Introduction à la statistique médicale

Statistical Parametric Mapping short course

Course 4:

Experimental Design

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Subtraction Logic

Cognitive subtraction originated with reaction time experiments (F. C. Donders, a Dutch physiologist).

Measure the time for a process to occur by comparing two reaction times, one which has the same components as the other + the process of interest.

Franciscus Cornelis Donders (1818-1889)

Example:

T1: Hit a button when you see a light
T2: Hit a button when the light is green but not red
T3: Hit the left button when the light is green and the right button when the light is red

T2 – T1 = time to make discrimination between light color

T3 – T2 = time to make a decision

Assumption of pure insertion: You can insert a component process into a task without disrupting the other components.
Widely criticized (we'll come back to this when we talk about parametric studies)

Activation and baseline condition

Aim:

To reveal brain activation related to a cognitive or sensori-motor process of interest (PI)

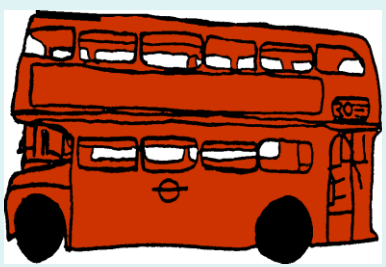
Cognitive Subtraction:

Contrast Activation task (engages PI) to a Baseline task (no PI).
Difference = Brain regions associated with PI.

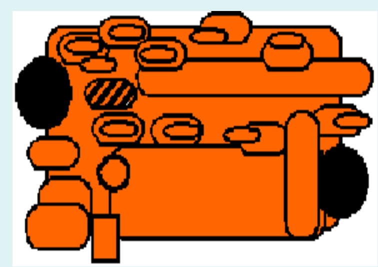
Example:

PI = Object recognition

Activation task: with PI



Baseline task: no PI

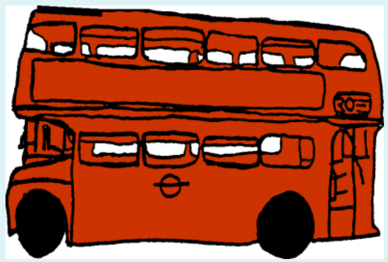


Difference = Brain regions associated with Object Recognition

Cognitive subtraction: stimulus or task change?

Stimulus Change

Activation condition *Baseline condition*



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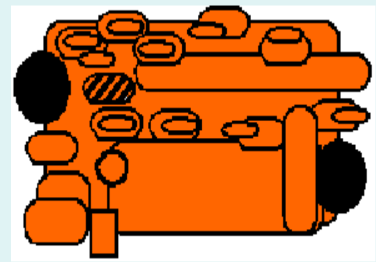
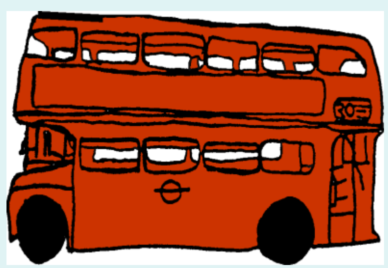


= **Object Recognition**

Task: (constant) "View picture" "View picture"

Stimulus (constant)

Activation condition *Baseline condition*



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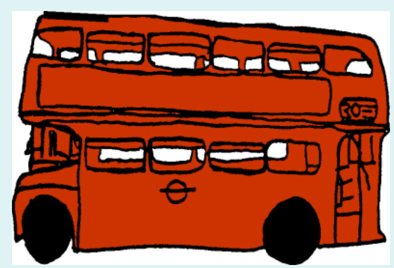


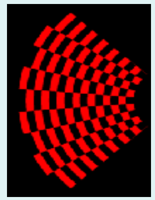
= **Name Retrieval**

Task: Change: "Name Object" "Say:"Yes"

Cognitive Subtraction: Baseline problems

- „Distant“ stimuli

-



➔ Several components differ!

- „Related“ stimuli

„Queen!“

-

„Aunt Jenny?“

➔ *Process* implicit in control task ?

- Same stimuli, different task

Name Person!

