 Hz vs. 85 Hz | 17-20 ms vs. 11 ms).

If your aim is to do a priming study (attention blink, RSVP) with 5 ms tachistoscopic stimulus presentation, you will have to build your own MRI compatible system.

VISUAL STIMULATION

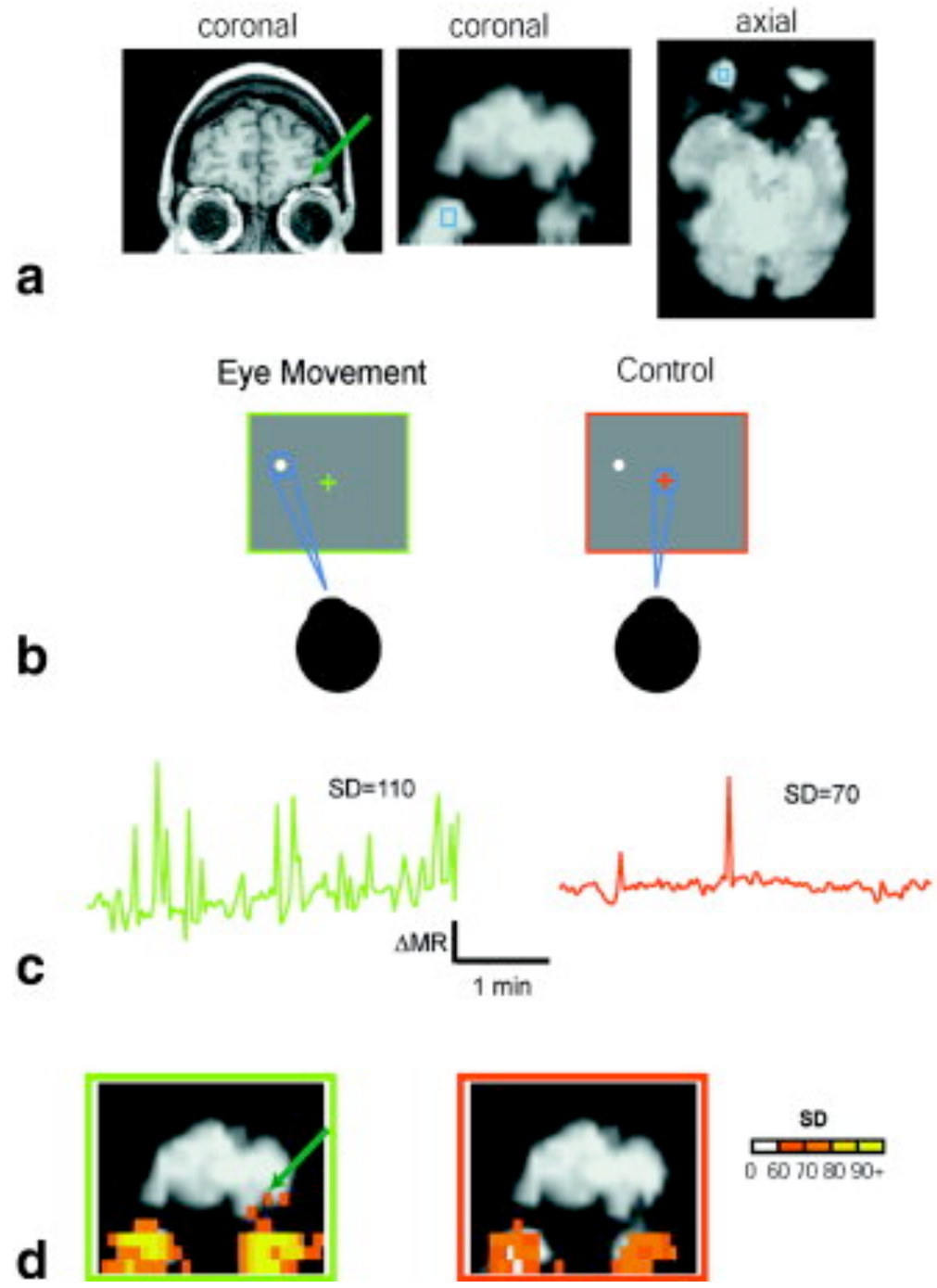
In general the visual environment is well within your control in MRI. Your choice of presentation system is a matter of practicality and/or need to control visual parameters.

However, the visual response will interact with your measured BOLD signal.

VISUAL STIMULATION: Unwanted effects?

Visual stimulation elicits neural activity, as do eye movements, introducing potential confounds into the experiment.

* variability in surrounding signal
* condition difference effects



Beauchamp, 2003

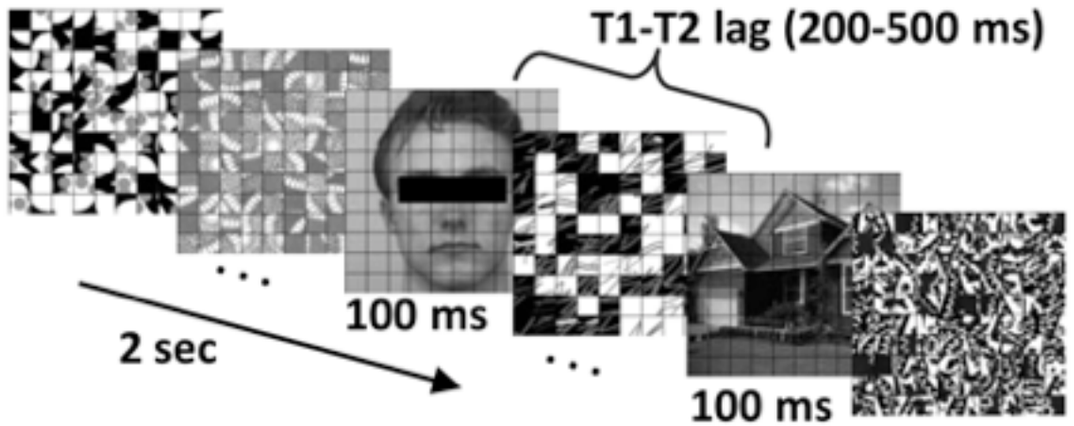
VISUAL STIMULATION: Unwanted effects?

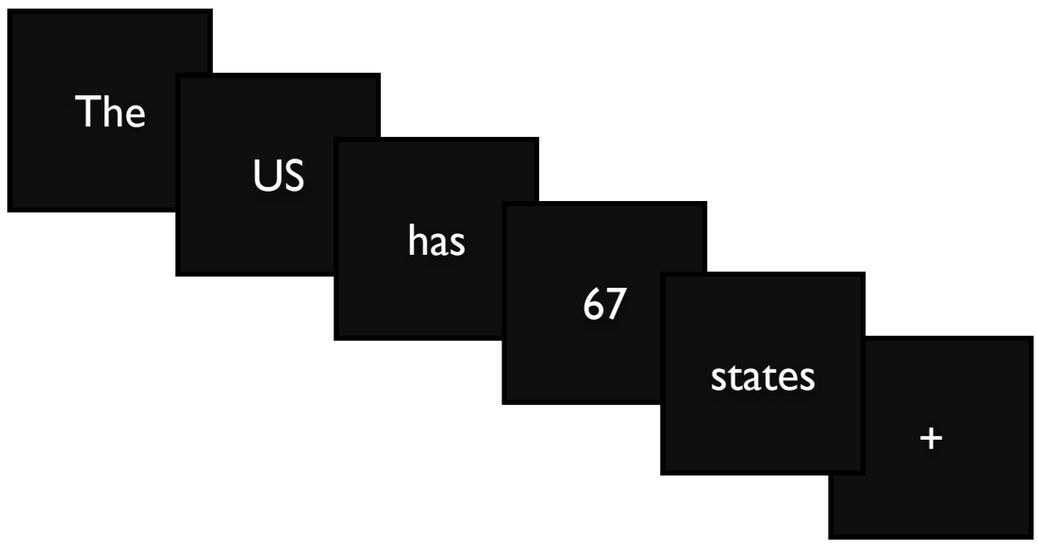
"The US has 67 states."
True or False

"My hair is blonde."
True or False

etc.

Lim et al, (2009), PNAS 106(39)





Harris et al., (2008). Annals of Neurology 63 (2)

VISUAL STIMULATION: Unwanted effects?

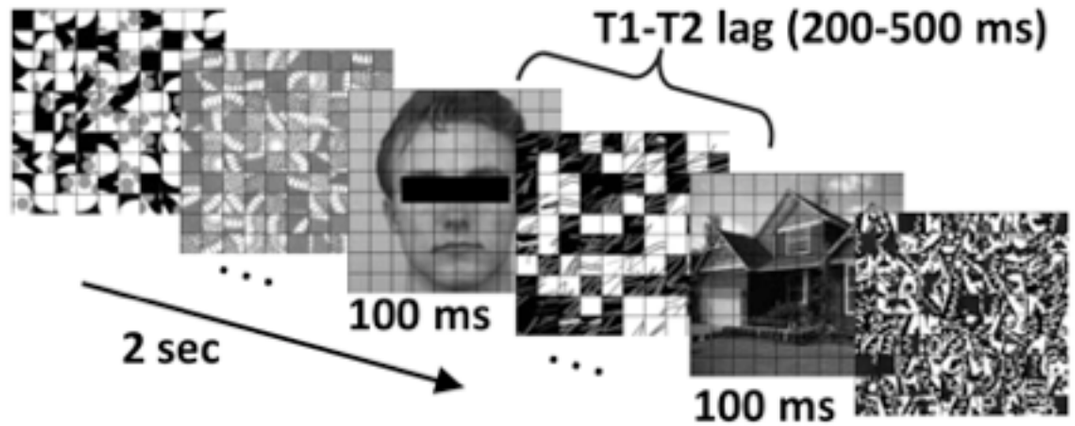
The CASE of READING & RSVP

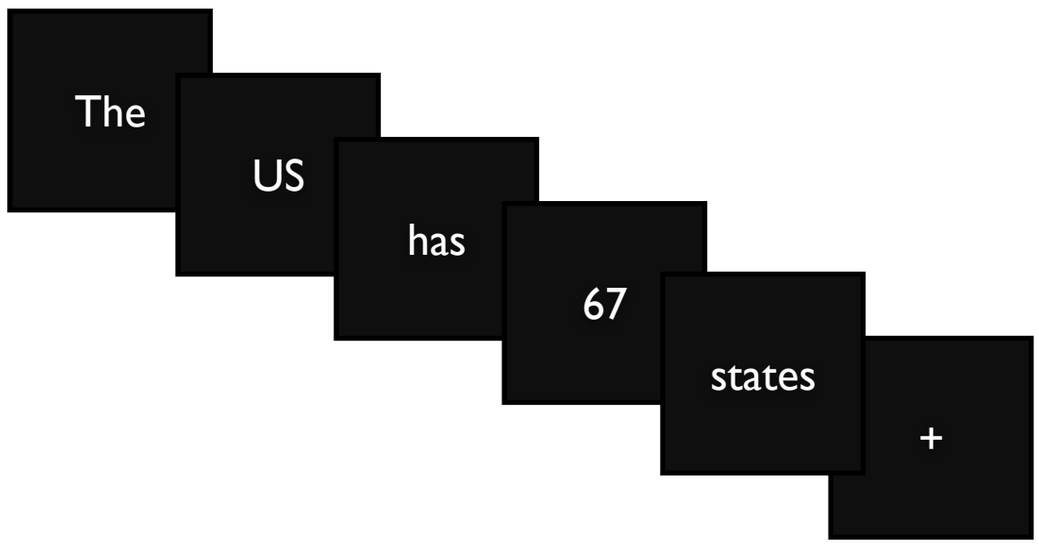
"The US has 67 states."
True or False

"My hair is blonde."
True or False

etc.

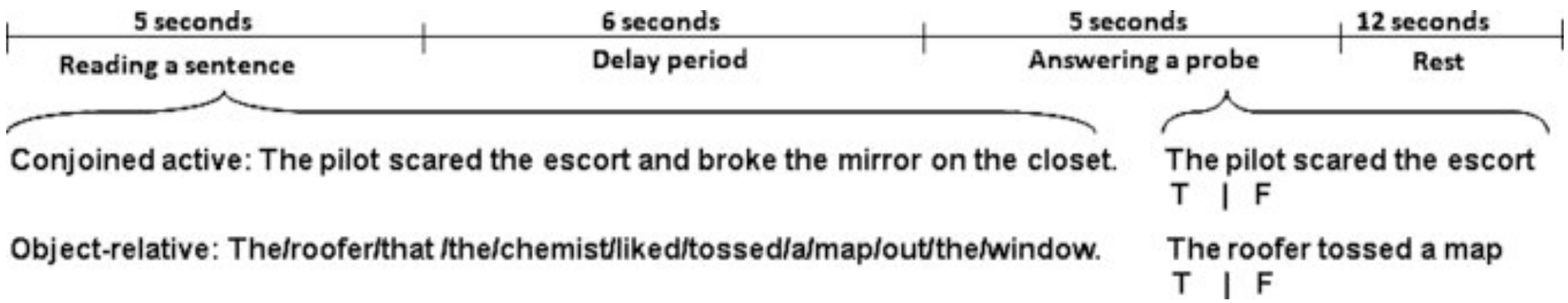
Lim et al, (2009), PNAS 106(39)

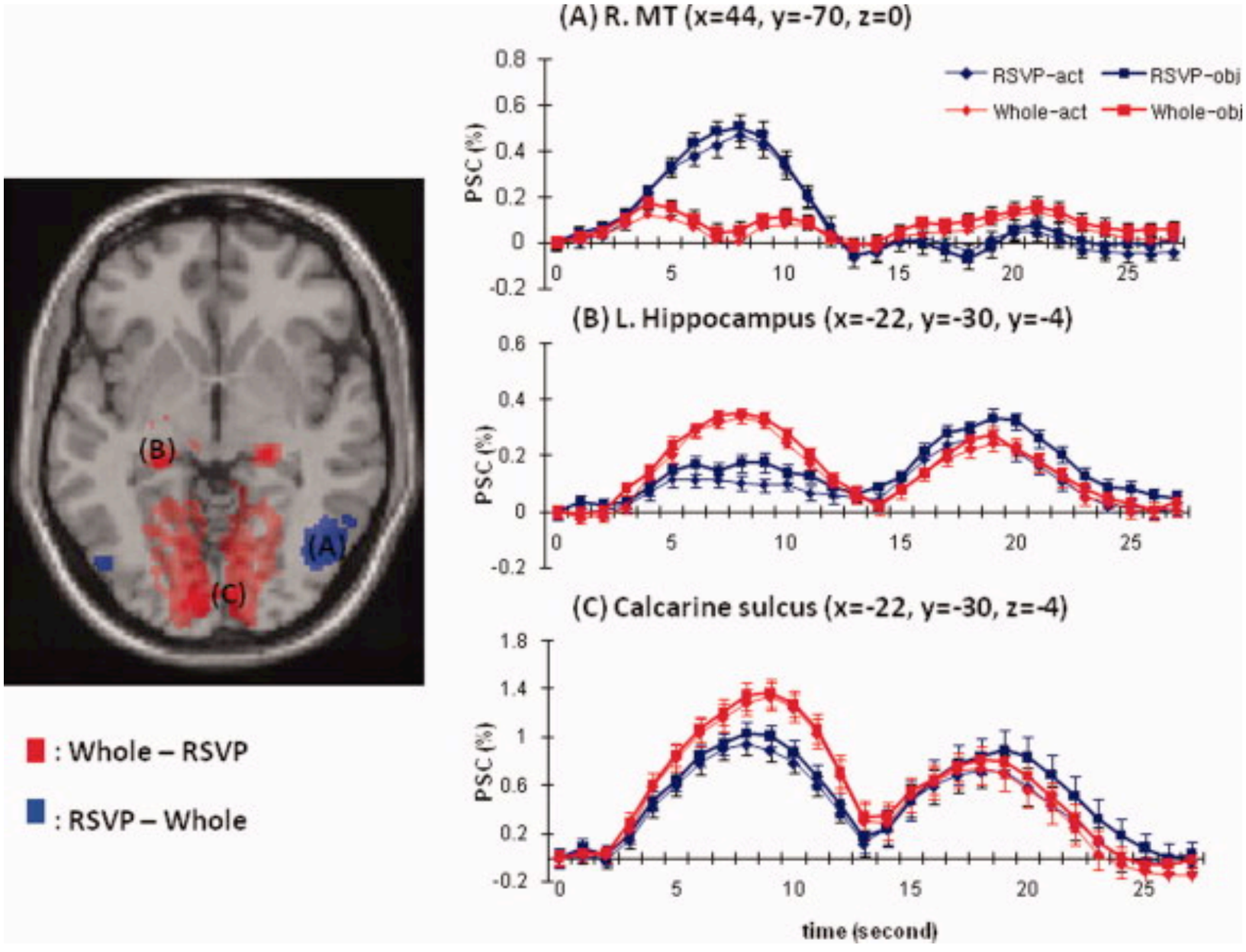




Harris et al., (2008). Annals of Neurology 63 (2)

