2.6 fMRI and BOLD

fMRI measures blood-oxygenation-level dependent contrast, or BOLD. BOLD is an indirect signal. It reflects changes in blood oxygenation related to neural activity through neurovascular coupling. It is not direct neuronal firing.

fMRI has strong spatial resolution and can map activity across much of the brain. Its weakness is temporal resolution. The hemodynamic response is slow and delayed, so fMRI is not ideal for millisecond timing.

Coloured activation maps are statistical maps, not raw photographs of thought. A coloured region usually means that the measured BOLD response differed between conditions according to an analysis threshold. This is why experimental design matters so much. The meaning of an activation depends on the comparison condition.

Reverse inference is a major limitation. If a region is active during a task, one cannot automatically infer a single mental state. A region may be involved in many processes. Responsible interpretation requires converging evidence, task design and caution.

Common trap: Do not write "fMRI directly measures neural activity." It measures a delayed vascular consequence of neural activity.

2.7 Method Comparison

Method	Signal	Main strength	Main limitation	Best exam phrase
EEG	scalp electrical fields	very high temporal resolution	weaker source localisation, artefacts	good for timing
ERP	averaged time-locked EEG	processing stages across time	depends on averaging and task design	event-locked evidence
MEG	magnetic fields	high temporal resolution, often better localisation than EEG	expensive, shielding and source constraints	timing plus source modelling
OPM-MEG	magnetic fields with wearable sensors	closer sensors and more movement tolerance	still needs careful modelling	movement-tolerant MEG
fMRI	BOLD blood oxygenation	strong spatial resolution	indirect and delayed	good for where, not fast timing

The best method depends on the question. If the question is "when does a process occur?", EEG or MEG is usually stronger. If the question is "where is activity stronger during one condition than another?", fMRI is often stronger. If both timing and source modelling matter, MEG can be powerful but still limited by the inverse problem.

Part 2 Active Recall Prompts

1. Why does EEG have high temporal but weaker spatial resolution?
2. What neural signal mainly contributes to scalp EEG/MEG?
3. Why are action potentials not the main scalp EEG source?
4. What makes an EEG artefact an artefact?
5. Why does averaging help ERPs?
6. Compare SQUID and OPM MEG systems.
7. Why does source orientation matter for MEG?
8. What is the inverse problem?
9. Why is the strongest sensor not necessarily above the source?
10. What does BOLD measure?
11. Why is fMRI temporally delayed?
12. What is reverse inference?
13. Which method would you choose for millisecond timing, and why?
14. Which method would you choose for spatial localisation, and why?
15. Why must every neuroimaging result be interpreted relative to a comparison condition?

3.5 Reading and Eye Movements

Reading is a learned cultural skill built on older visual and language systems. It requires mapping visual marks to language representations. The brain did not evolve specifically for printed text, so reading recruits and adapts existing mechanisms.

Eye movements matter because information is mainly acquired during fixations, not during saccades. Skilled reading depends on where the eyes fixate, how long they remain, how often they regress and how attention is distributed around fixation.

The perceptual window in reading is asymmetric for languages read left-to-right. More useful information is typically available to the right of fixation than to the left. This reflects learned attentional allocation as well as visual processing constraints.

H1 sentence: Reading is a biological and cultural skill: it reuses visual attention, eye movement control and language networks.

3.6 Dual Route Model of Reading

The dual route model explains how written words can be read aloud. It includes lexical routes and a grapheme-to-phoneme conversion route.

The lexical-semantic route uses stored word knowledge and meaning. The lexical non-semantic route can support reading familiar words aloud without necessarily accessing meaning. The grapheme-to-phoneme conversion route applies spelling-to-sound rules and is important for reading unfamiliar regular words or nonwords.

This model is high-yield because disorders reveal the routes. If a person struggles with nonwords, the grapheme-to-phoneme route is implicated. If a person struggles with irregular words, lexical route problems are implicated.

Common trap: Do not treat reading as one route. Different word types reveal different processing pathways.

3.7 Aphasia and Language Disorders

Broca's aphasia is associated with damage to the posterior inferior frontal lobe. It involves effortful, non-fluent speech production, while comprehension is relatively preserved. Wernicke's aphasia is associated with posterior superior temporal regions. It involves fluent speech that can lack meaning, with impaired comprehension.

