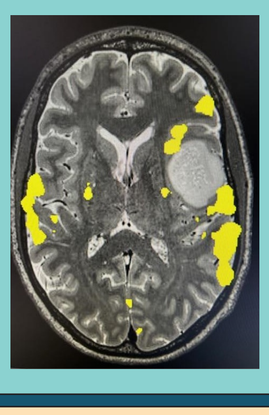
Comparative Analysis of Functional MRI Task Effectiveness in Pre-surgical Language Mapping: the Utility of the Sentence Completion Task



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Aim

Optimise the fMRI protocol for pre-surgical language mapping, to improve surgical planning and outcomes for brain tumour patients

How do brain activation patterns elicited by the Sentence Completion task compare to those of antonyms & verb generation?

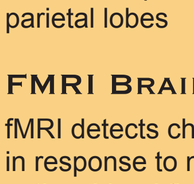
Which task or combination of tasks provides the most comprehensive coverage of language areas?

Background

Tumours

More than **88,000** people are currently living with a brain tumour in the UK

Roughly **12,700** new diagnoses each year
(that is equivalent to 1-2 new cases every hour!)



Over **100** different types of brain tumour

Gliomas are the most common type of neoplasm

(Cancer Research UK, 2024, data from 2017-2019)

Neuroanatomy

Frontal lobe: One of most common brain tumour locations in adults

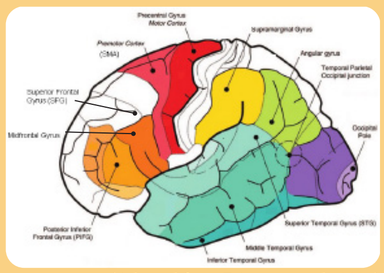
Temporal lobe: Most common location for low-grade gliomas (LGG) - accounting for 80% of LGG cases

(Ajithkumar et. al., 2019)

Language Areas

Language requires multiple brain regions for both receptive and expressive function

Critical areas being the frontal, temporal, & parietal lobes



(Adapted from Démonet et al., 2005)

fMRI Brain Mapping

fMRI detects changes in blood oxygenation that occurs in response to neural activity. When neurons become active, blood flow to that area increases, bringing more oxygenated haemoglobin. This change in the ratio of oxygenation to deoxygenation is detected by the MRI scanner and seen as **'activation' in brain regions**.

Statistical analysis of activation patterns across different language domains, elicited by multiple tasks, creates a **patient-specific map** of the language network.

Mapping eloquent language areas before surgical decision-making has several potential **benefits** such as:

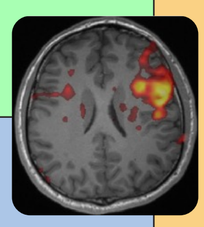
- **More aggressive therapeutic approach**
- **Minimising post-operative deficits**
- **Shortening surgical time**
- **Increasing extent of resection**
  (minimising liklihood of recurrence) (Petrella et al 2006)

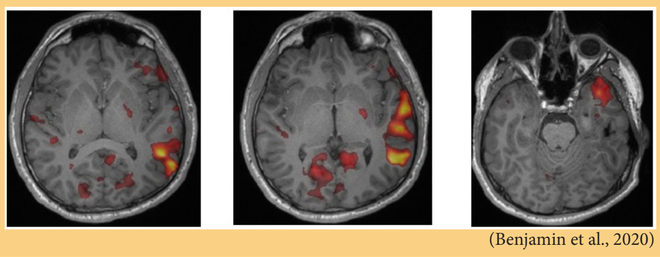
Tasks

A single task cannot encompass all aspects of language, therefore, employing multiple paradigms is recommended to achieve a more comprehensive map (Unadkat et al., 2019).

There is no accepted standardised protocol but a set of tasks should be relatively challenging (to stimulate activation) and together should provide lateralisation and localisation of both expressive and receptive language areas (Agarwal et al., 2019; Black et al., 2017).

TASKS	Targeted Activation Areas
Antonyms (image right)	**Broca's:** Inferior Frontal Gyrus (IFG) Middle Frontal Gyrus (MFG) **Wernicke's:** Superior Temporal Gyrus (STG) Supramarginal Gyrus (SMG) Angular Gyrus (AG)
Verb Generation (image right)	Broca's Area Pre-SMA (pre Supplementary Motor Area) Middle Temporal Gyrus (MTG) STG
Sentence Completion (image below)	STG, MTG Insula Wernicke's Area Broca's Area





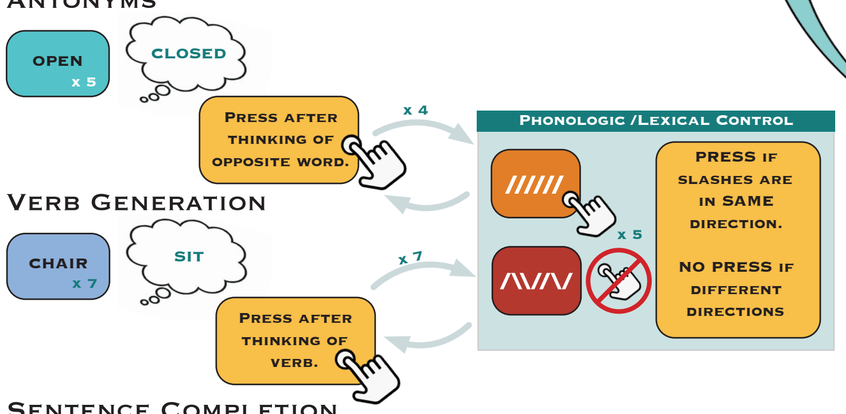
(Benjamin et al., 2020)