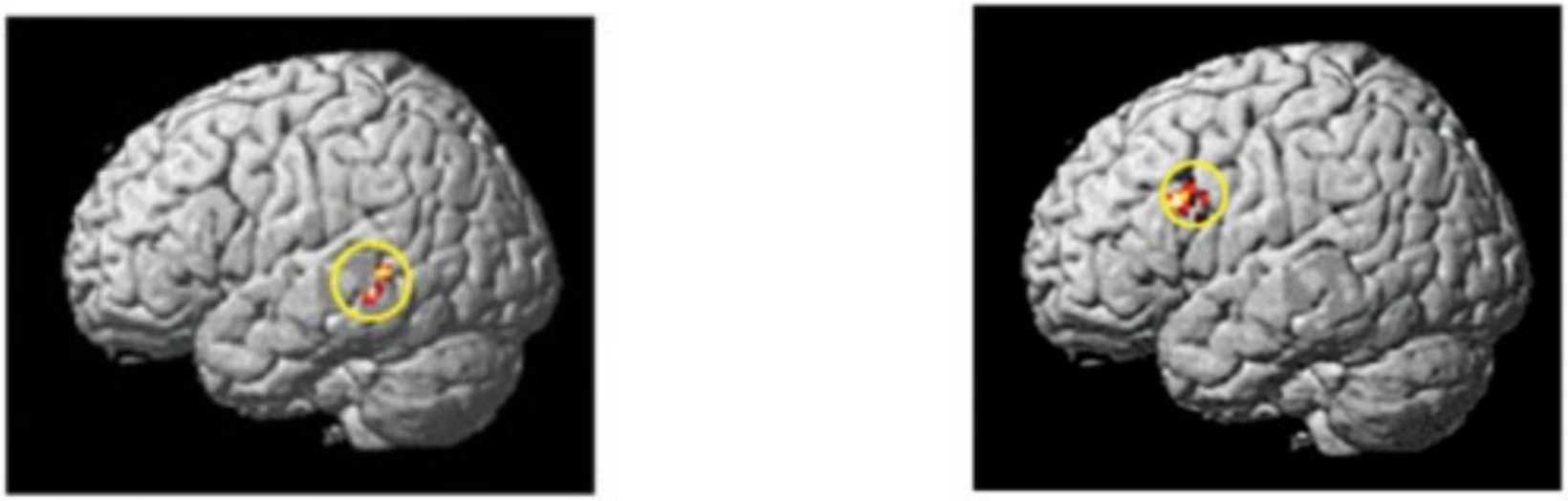
Lee & Newman (2010), HBM 31(1), 65-79



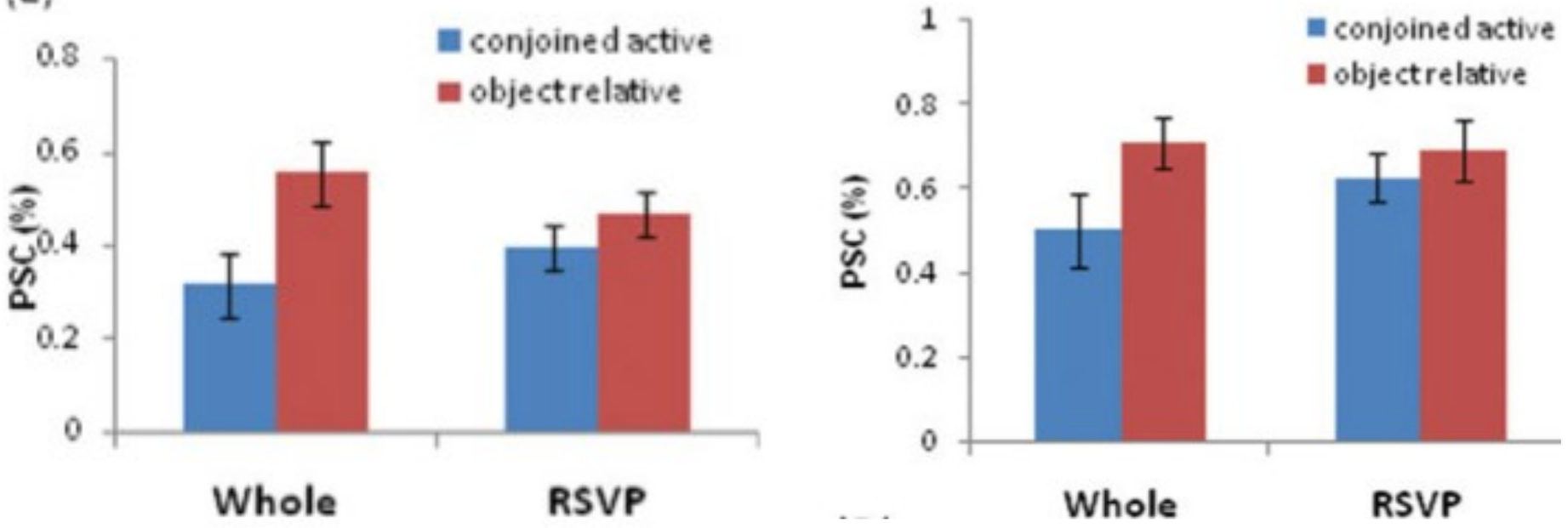


Lee & Newman (2010), HBM 31(1), 65-79

(D)



(E)

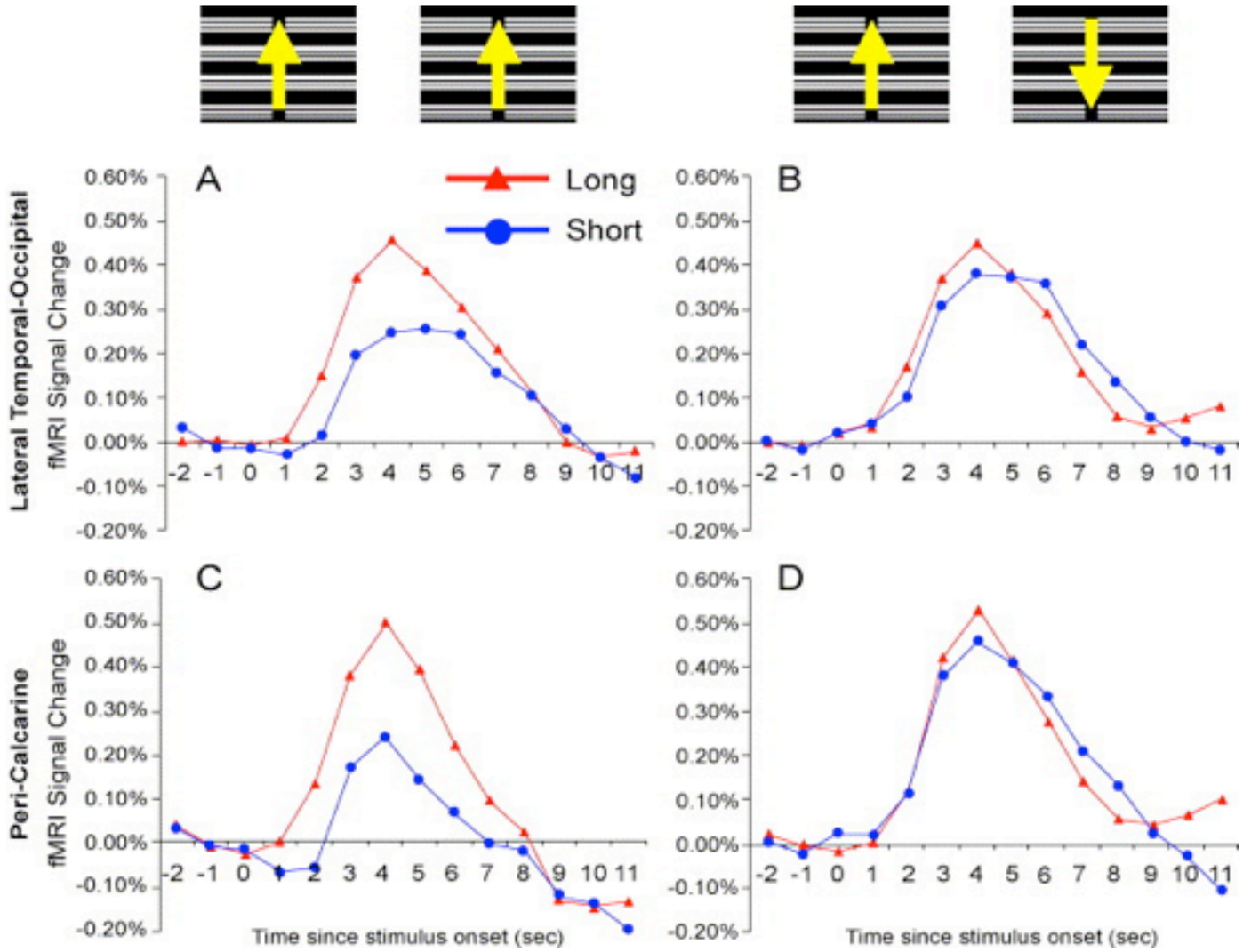


RSVP creates a unique psychological state that may be different than what you intended to measure, suggesting a trade-off between eye-movement control and psychophysical experience.

VISUAL STIMULATION: Unwanted effects?

Visual stimulation elicits neural activity, that adapts (varies) with repetitive activation.

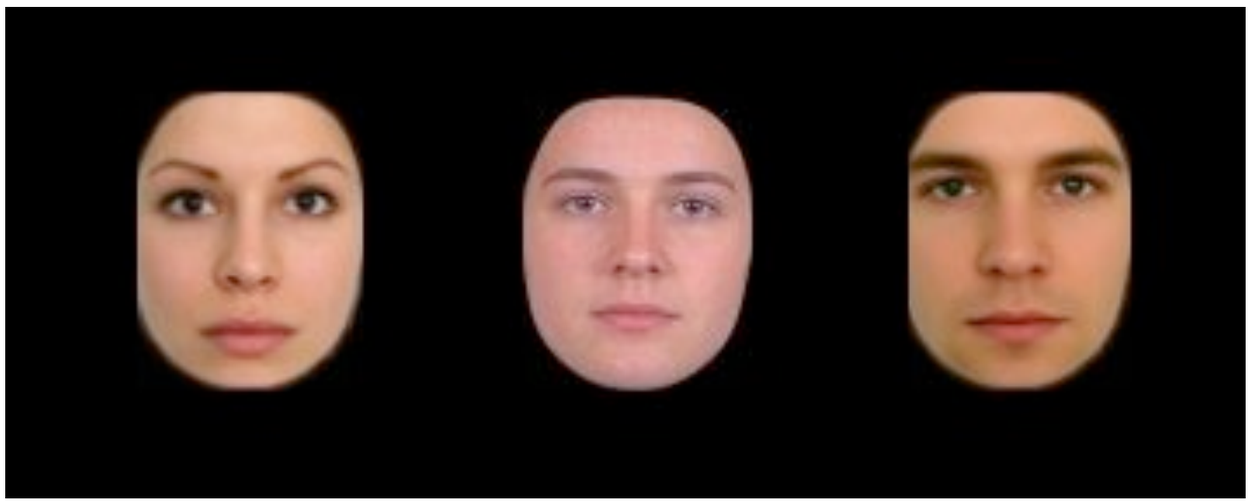
* will impact both behavior and neural response to a set of stimuli



Huettel et al., (2004), NeuroImage 23(1)

VISUAL STIMULATION: Unwanted effects?

Effect is present for more complex stimuli as well.



* to avoid the effect one can show similar stimuli at slower presentation rates, or vary the stimuli - in either case keeping this factor constant across conditions

VISUAL STIMULATION

In general the visual environment is well within your control in MRI. Your choice of presentation system is a matter of practicality and/or need to control visual parameters.

↓

In ways that may require you to readjust the psychophysical experience of your experiment.

VISUAL STIMULATION

In general the visual environment is well within your control in MRI. Your choice of presentation system is a matter of practicality and/or need to control visual parameters.

However, the visual response will interact with your measured BOLD signal.

In ways that may require you to readjust the psychophysical experience of your experiment.

AUDITORY STIMULATION

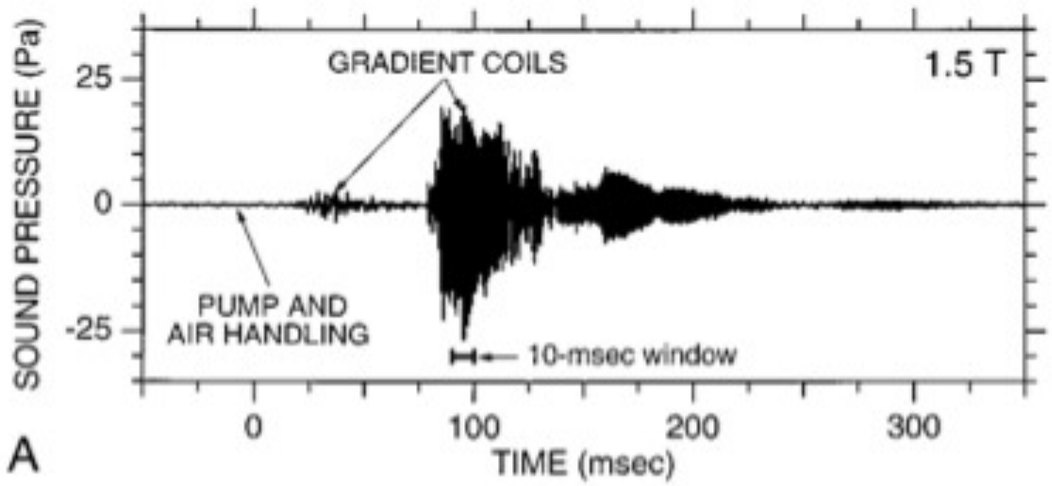
30 dB quiet whisper (library)
60-70 dB normal conversation
88 dB motorcycle
~ 100 dB MRI (EPI, Spin-Echo)
110 dB power saw

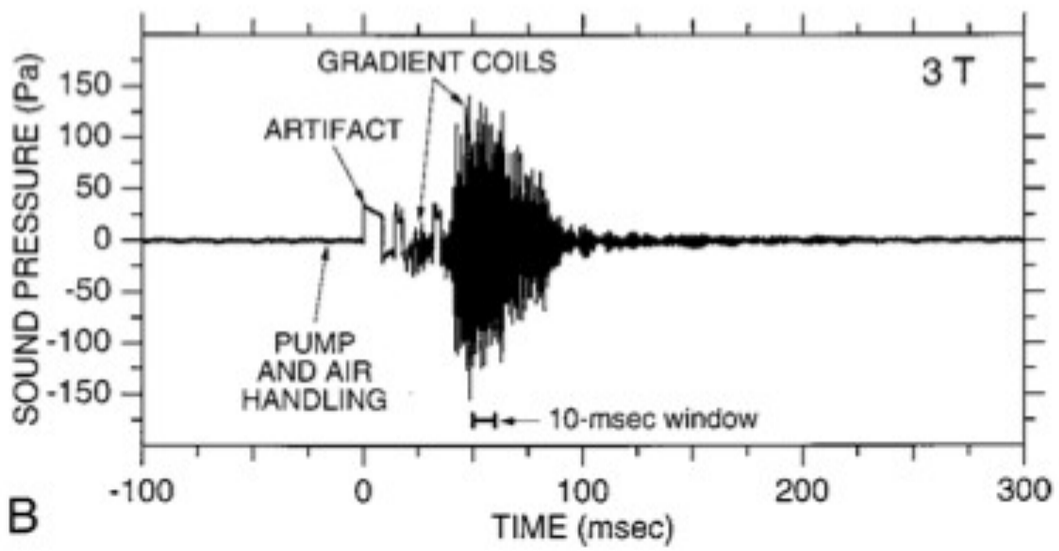
Counter et al., (1997) JMRI, 7(3)
McJury & Shellock (2000) JMRI 12