These disorders are useful because they separate production and comprehension. They show that language is not one indivisible ability. A person can know what they want to say but struggle to produce speech, or produce fluent speech that fails to carry meaning.

Specific language impairment, stuttering and Williams syndrome broaden the developmental and disorder picture. They remind us that language difficulties can arise through different mechanisms, not only acquired adult lesions.

H1 sentence: Aphasia evidence shows that language depends on separable but interacting neural systems.

3.8 Dyslexia

Dyslexia is not explained by low intelligence or poor vision alone. The course emphasises phonological processing as a central account, while also discussing visual/dorsal stream evidence.

Phonemic awareness is the ability to recognise that spoken language is made of individual sounds. Many dyslexic readers struggle with tasks requiring blending, segmenting, rhyme, nonword reading or discriminating similar speech sounds. Because alphabetic reading maps print to sound, phonological difficulty can strongly affect reading acquisition.

The dorsal stream account adds a visual-processing dimension. Dorsal and magnocellular pathways are associated with motion, spatial processing and fast transient signals. Reading requires spatial attention, eye movement guidance and stable fixation. Evidence that some at-risk pre-readers show dorsal/magnocellular differences before reading failure suggests that visual processing may contribute causally rather than merely result from poor reading.

Common trap: Do not reduce dyslexia to one simple cause. The course presents phonological processing as central while also treating dorsal stream evidence seriously.

Part 3 Active Recall Prompts

1. Why is language broader than speech?

2. What does the McGurk effect show about speech perception?
3. How does phoneme restoration show top-down processing?
4. What is the mental lexicon?
5. Why does word context help letter recognition?
6. How does right visual field presentation relate to left-hemisphere language processing?
7. Why is visual field not the same as eye?
8. Why is reading considered a learned cultural skill built on older systems?
9. What happens during fixations versus saccades?
10. Compare the lexical route and grapheme-to-phoneme conversion route.
11. Why are nonwords useful for testing reading routes?
12. Compare Broca's and Wernicke's aphasia.
13. Why does aphasia evidence support modular but interacting systems?
14. Why is phonemic awareness important for reading?
15. How can dorsal stream processing relate to dyslexia?

Part 4. Sensory Processing, Attention, Navigation and Memory

4.1 Big Picture

The final part of the course follows sensory information from physical energy to perception, attention, navigation and memory. The key idea is transformation. Sound waves and light do not automatically become experience. They are encoded by receptors, organised by neural pathways, selected by attention and connected to memory systems.

The main chain is:

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physical stimulus -> sensory transduction -> neural pathway -> cortical processing -> attention / recognition -> navigation or memory
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This part is heavy on brain-region matching. The strongest way to revise is to pair each region with a function, a disorder or a case study.

H1 sentence: Perception and memory are constructed through specialised neural transformations, not passively copied from the world.

4.2 Audition

Sound begins as changes in air pressure. The outer and middle ear convert pressure waves into mechanical movement. The tympanic membrane vibrates. The ossicles transmit and amplify movement to the oval window. Fluid movement in the cochlea moves the basilar membrane.

The organ of Corti contains hair cells. Bending of stereocilia changes hair-cell voltage and transmitter release. Hair cells themselves are not the main long-distance action-potential output. Spiral ganglion cells generate action potentials, and their axons form the auditory nerve.

Place coding is central. Different sound frequencies produce maximal vibration at different places along the basilar membrane. High frequencies peak closer to the base; low frequencies peak closer to the apex. Primary auditory cortex preserves frequency-based organisation as a tonotopic map and is located in the superior temporal gyrus of the temporal lobe.

Cochlear implants use this logic. They can bypass damaged hair cells and stimulate spiral ganglion cells at different cochlear locations. They can restore partial hearing, especially for speech, but they do not reproduce normal hearing perfectly.

Common trap: Do not say hair cells form the auditory nerve. Spiral ganglion cell axons form the auditory nerve.

4.3 Vision: Retina to V1

Vision begins when light reaches photoreceptors in the retina. Rods are sensitive in low light and do not support colour detail. Cones support daylight vision, fine detail and colour, and are concentrated in the fovea.

The core retinal chain is:

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photoreceptors -> bipolar cells -> ganglion cells -> optic nerve
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