-

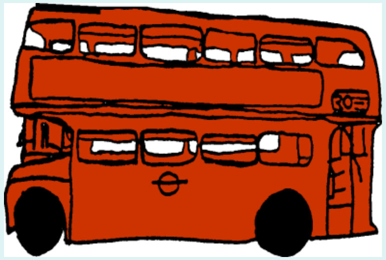
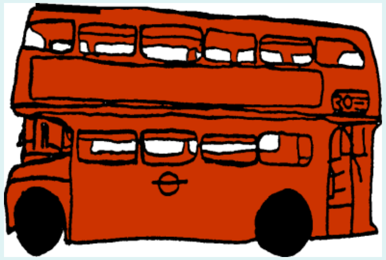
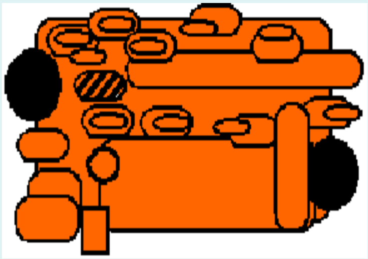
Name Gender!

➔ Interaction of process and task ?

Cognitive subtraction: serial subtractions

Baseline condition for one contrast acts as activation condition for another contrast

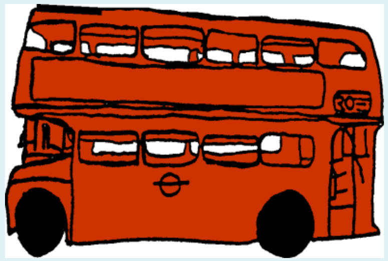
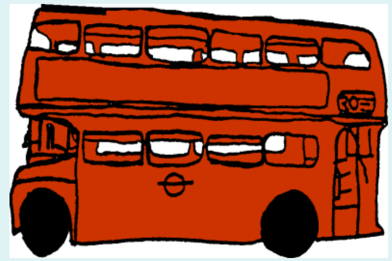
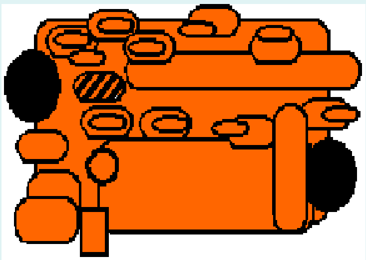
Example:

	Condition A.		*Condition B.*		*Condition C.*
Stimulus:		-		-	
Task:	**Name Object**		**Say:"Yes"**		**Say:"Yes"**

A-B = Name Retrieval
B-C = Object Recognition

Very limited…

Problem with serial subtractions

	Condition A	*Condition B*	*Condition C*
Stimulus:			
Task:	Say: Name of Object	Say:“Yes”	Say:“Yes”

<u>Assumptions:</u>

A - B = only changes processing associated with Name Retrieval
B - C = only changes processing associated with Object Recognition

BUT

1. There may be <u>*implicit*</u> naming in condition B. In which case: naming component is removed from A-B and introduced into B-C.
2. Name Retrieval may increase the demands on object recognition

i.e A - B : May reveal Object recognition NOT Name retrieval.
B - C : May reveal Object Recognition AND Name Retrieval

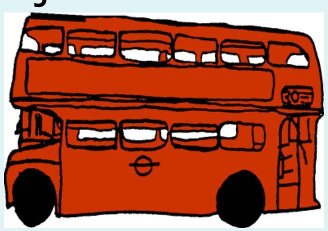
Factorial design: main effects & interaction

Stimuli (A/B)		Task (1/2)	
		Viewing	Naming
	Colours	A1	A2
	Objects	B1	B2

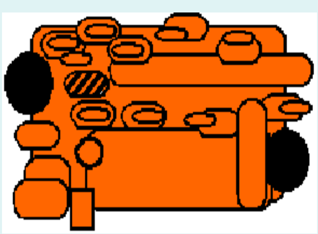
Main effect of task:
(A1 + B1) – (A2 + B2)