AUDITORY STIMULATION

Magnitude of Noise in 1.5T vs. 3T

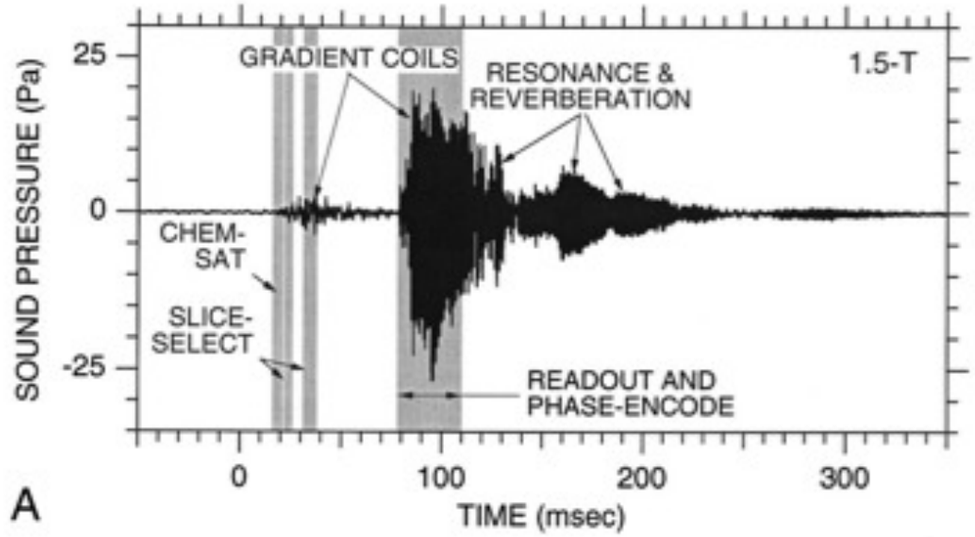
25 Pa = 122 dB

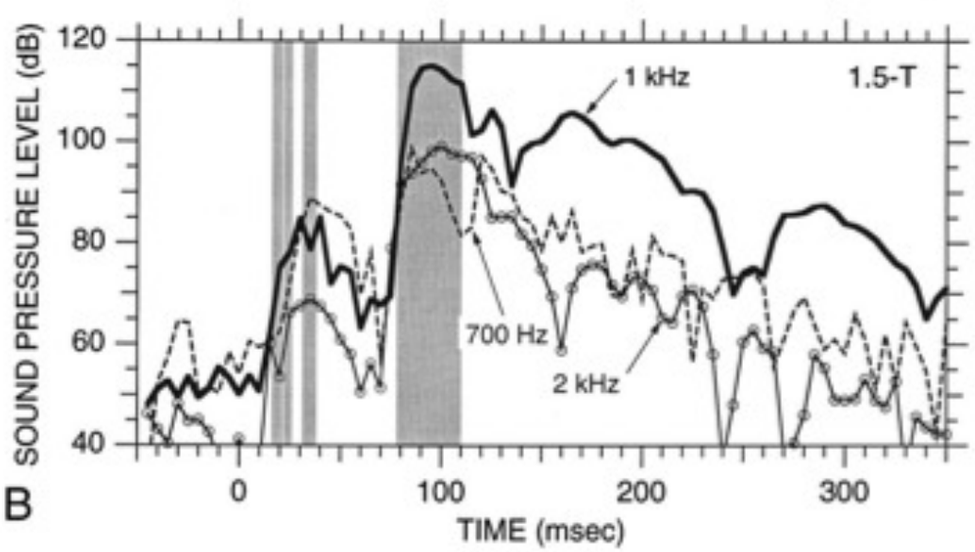




150 Pa = 137 dB

Noise Classes in 1.5T

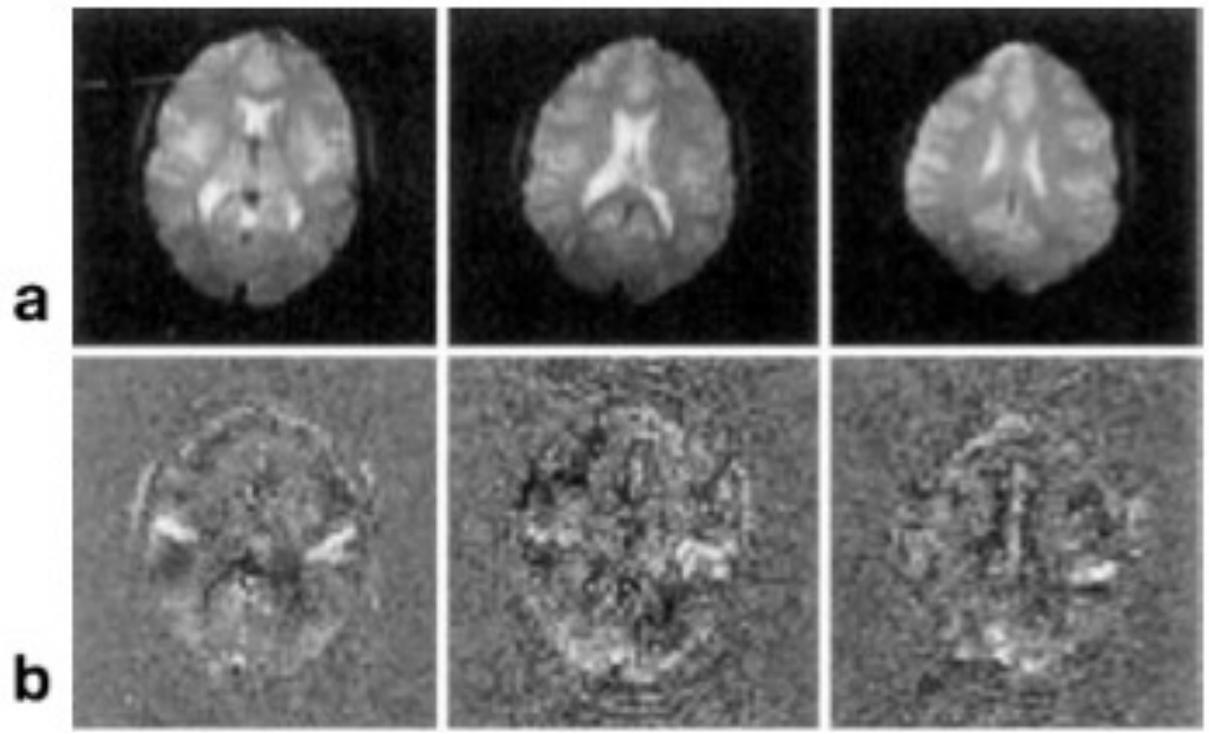


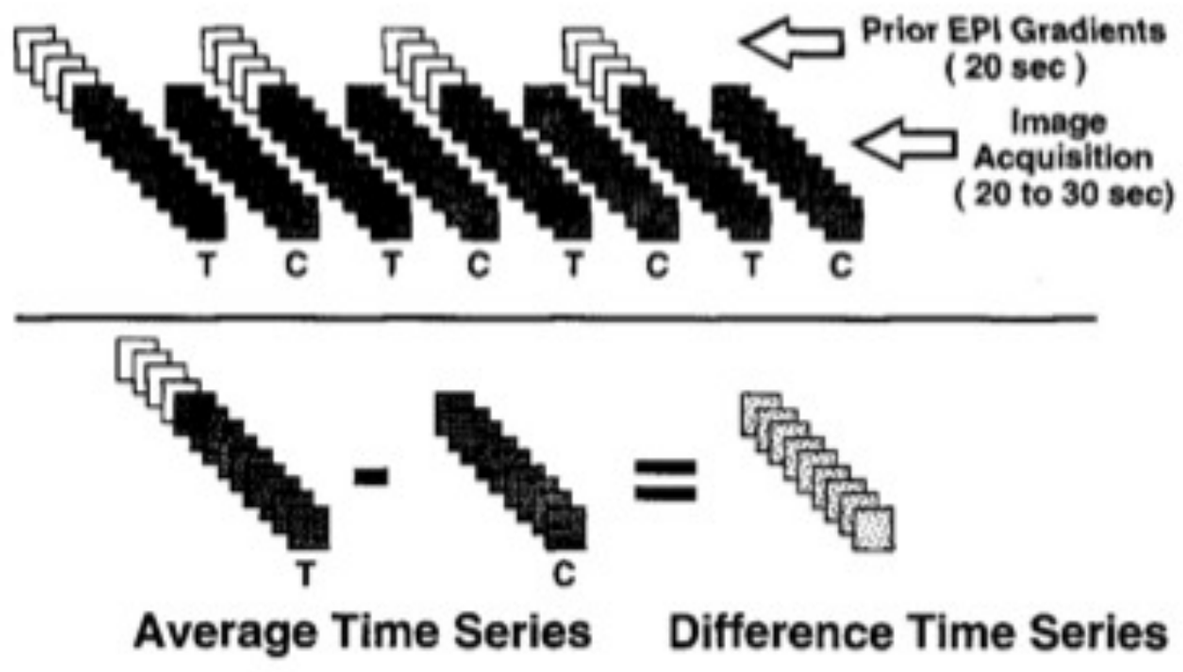


Ravicz et al., (2000), J Acoust Soc Am 108(4)

AUDITORY STIMULATION

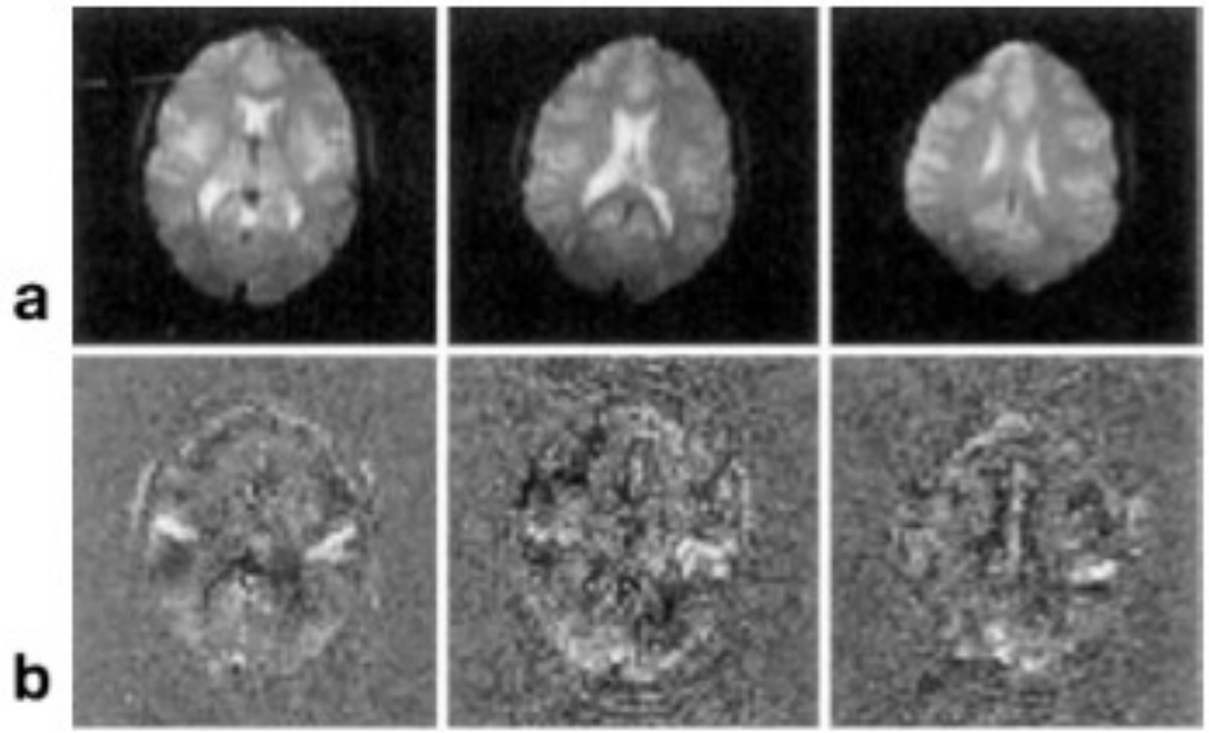
Noise elicits neural activity (Bandettini et al., 1998)



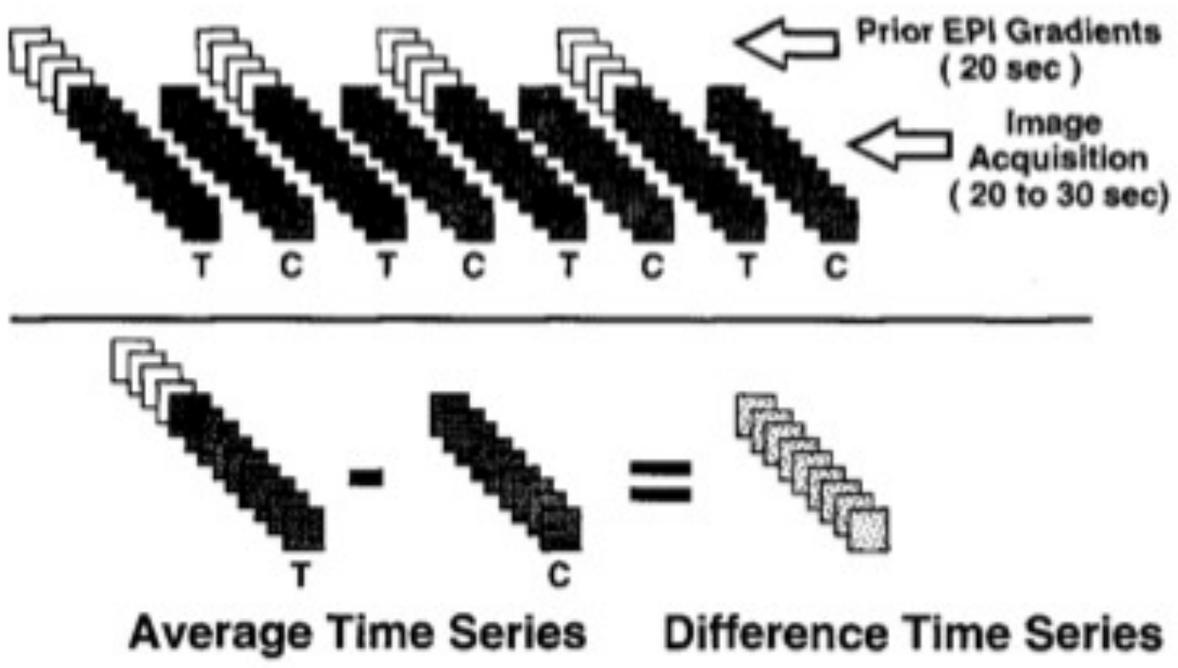


AUDITORY STIMULATION

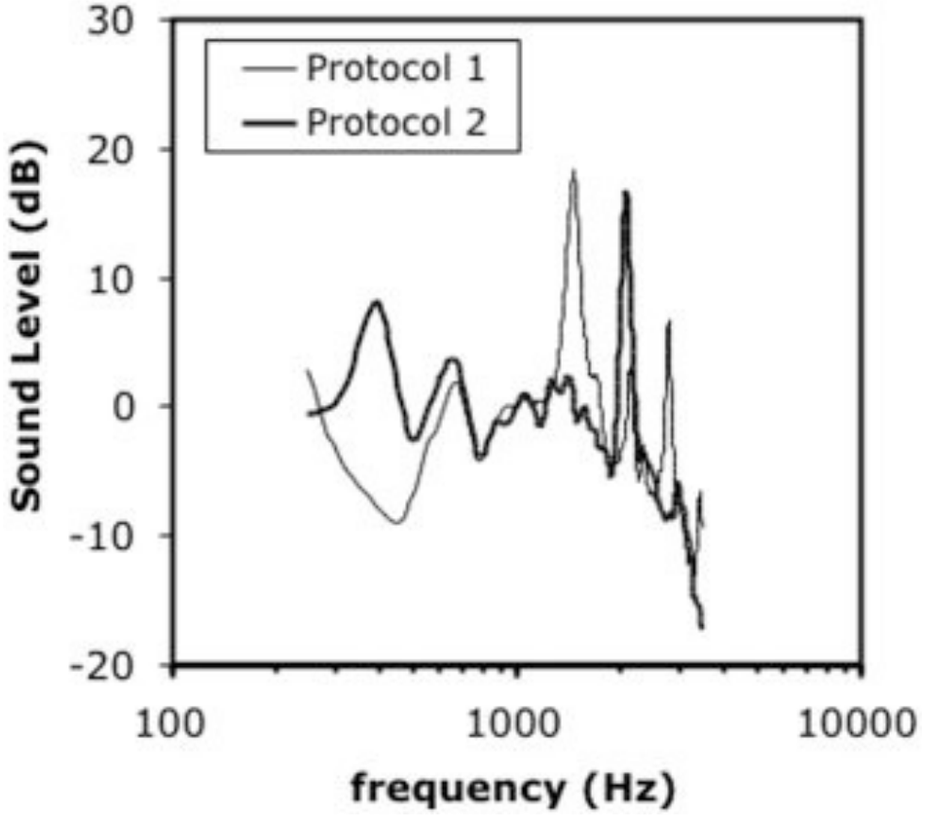
Noise elicits neural activity (Bandettini et al., 1998)



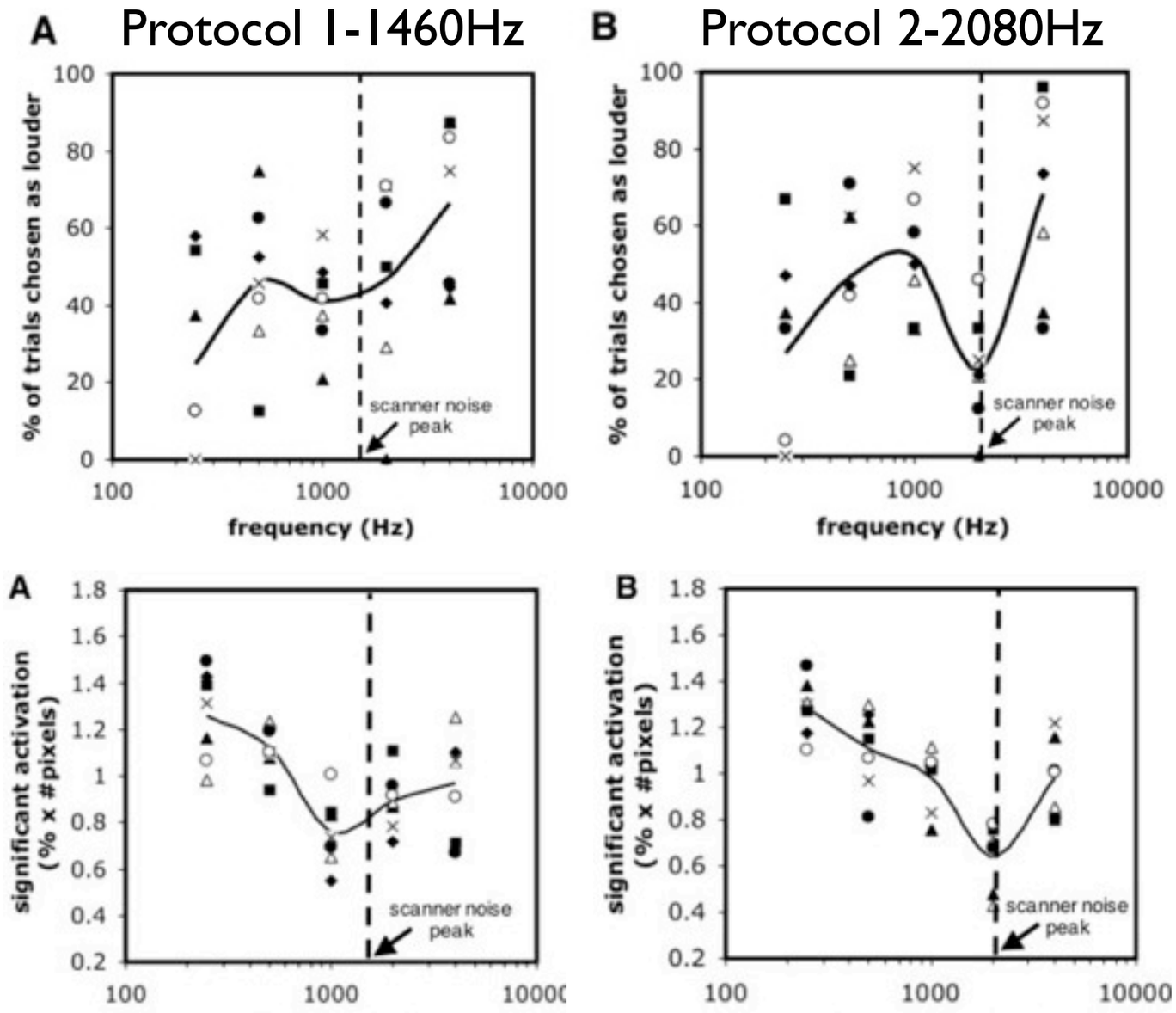
Does this noise change the participants' auditory experience in the scanner?



