11.1 — Subtraction paradigm in brain imaging

The subtraction paradigm is the basic one in PET and fMRI experiments.

Just looking at the pattern of recorded blood flow while the subject is performing an experimental task is not going to tell you a lot about the connection between the cognitive task and blood flow (and hence neural activity). For instance, the pattern of blood flow in the brain on presentation of a spoken word does not necessarily indicate the brain activity specifically associated with hearing a word. Some of the blood flow is likely to be the result of processing the visual signals reaching the brain, and other activities the brain is engaged in.

What can be done in the simple case is to measure the blood flow in a control state. This might be for example be the state of looking fixedly at a cross-hair (+) on a screen in the scanner. If the pattern of blood flow in this condition is subtracted from the pattern of blood flow in the condition of looking fixedly at the cross-hair and simultaneously hearing a spoken word, the resulting blood-flow pattern can be presumed to indicate the blood flow associated with hearing a word. (Even if the subject has their eyes shut during the experiment, we need to take the blood-flow pattern in this state and without hearing a word from the pattern associated with hearing the word.)

The subtraction paradigm thus relies on identifying conditions that are in minimal contrast with one another, where the minimal contrast corresponds to the task to be investigated. Fundamental to this paradigm is the assumption that a cognitive task can be added to another cognitive task without any effect on it. This assumption turns out to be questionable (because of the non-linear nature of brain processes).

In order for experiments of this sort to reveal anything about brain locations associated with particular cognitive tasks the change in blood flow associated with the different conditions must of course be averaged across subjects.

The subtraction paradigm is used in the PET studies referred to in the textbook (p. 000). Schematically the design of the experimental conditions in this study is as follows:

Control condition	Control condition plus	Control condition plus seeing/ hearing words plus
fixation on point	seeing words or non-words[*]	saying words
	hearing words or non-words	saying related words (generating verbs)
(1)	(2)	(3)
Pattern (2) minus pattern (1) indicates the pattern associated with hearing or reading words		
	Pattern (3) minus pattern (2) indicates the pattern associated with production of the word or a related word	

[*]: The category of words here included both actual and possible words, while non-words were simple tones and vowel sounds.

The results of the experiments are summarized below (note this is a partial presentation, and leaves out many complexities):

Condition	Blood flow (after subtraction)
Seeing possible words	Increase in visual areas in both hemispheres
Hearing possible words	Increase in secondary auditory area and in Wernicke's area
Hearing non-words	Increase in secondary auditory area
Speaking tasks	Increase in motor and sensory facial areas in both hemispheres, and the right cerebellum
Saying related words	Increase in the frontal lobe including Broca's area (also increases in various other areas)