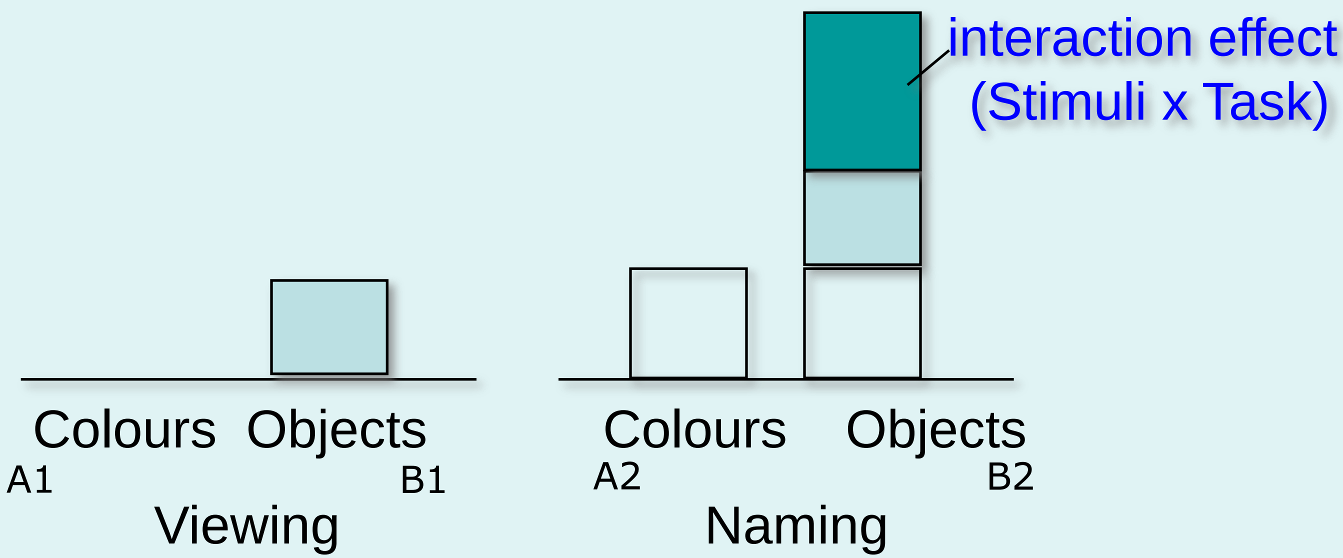
Main effect of stimuli:
(A1 + A2) – (B1 + B2)

Object



Colour





Factorial design: main effects & interaction

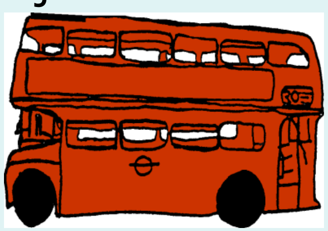
Task (1/2)

Stimuli (A/B)	Viewing	Naming
Colours	A1	A2
Objects	B1	B2

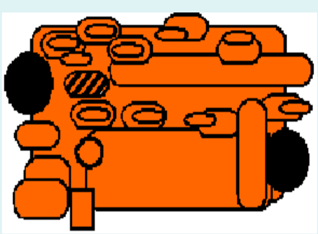
B2 – A2 = Object Recognition
during naming