AUDITORY STIMULATION



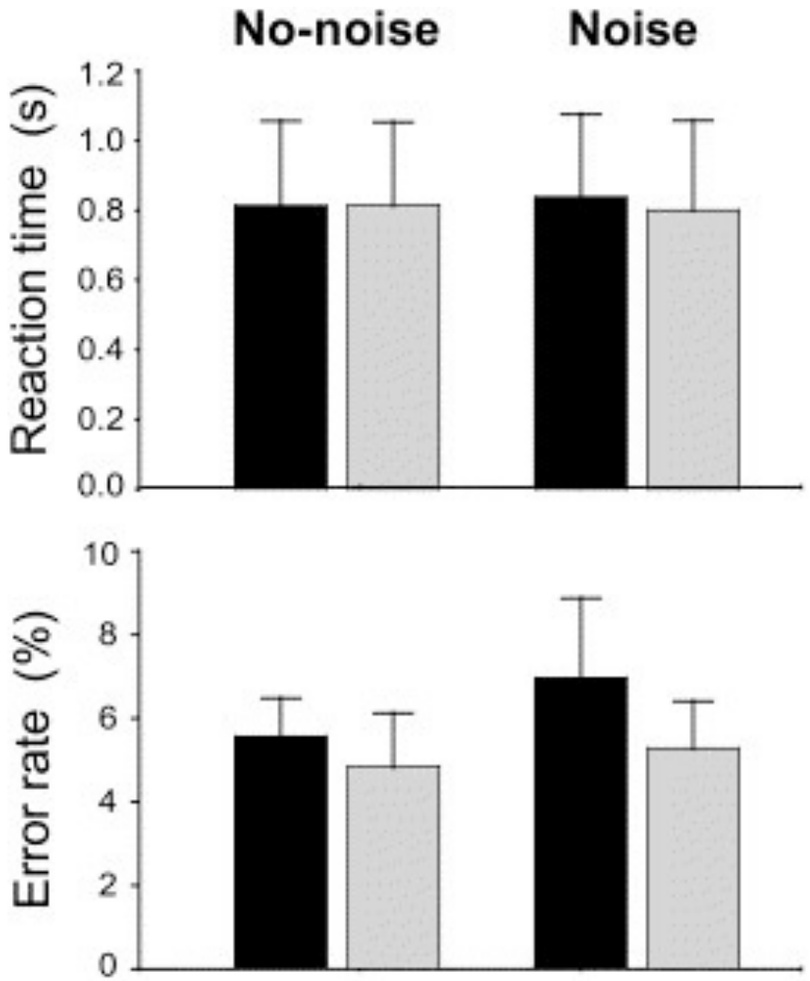
Scarff et al, (2004) HBM, 22, 341-349

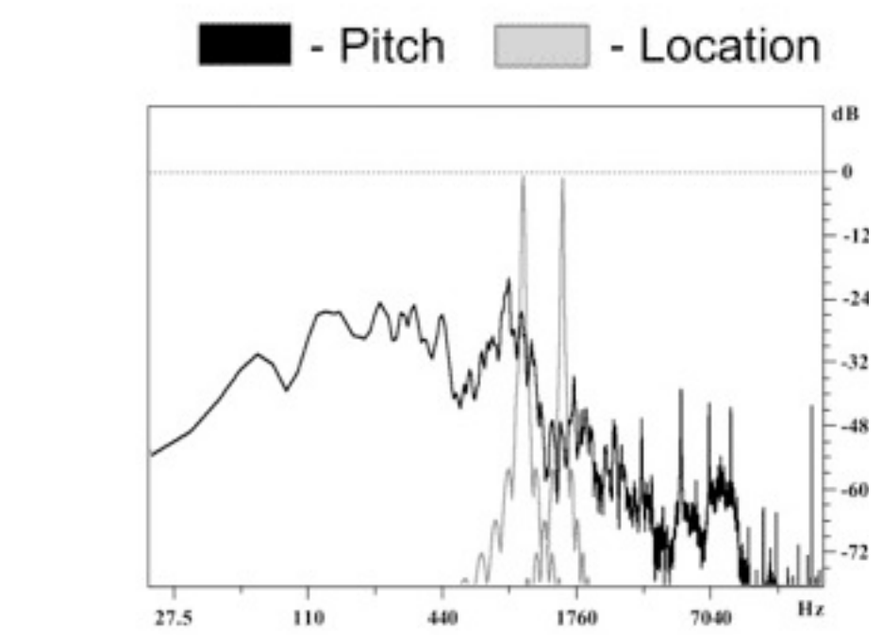


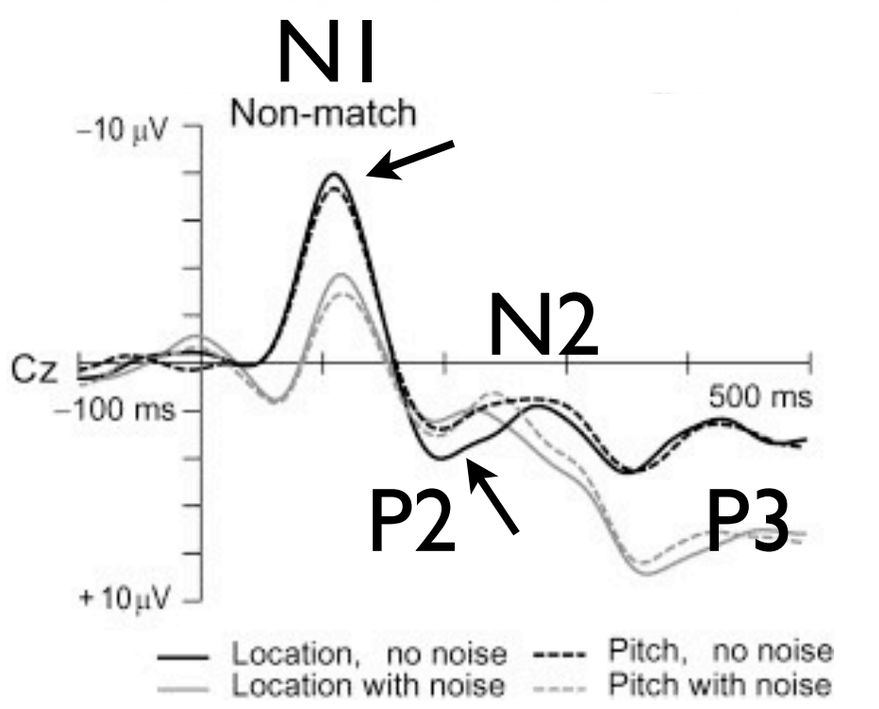
Scanner noise impairs frequency specific auditory discrimination.

AUDITORY STIMULATION

Novitski et al, (2003) NeuroImage, 20 (2), 1320-1328

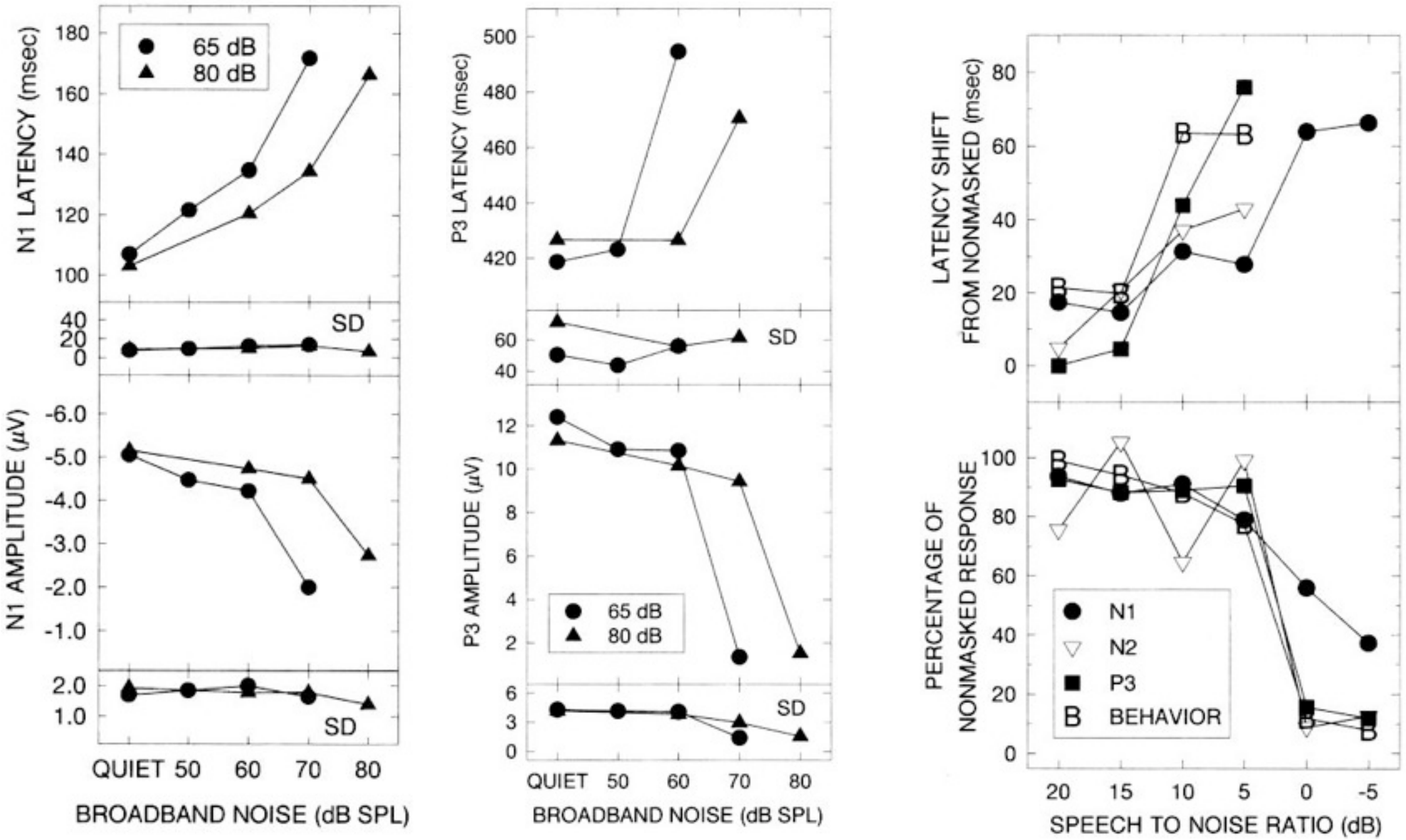






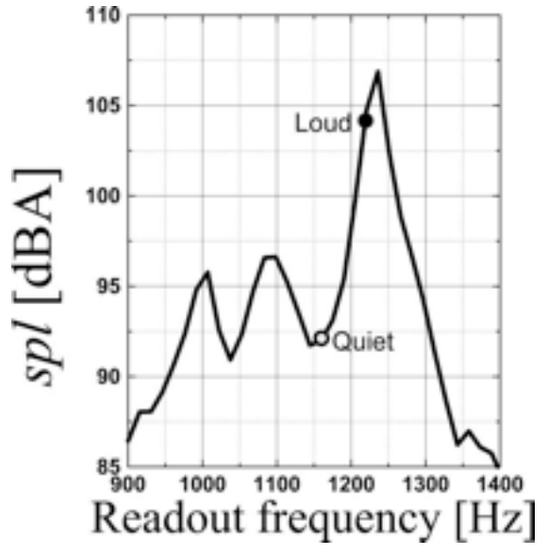
Scanner noise may change neural processing of auditory stimuli.