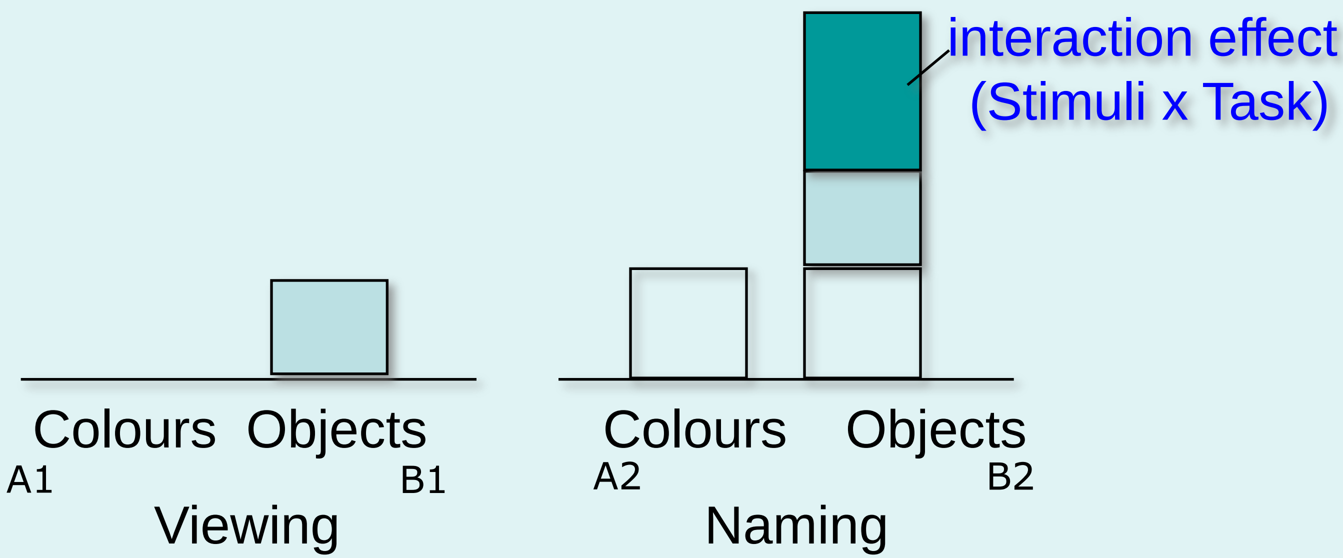
B1 – A1 = Object Recognition
during viewing

Object



Colour





Factorial design: main effects & interaction

Stimuli (A/B)		Task (1/2): Viewing	Task (1/2): Naming
	Colours	A1	A2
	Objects	B1	B2

Interaction of task and stimuli:
Can show a failure of pure insertion

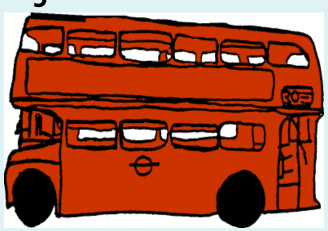
(B1 – A1) – (B2 – A2)

The effect of Naming on Object recognition

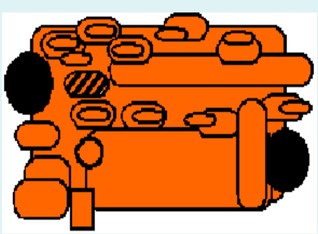
(A2 – A1) – (B2 – B1)

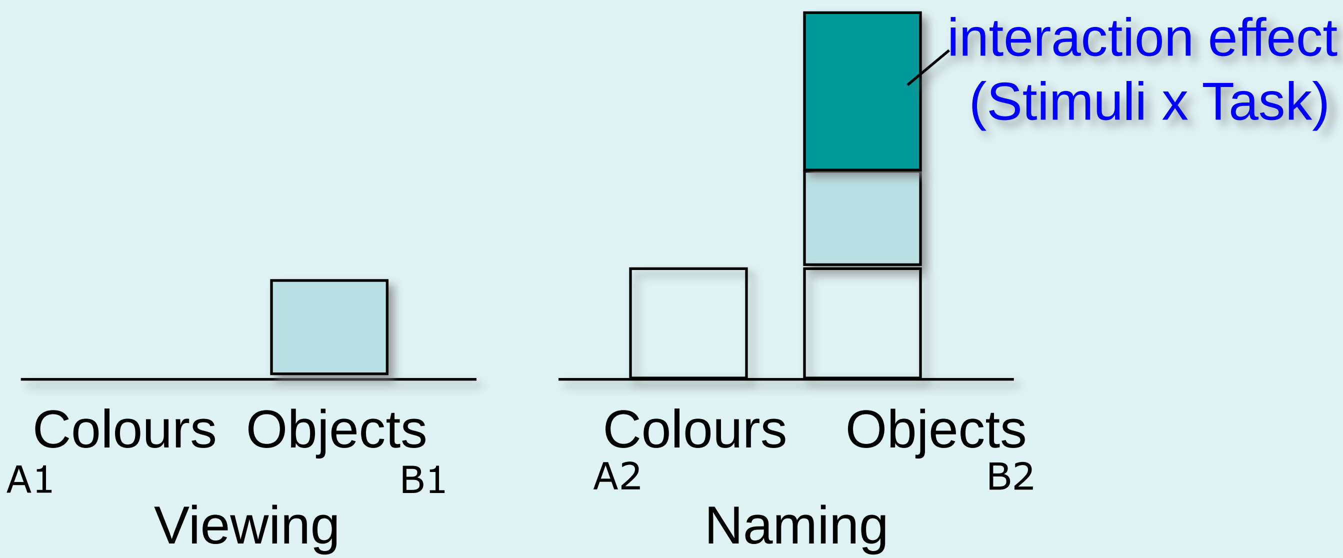
The effect of object recognition on Naming