AUDITORY STIMULATION

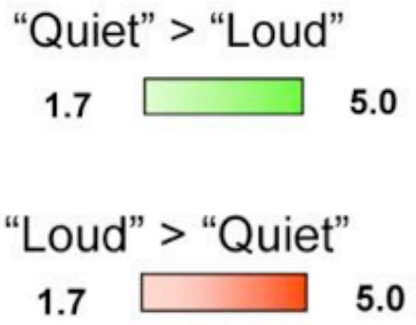


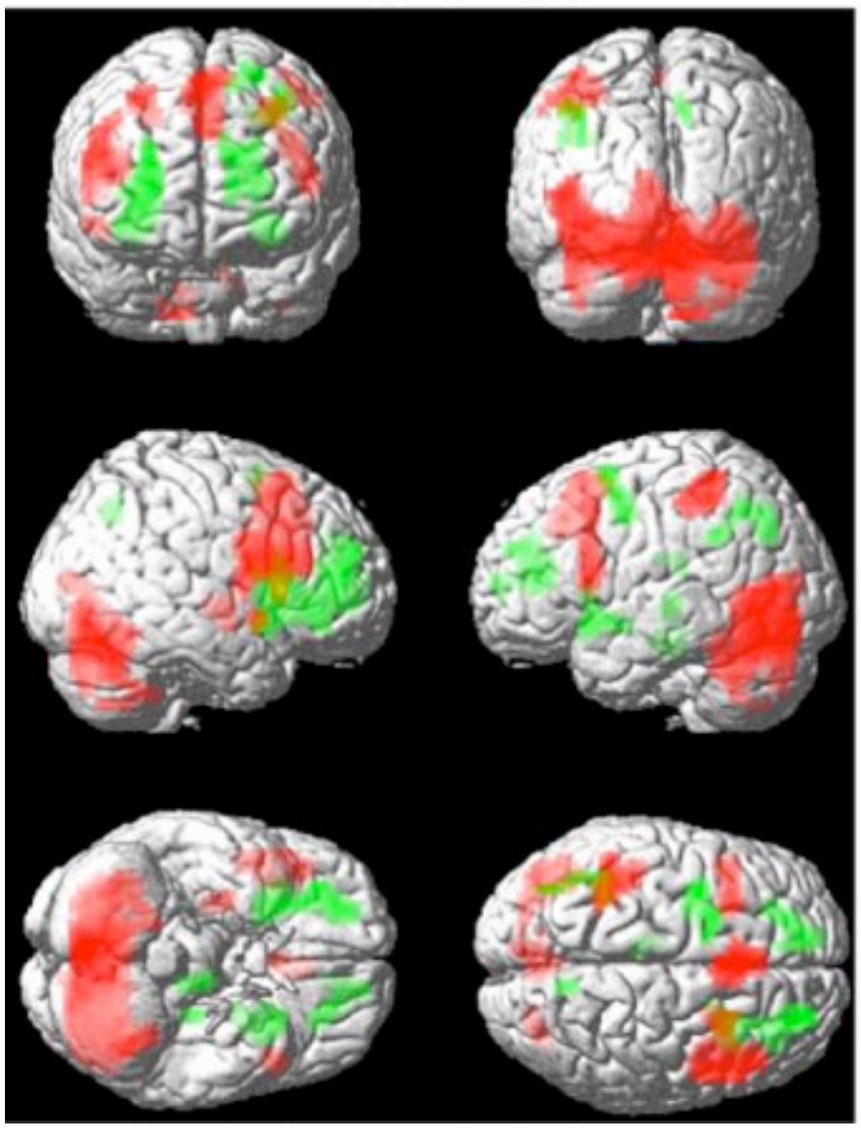
Whitting et al (1998) Ear & Hearing

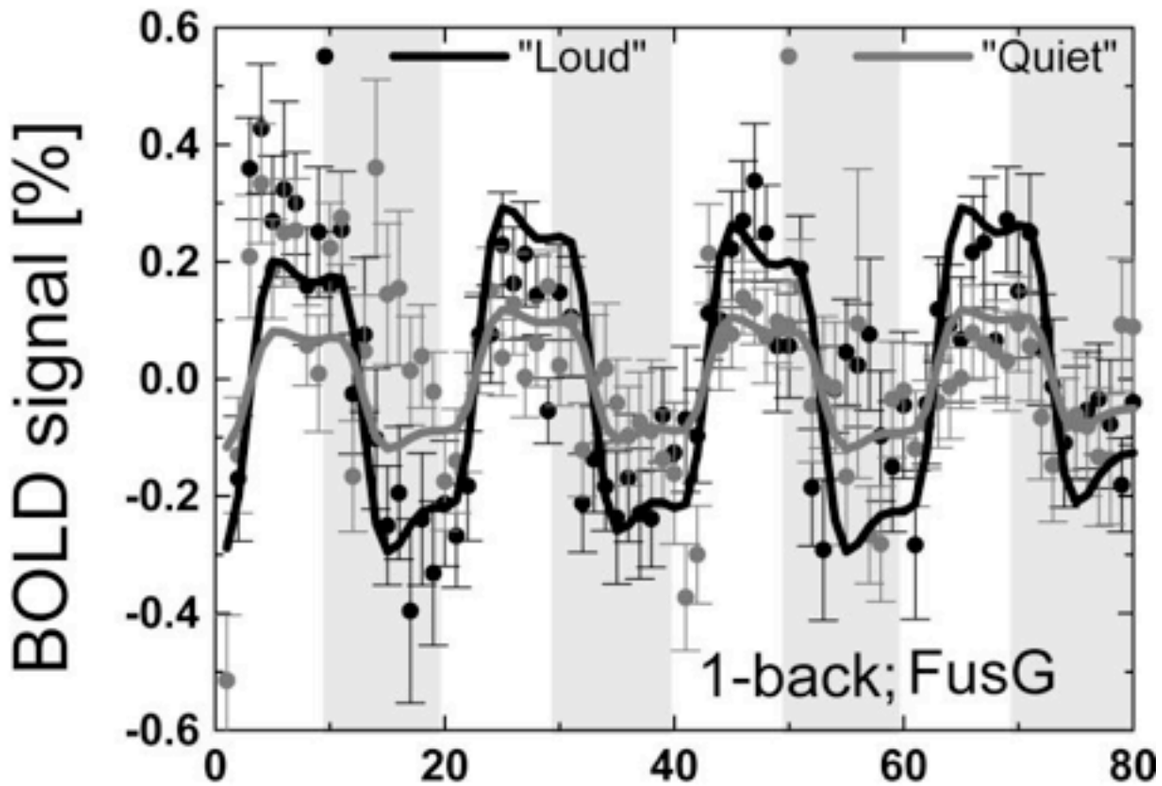
AUDITORY STIMULATION



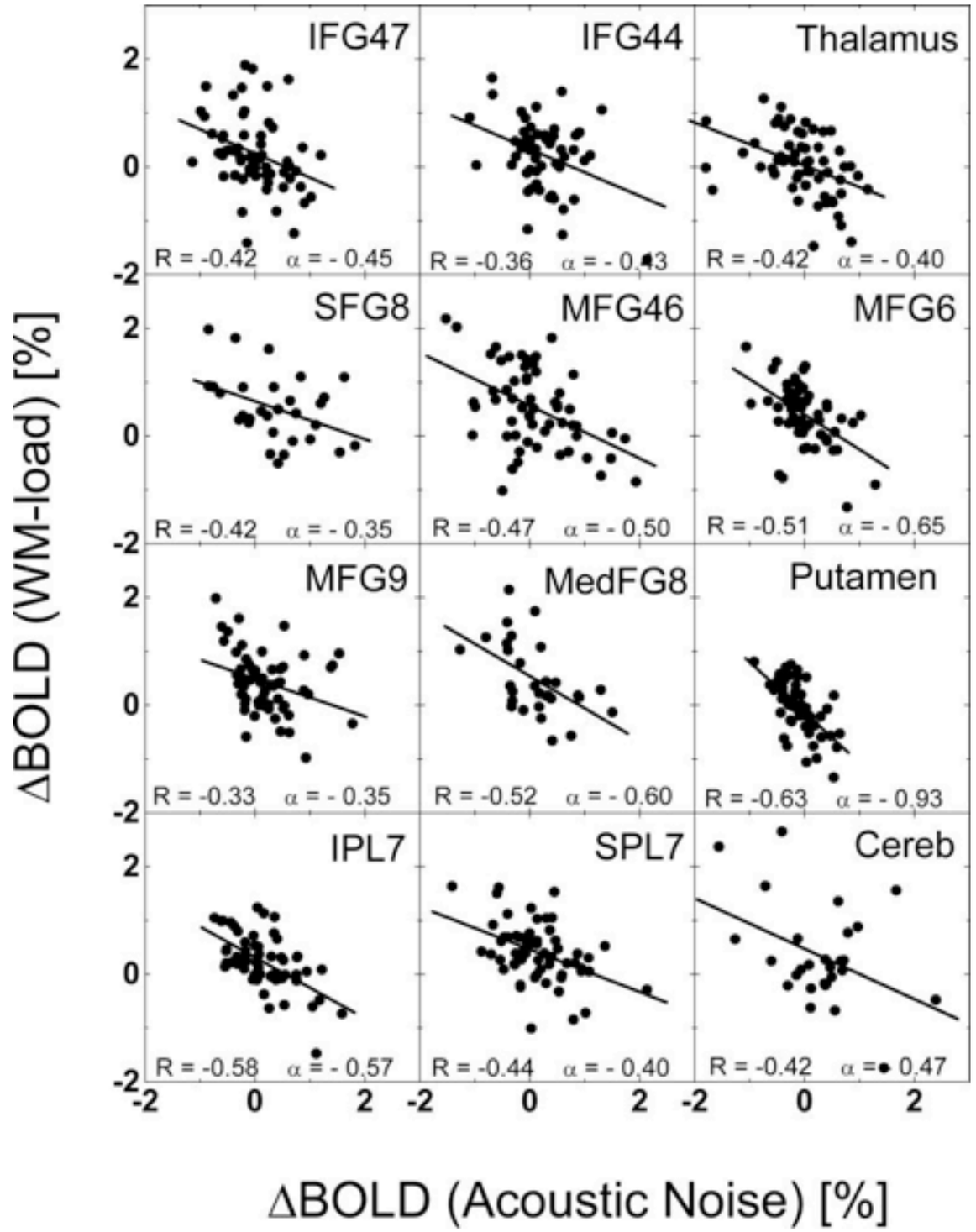
Tomasi et al., (2005), NeuroImage, 27(2).







AUDITORY STIMULATION



AUDITORY STIMULATION

Does this noise change the participants' auditory experience in the scanner?

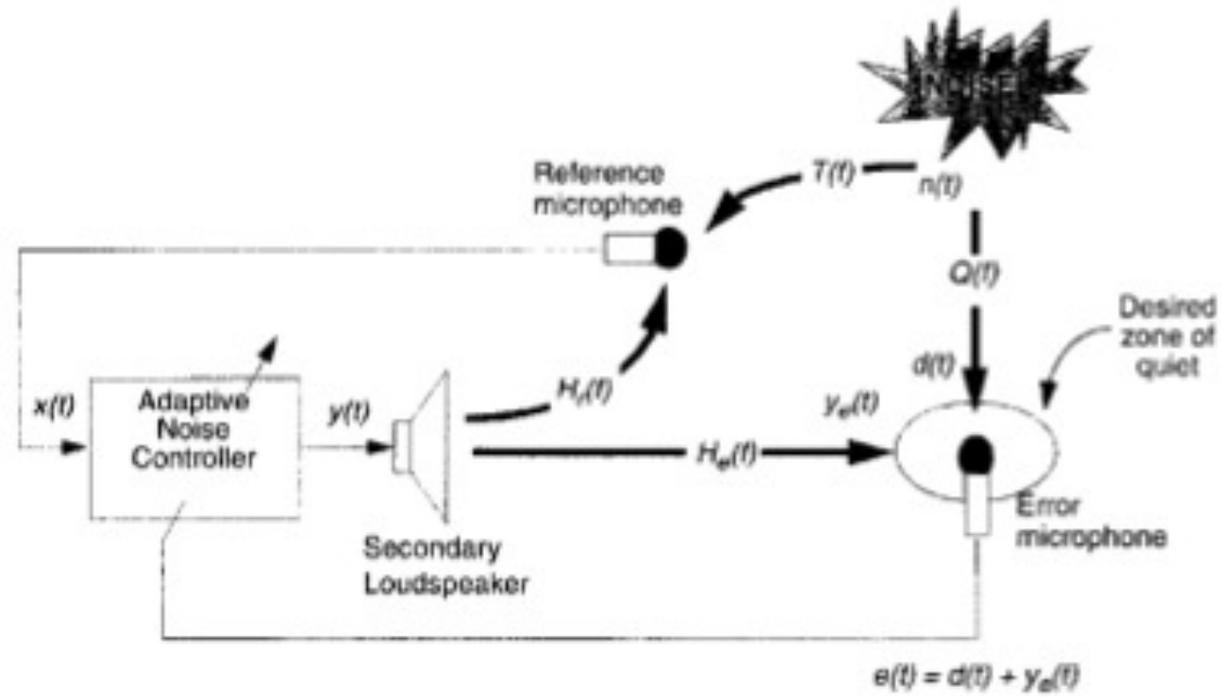
Yes, it does.

Passive attenuation (i.e., headphones + earplugs)

31-38 and 25-29 dB of attenuation respectively
38-43 dB at 1-1.4 kHz of attenuation together
foam padding around body & room ~ 30 dB attenuation

AUDITORY NOISE ATTENUATION?

1. Active Noise Attenuation (Goldman, 1989; McJury, 1997)

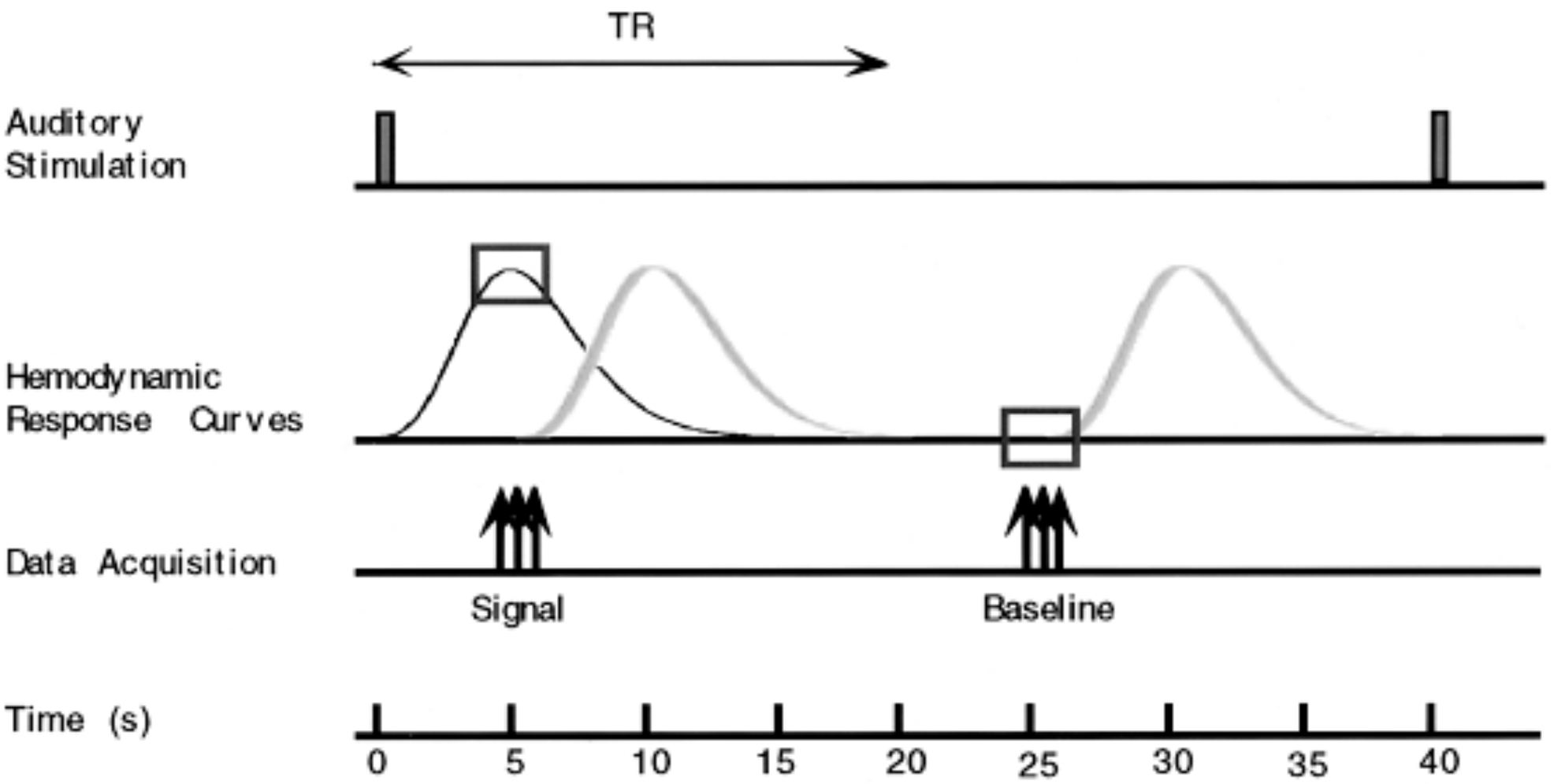


Noise is conducted through head and body!

2. Hardware Redesign (e.g., Cho, 1998 - Silent MRI)

AN ALTERNATIVE PROTOCOL for TONOTOPY

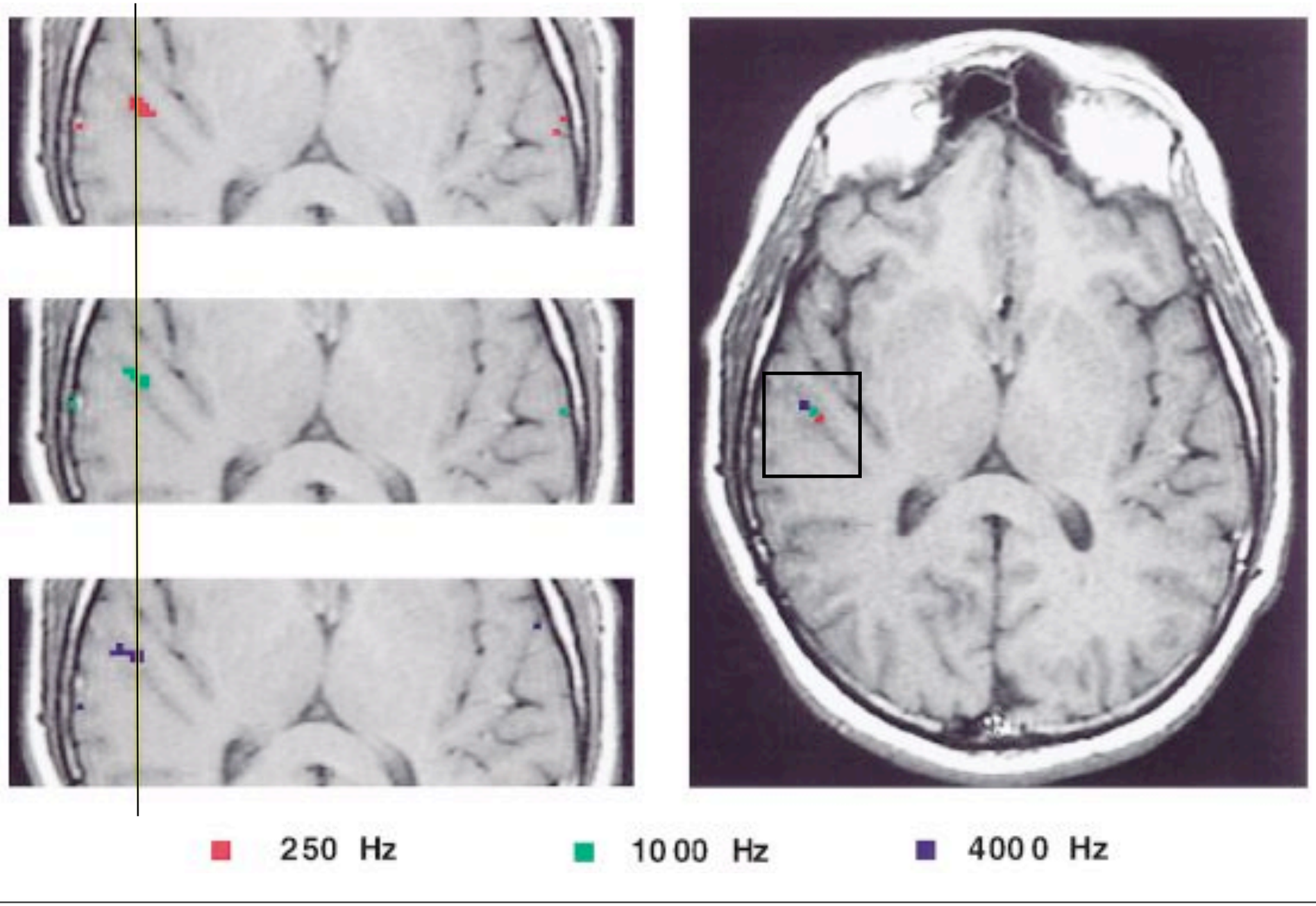
(Yang et al., (2000) MR in Medicine, 43, 185-190)