Object



Colour





Parametric Designs: General Approach

- Parametric designs approach the baseline problem by:
  - Varying the stimulus-parameter of interest on a continuum, in multiple (n>2) steps...
  - ... and relating signal to this parameter
- Possible tests for such relations are manifold:
  - Linear
  - Nonlinear: Quadratic/cubic/etc.
  - „Data-driven“ (e.g., neurometric functions)

Parametric design

- No need to find baseline that controls for all but the process of interest
- Segregates areas showing differential effects (linear and nonlinear effects)

But:

- Common effects can not be revealed without a baseline.
- Limited to continuous variables (e.g. duration, frequency, word length, R.T.s etc)

Parametric design: Model-based regressors

"Signals derived from a computational model for a specific cognitive process are correlated against BOLD from participants performing a relevant task, to determine brain regions showing a response profile consistent with that model."

The model describes a transformation between a set of stimuli inputs and a set of behavioural responses.

See e.g. O'Doherty et al., (2007) for a review.

Model-based regressors: Example

Question

Is the hippocampus sensitive to the probabilistic context established by event streams? Rather than simply responding to the event itself.

The same question can be formulated in a quantitative way by using the information theoretic quantities 'entropy' and 'surprise'.

- 'surprise' is unique to a particular event and measures its improbability.

$$I(x_i) = -\ln p(x_i);$$

- 'entropy' is the measure of the expected, or average, surprise over all events, reflecting the probability of an outcome before it occurs.

$$H(X) = \sum_i -p(x_i)\ln p(x_i) = \langle I(x_i)\rangle$$

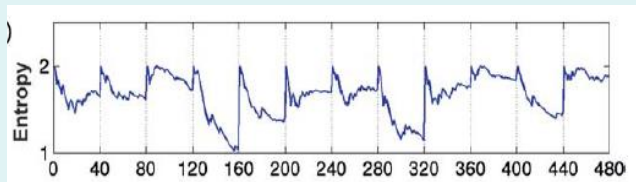
xi is the occurrence of an event. H(X) quantifies the expected info of events sampled from X.

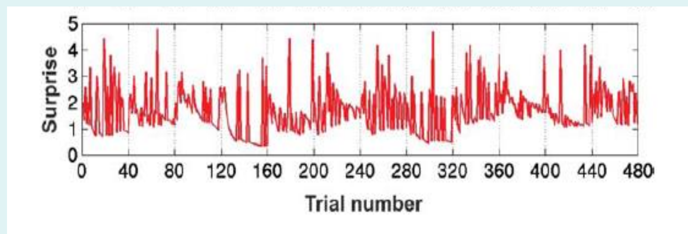
Thus, hippocampus would be expected to process 'entropy' and not 'surprise'.