AN ALTERNATIVE PROTOCOL for TONOTOPY

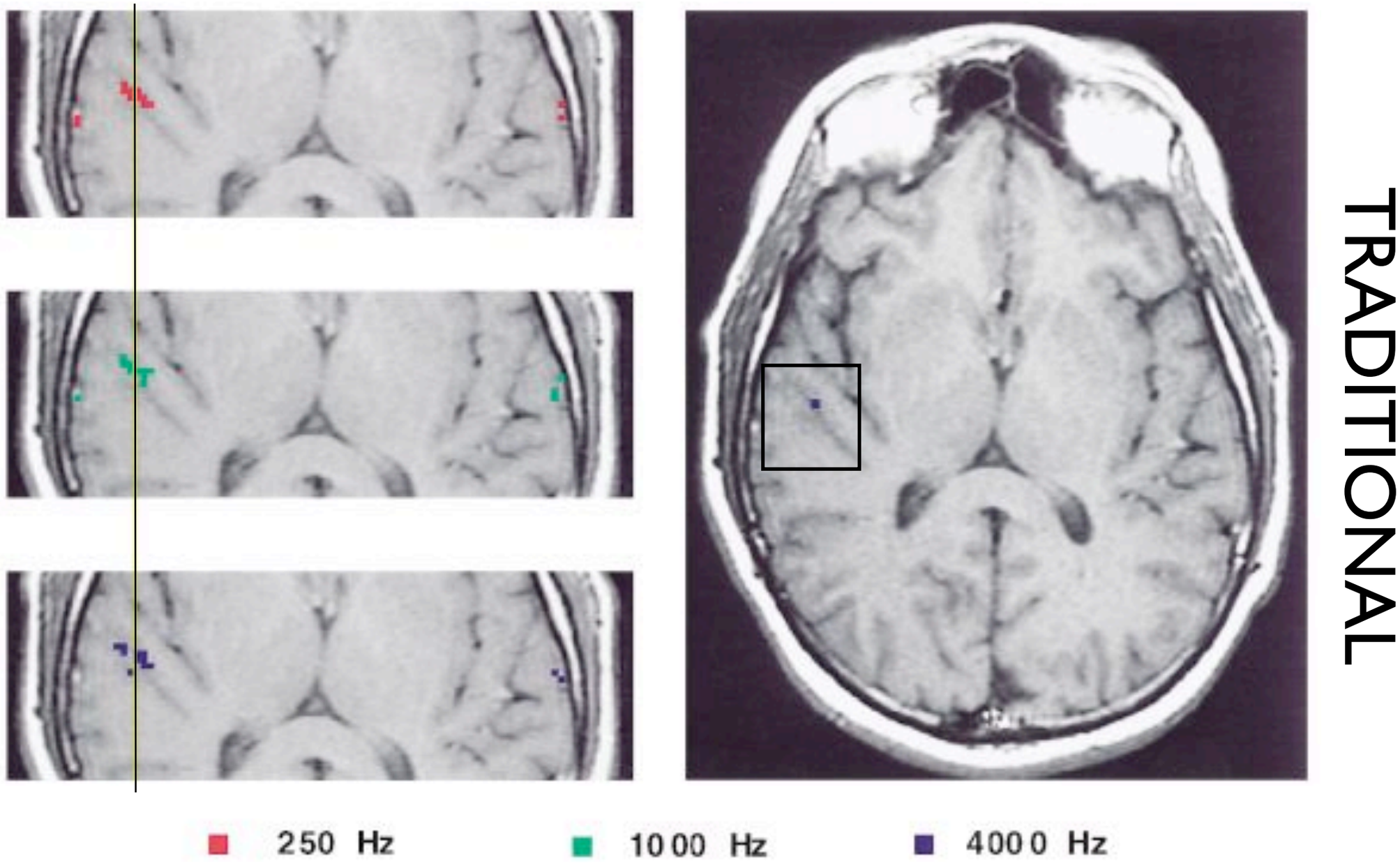
medial to lateral shift in Heschl's gyrus corresponding to a low-to-high frequency shift, specific for stimulated laterality

SILENT



AN ALTERNATIVE PROTOCOL for TONOTOPY

medial to lateral shift in Heschl's gyrus corresponding to a low-to-high frequency shift, specific for stimulated laterality - ABSENT!



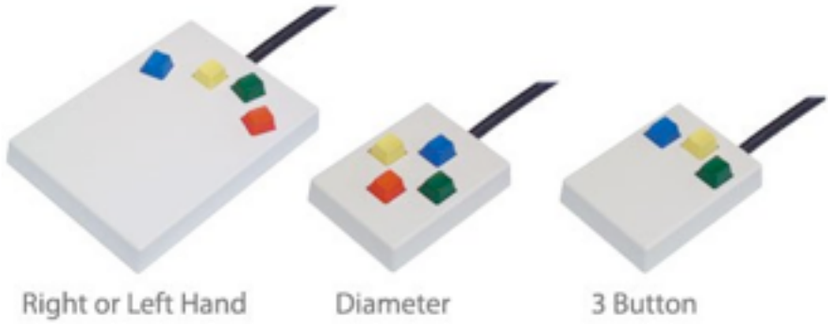
AUDITORY STIMULATION

Auditory environment is contaminated by noise within the scanner, which activates auditory cortex and may change perceptual thresholds and cognitive strategy.

↓

Note that these problems can not be resolved simply by using a within subject design.

RESPONSES & MOTION

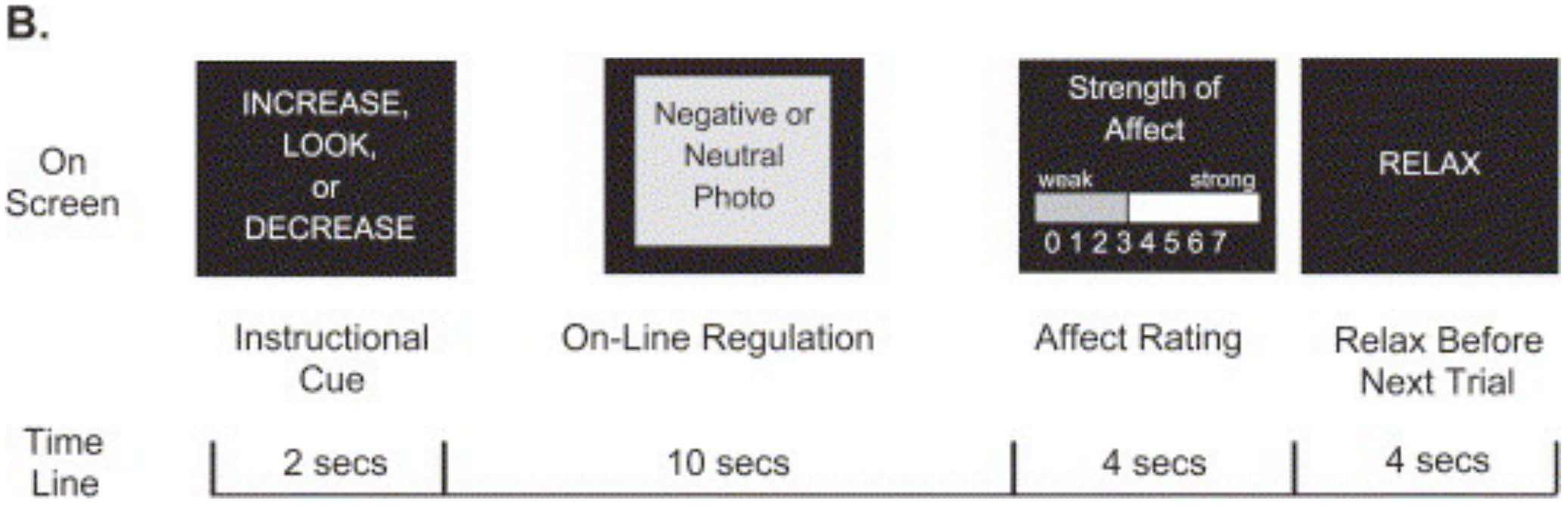


Many devices available (pads, buttons, grip etc.) but in all cases responses are limited to 10 if using all 10 fingers, and 20 if using the toes too.

RESPONSES & MOTION

e.g., likert scale becomes problematic

Ochsner et al., (2004), NeuroImage 23



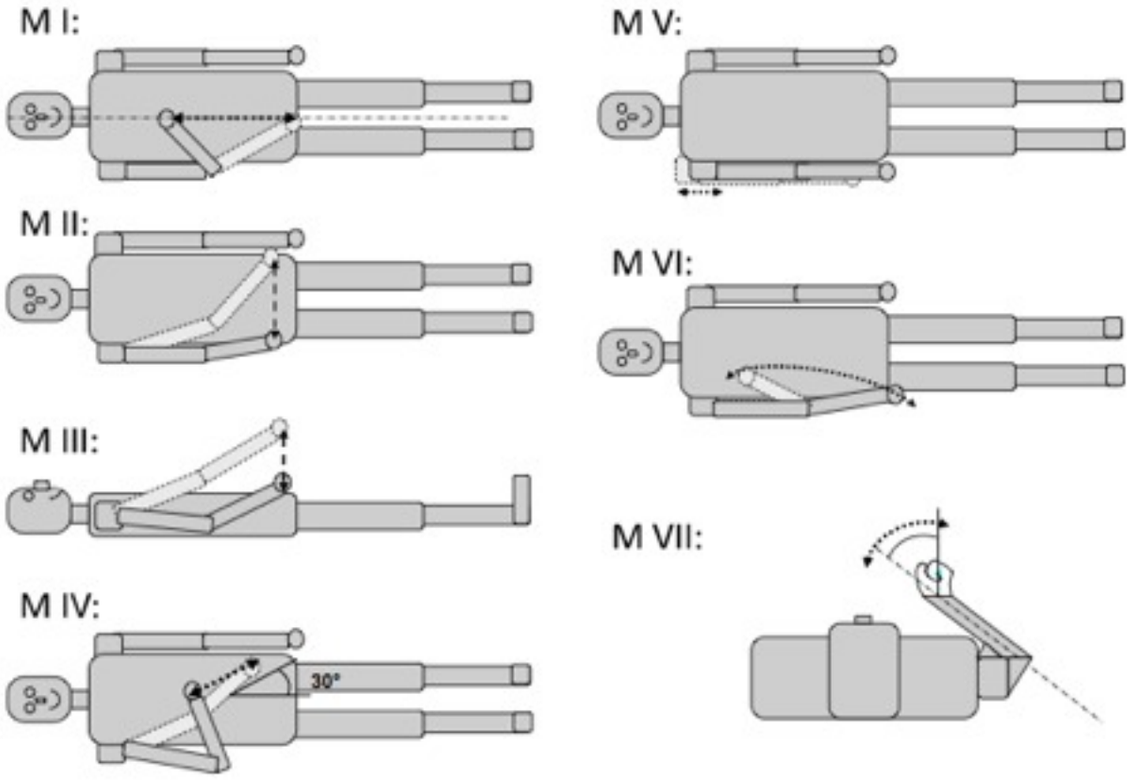
multiple values assigned to each button

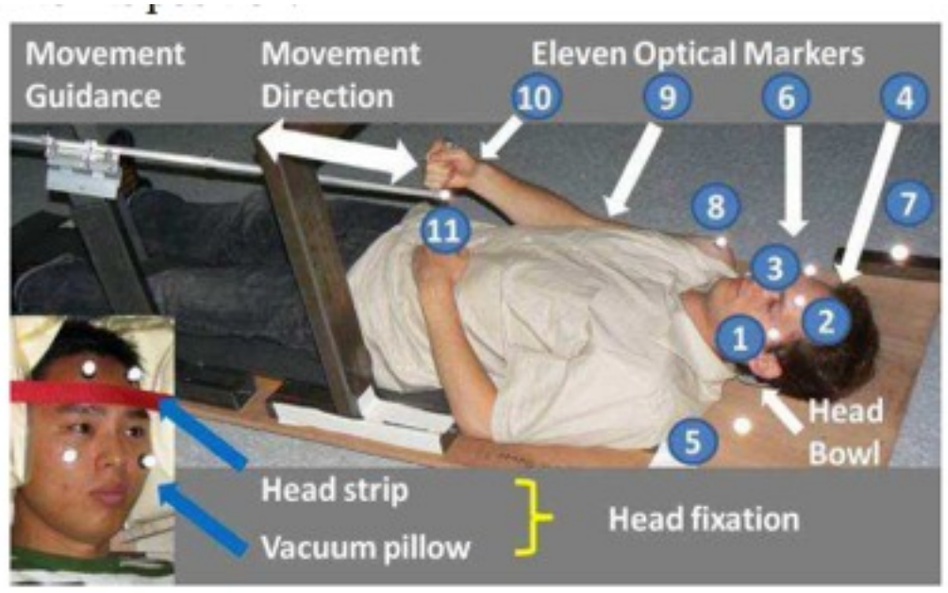
use both hands

change scale

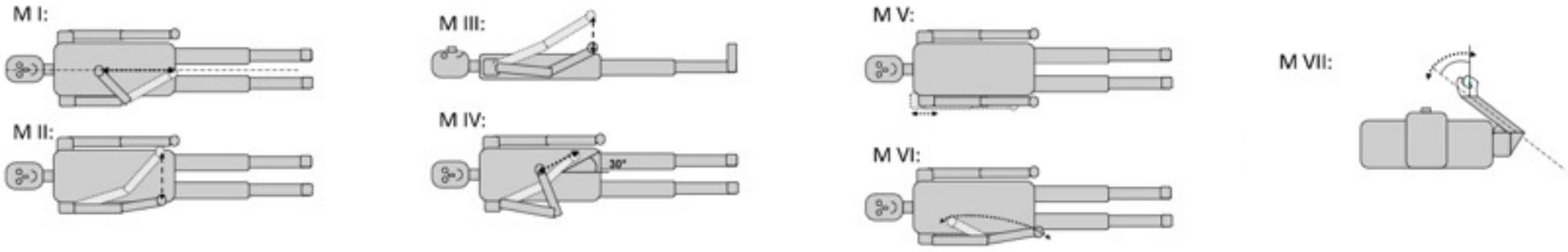
RESPONSES & MOTION

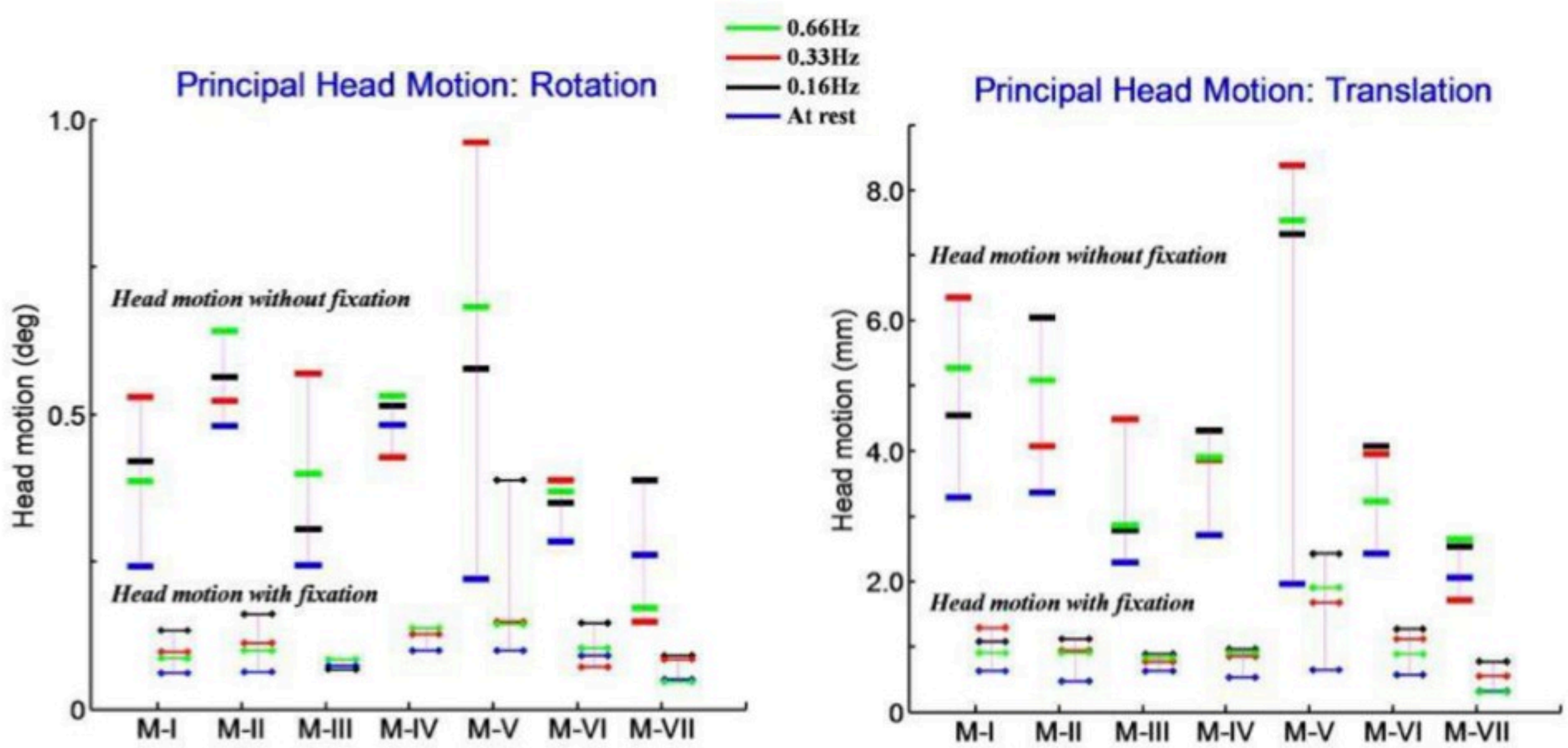
Upper body movement introduce motion artefacts (joysticks?) e.g., Yu et al., (2009), IEEE 11th International Conference on Rehab Robotics





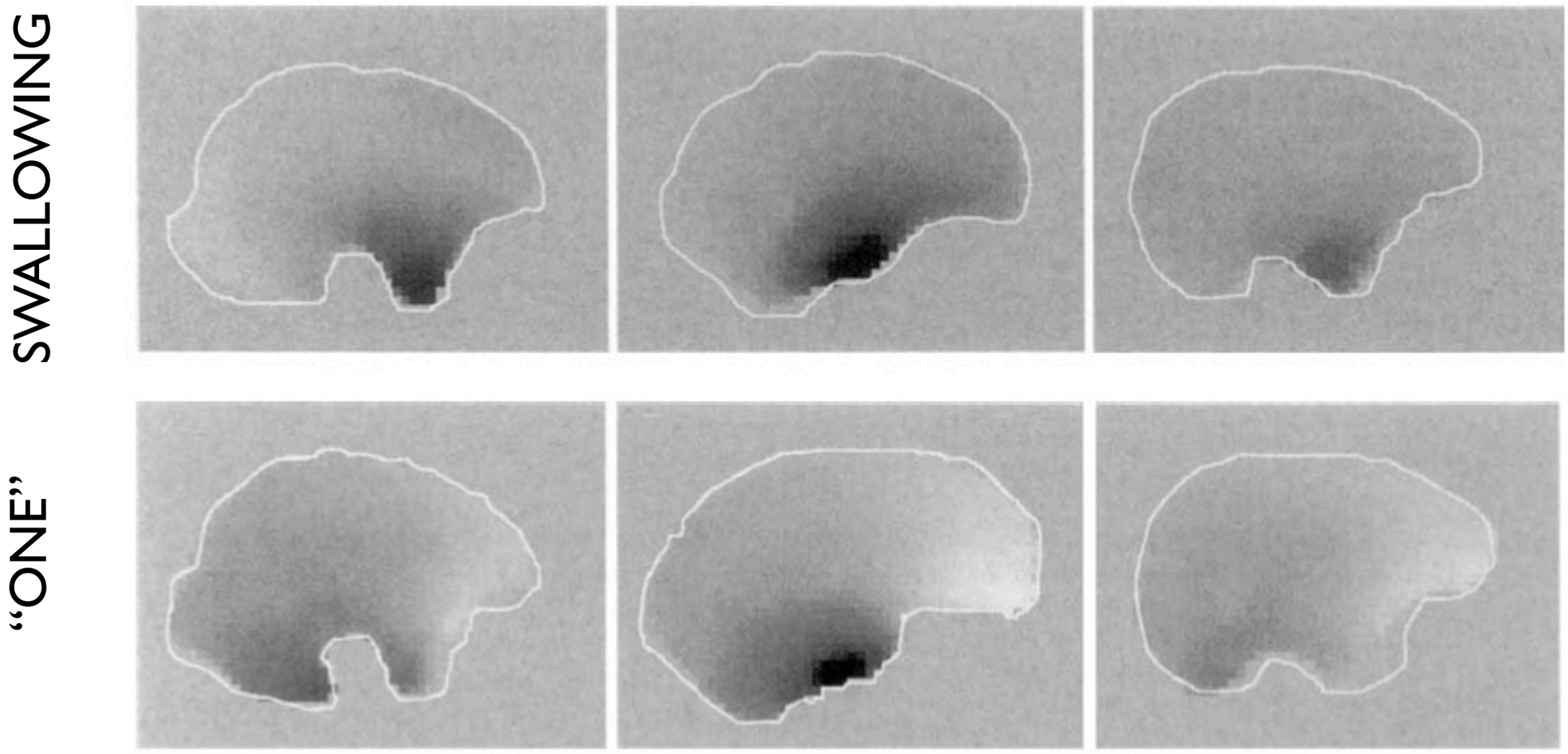
RESPONSES & MOTION





RESPONSES & MOTION

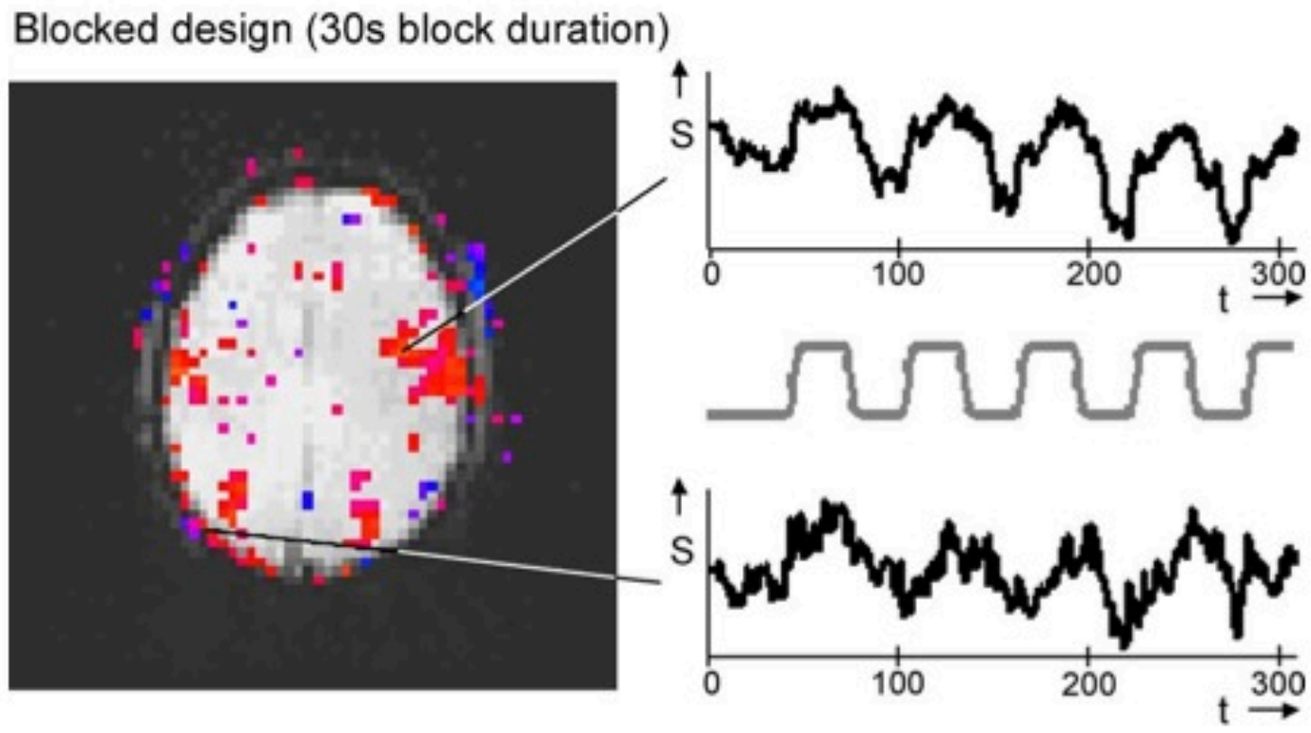
Verbal responses can also introduce motion artefacts through: movement of jaw, tongue, swallowing, opening of air cavity, air pressure changes with vocalization



Birn et. al., 1998

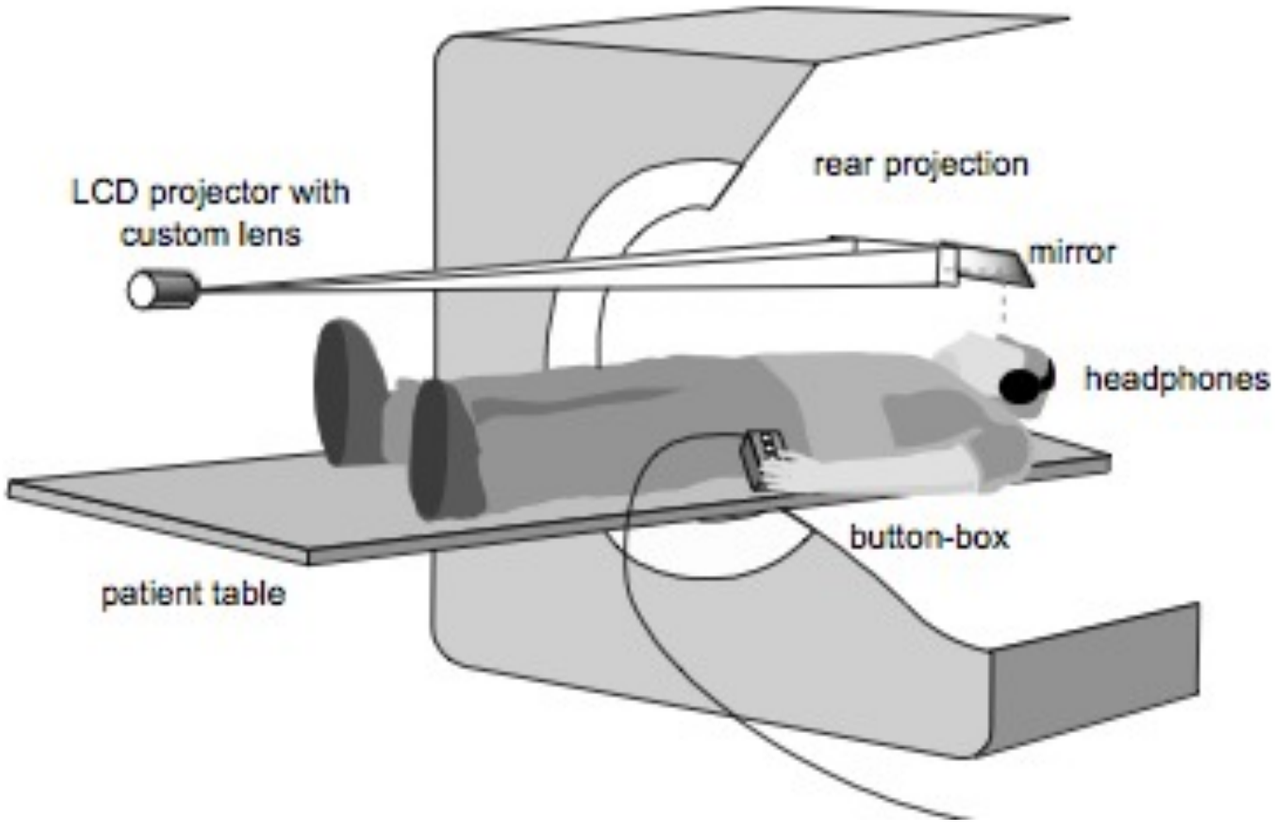
RESPONSES & MOTION

Partial Solution: Artefact and HRF have different time courses and so can be dissociated by ignoring the TRs during the artefact. Interestingly, modeling artefact is not useful!



Birn et. al., 2004

SENSORY ENVIRONMENT



MRI facilitates exploration of a largely stationary and visual world. This is not unrepresentative of human functioning, but is certainly limiting in the kinds of experiences that can be explored (e.g., Schizophrenia and word salad, confabulation, navigation & dry-sensor EEG)

STATE FACTORS in the MRI ENVIRONMENT

The MRI experience differs from every day life:

- novel, intimidating environment (pre-test procedures, metal/safety screening, metal wand, ear buds, head-movement, constraints on movement/head restraint, and emergency squeeze ball)

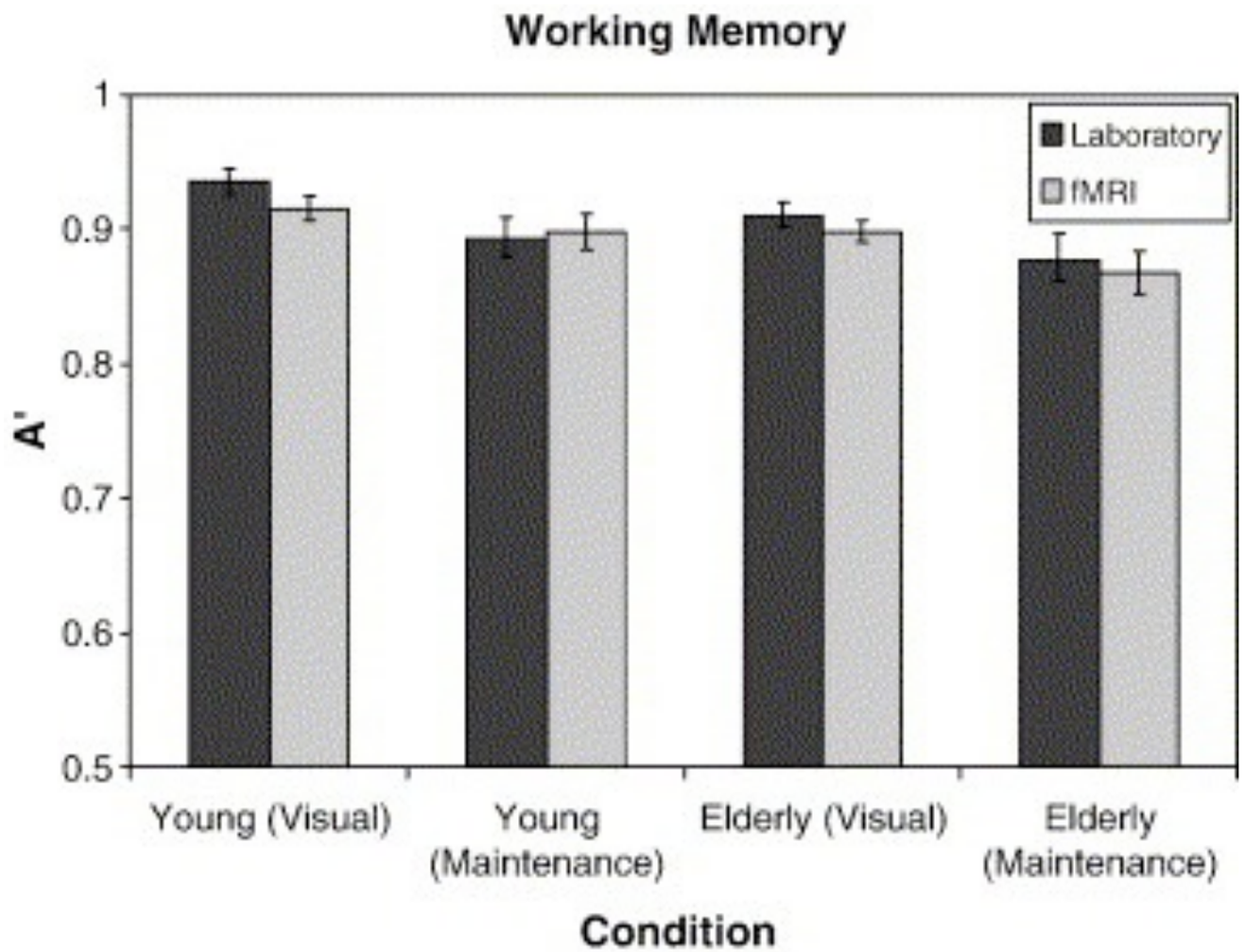
- sensory deprivation (you can't see the experimenter, you can't be heard during the scan)

- lack of control over environment (head-first in scanner, confined space, pressure to perform)