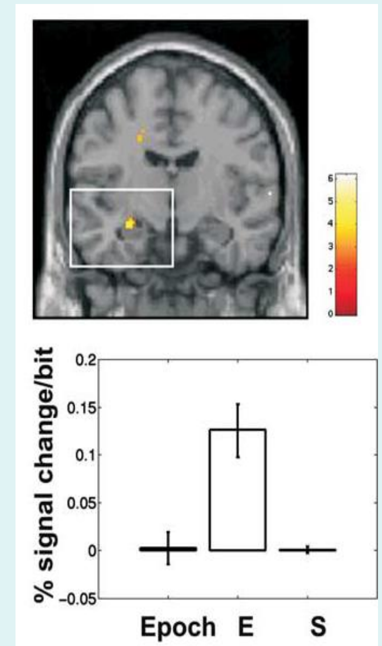
Model-based regressors: Example

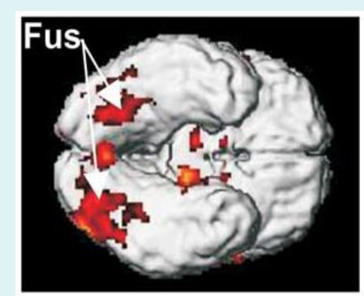
Participants responded to the sampled item by pressing a key to indicate the position of that item in the row of alternative coloured shapes.

The participants will learn the probability with which a cue appears.







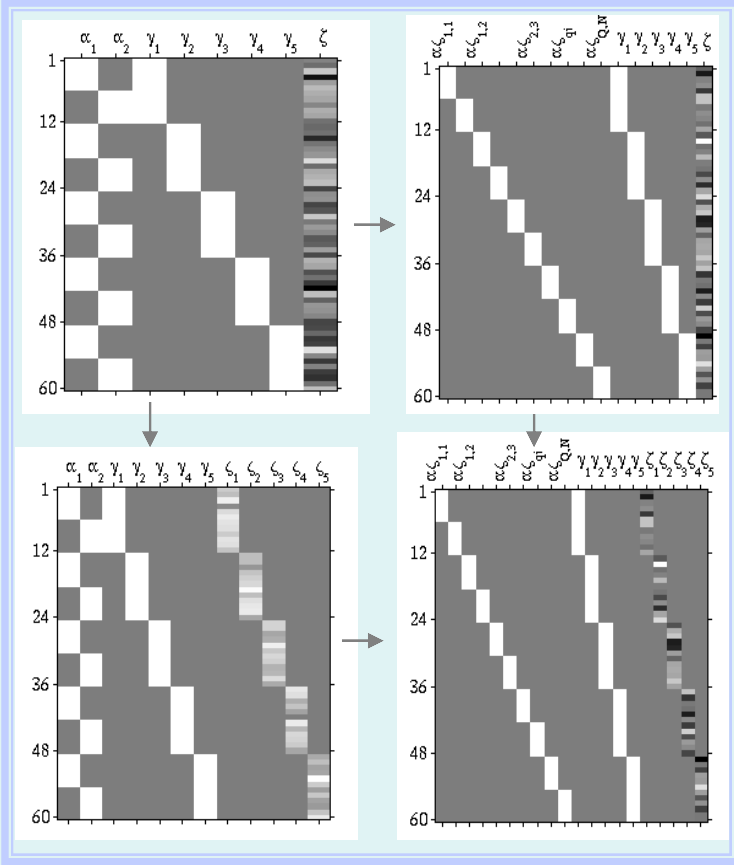


Strange et al., (2005)

Model selection

- Model must fit *i.e. model assumptions met*
  - at *every* voxel
- Omitting relevant effects
  - effects contribute to variance
    - ⇒ residuals not *iid*. Normal
    - ☹ model not valid
  - outcomes?
    - variance ↑ *(usually, but can ↓)*
    - increased residual *d.f.*
    - invalid inference
- Including irrelevant effects
  - 😐 “waste” degrees of freedom
  - 😐 conservative tests

  but safest!



Conclusions…

General Linear Model

- (simple) standard statistical technique
  - temporal autocorrelation – *a Generalised Linear Model*
- single general framework for many statistical analyses
  - flexible modelling $\Leftarrow$ basis functions
- design matrix visually characterizes model
  - fit data with combinations of columns of design matrix
- statistical inference: *contrasts*…
  - *t*–tests: planned comparisons of the parameters
  - *F*–tests: general linear hypotheses, model comparison