- fatigue

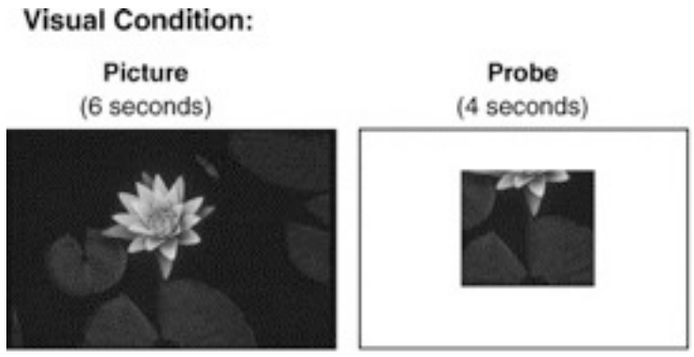
Raz et al., 2005, NeuroImage

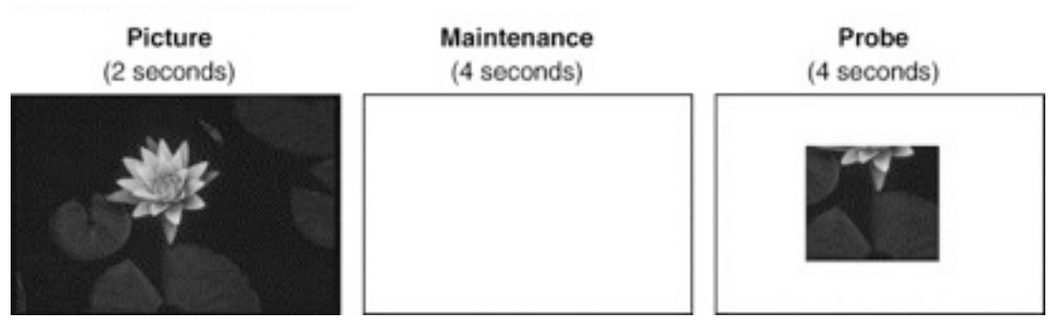
STATE FACTORS in the MRI ENVIRONMENT

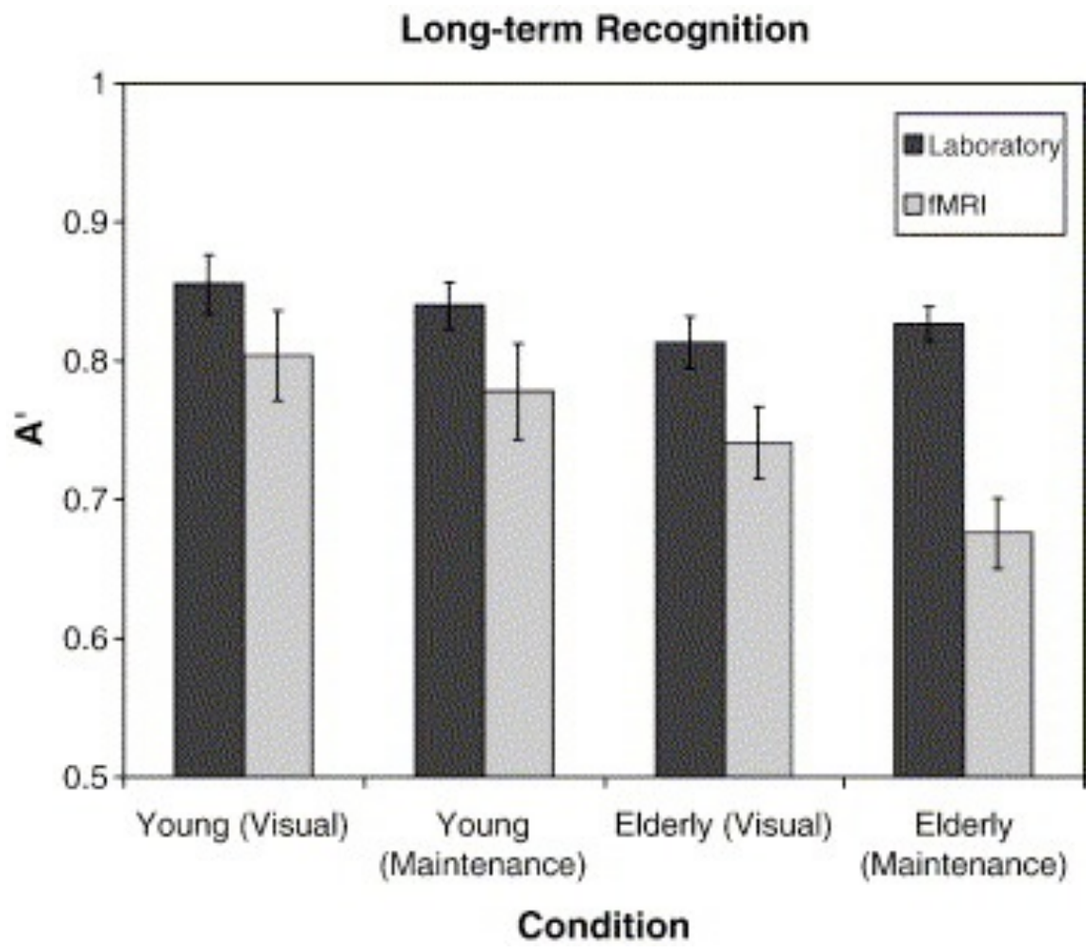


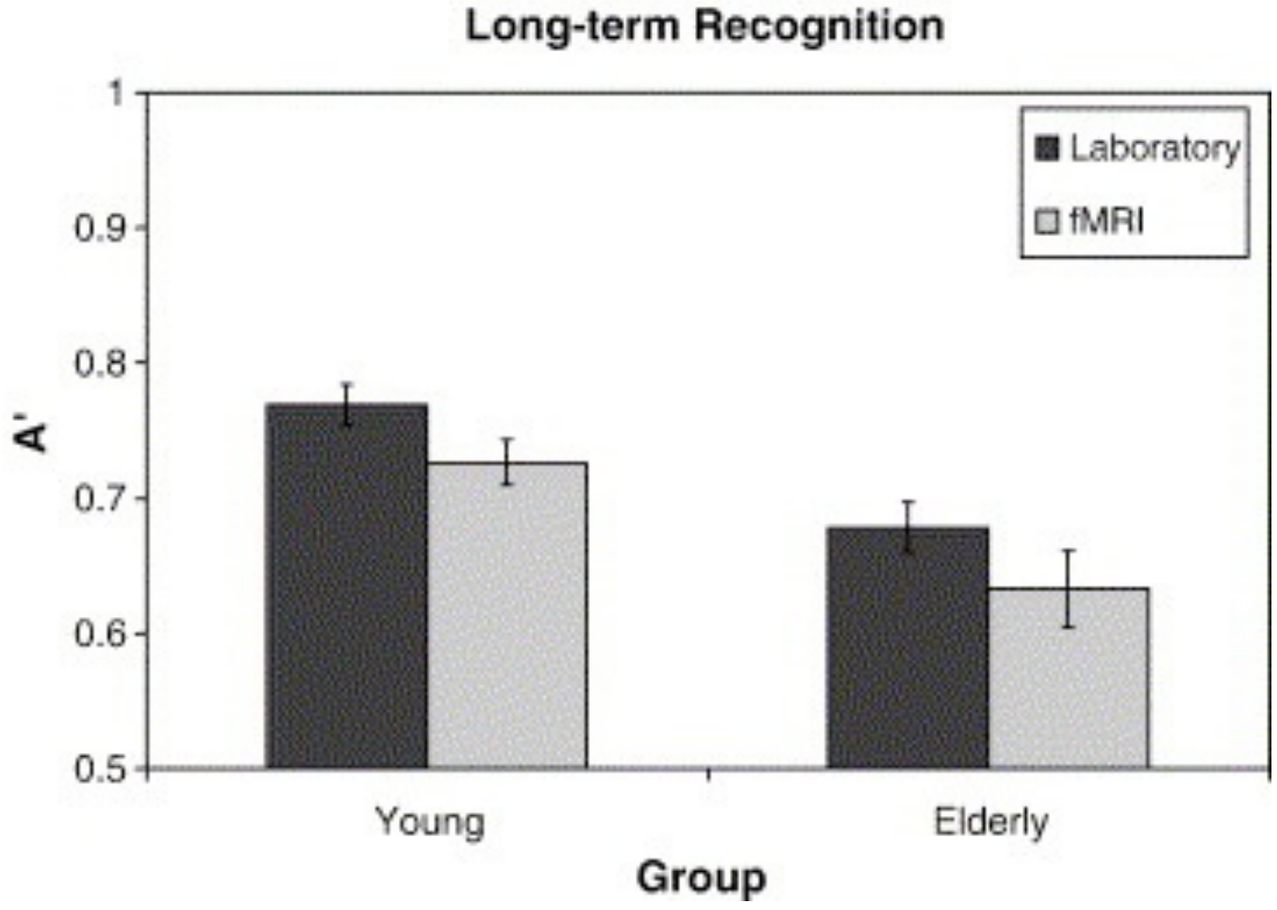
Gutchess & Park, 2006, Brain Res

STATE FACTORS in the MRI ENVIRONMENT



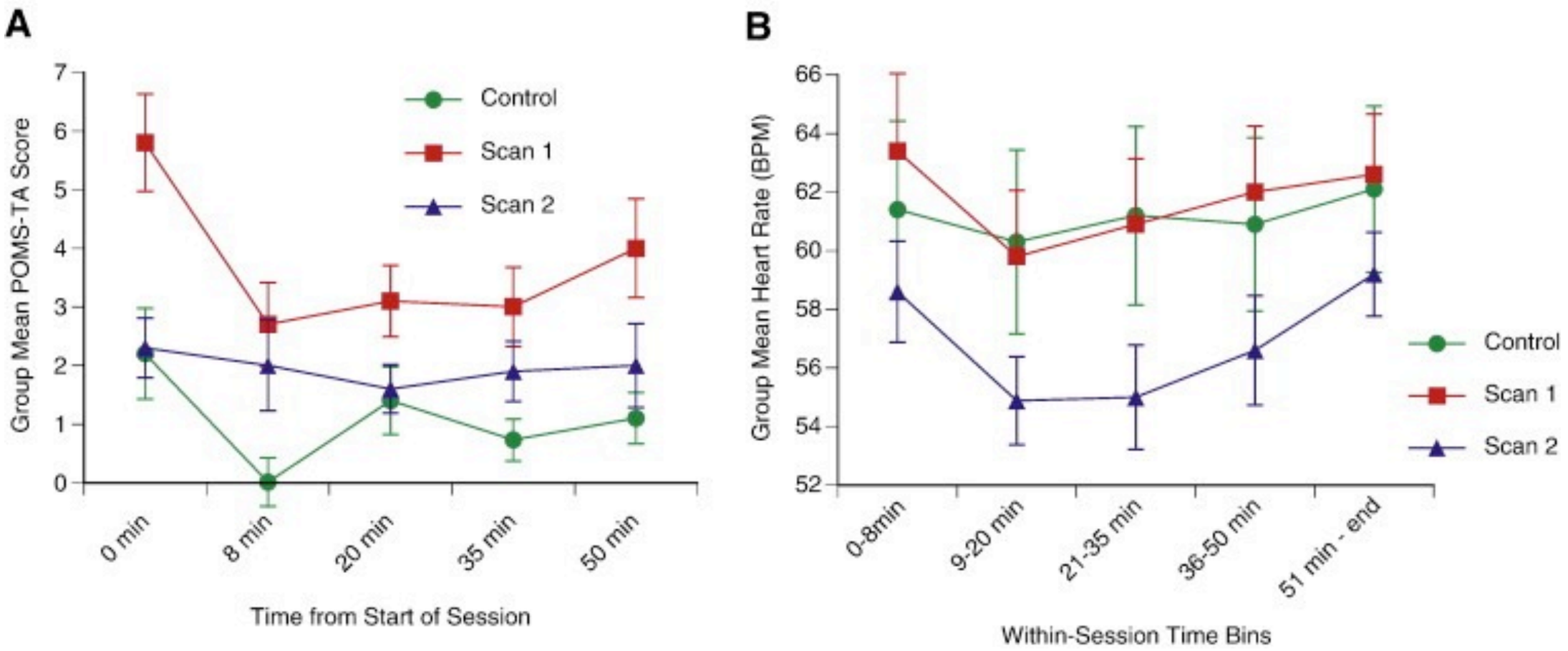






ANXIETY

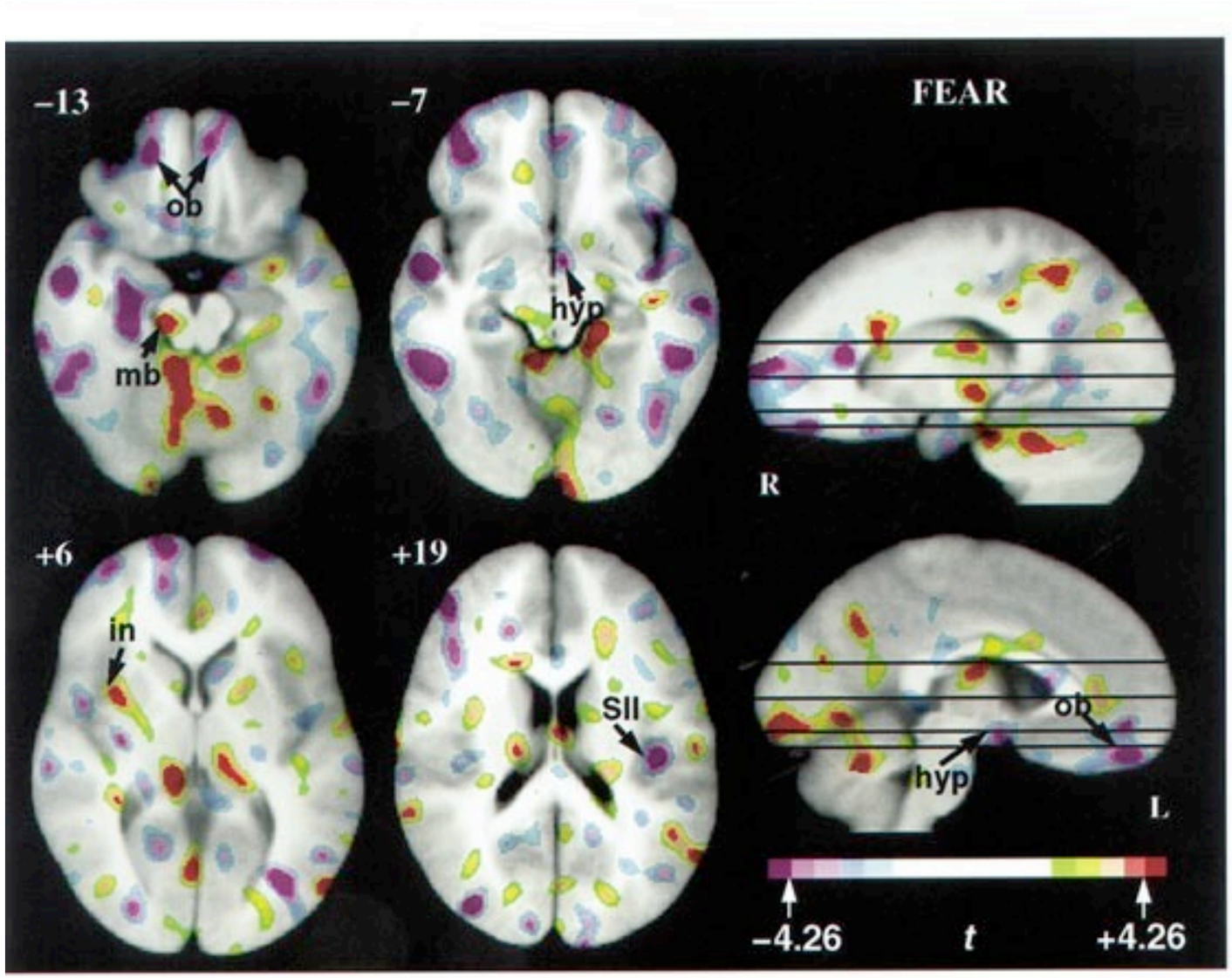
- occurs in ~30% of scanned subjects, with 5-10% experiencing significant anxiety (Robinson 1996) e.g., heavy breathing, heart palpitations, blood pressure, dizziness



Chapman et al, 2010, Psych Res: Neuroimaging

ANXIETY

- correlates of anxiety have included anterior cingulate, medial & orbitofrontal cortex, amygdala



Damasio, 2000, NN

ANXIETY

What is the potential impact of this effect?

- adding noise (some folks will have overall attenuated/enhanced activity across conditions making contrasts weaker)

- if you did not randomise or require an order to your experiment, early/late scans may show different patterns than mid-scan conditions

- if you scan a pre- and post-treatment group - you may see a medication effect that's actually related to anxiety

WHAT ABOUT FATIGUE?

Elliott et al., (1999), MR in Medicine, 41, 1230-1235

- reported decrease in extent of activity when task occurred in first two vs. last two blocks of scanning (visual and motor)

Is that fatigue or is that learning?

- motion (translational) increased from 3.29 mm to 4.56 mm, and the variance in motion increased from 1.36 mm to 2.25 mm ($p < 0.1$)

CLOSING THOUGHTS

OUR AIM is to ACQUIRE MEANINGFUL DATA in order to better understand brain function.

In general the visual environment is well within your control in MRI. But this environment is poorly suited for the exploration of audition, response generation, and interaction the environment (even in 3D).

The fMRI dataset you collect will increase in value with time and effort put towards replicating the actual psychophysiological experience that you seek - even if it involves new technology, extra practice time, or time in a simulated environment.

happy experimenting !