Methods

Tasks

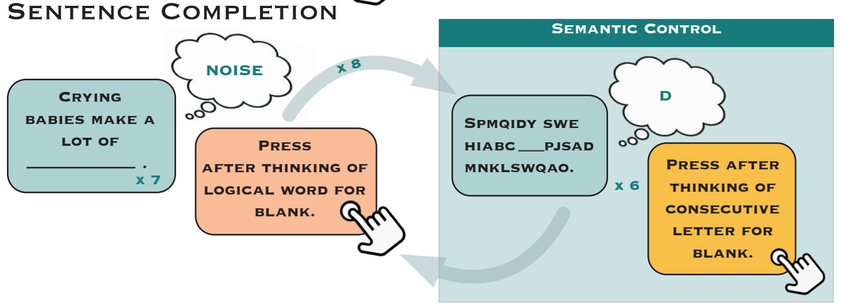
All tasks in block design alternating with control for multiple runs

Antonyms



Verb Generation

Sentence Completion



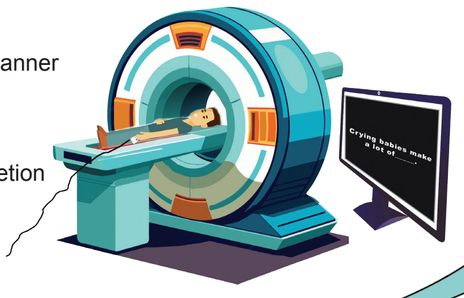
Protocol

3T Prisma Siemens scanner

Task fMRI x 3

- Antonyms
- Verb Generation
- Sentence Completion

T2w structural



Approved by BSMS ethics committee

Participants

5 healthy subjects
(3 F, 2 M; mean age = 34 yrs)
Written consent obtained

Analysis

SPM12 / GLM approach

Group-level analyses

- One-sample t-tests for each task across participants
- Paired sample t-tests for differences in activation between tasks

Activation maps were thresholded at p < 0.001 (uncorr)

- Cluster extent threshold of 20 voxels

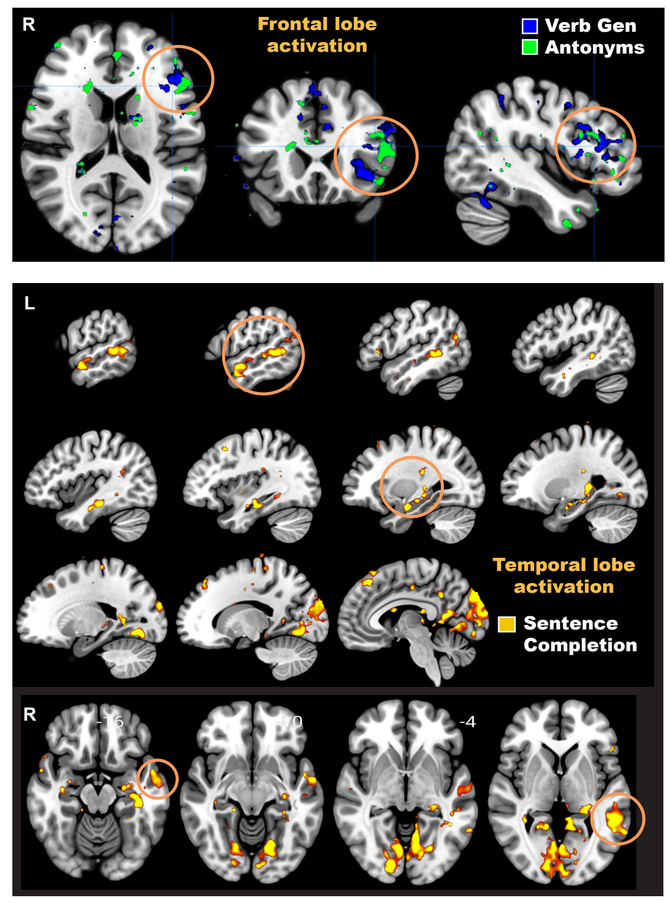
Results

Significant Activation Areas (p<0.001 unc)

[all LEFT-sided]

TASK	GROUP ANALYSIS (one-tailed t-test - in order of activation strength)	INDIVIDUAL ANALYSIS Trends nearing significance (p=0.008)
Antonyms (AG)	no significant activation areas at group level	Inferior Frontal Gyrus Anterior Insula Middle Frontal Gyrus Superior Frontal Gyrus Inferior Temporal Gyrus
Verb Generation (VG)	Anterior Insula Inferior Frontal Gyrus Superior Temporal Gyrus Cerebellum	Middle Frontal Gyrus
Sentence Completion (SC)	Superior Occipital Gyrus Middle Temporal Gyrus Lingual Gyrus Superior Temporal Gyrus Temporal Pole Superior Frontal Gyrus Precuneus (superior parietal)	Angular Gyrus Supramarginal Gyrus Inferior Frontal Gyrus

TASK COMPARISON	No significant findings at (p<0.001 - paired t-test) (below are observations base on number of voxels)	
SC > VG & AG	Stronger activation for SC: Superior Temporal Gyrus Inferior Parietal Lobule (Angular & Supramarginal)	Stronger activation for VG: Middle Frontal Gyrus Stronger activation for AG: Superior frontal gyrus
VG > AG	Stronger activation for VG: Middle Frontal Gyrus Inferior Frontral Gyrus	Stronger activation for AG: Superior frontal gyrus



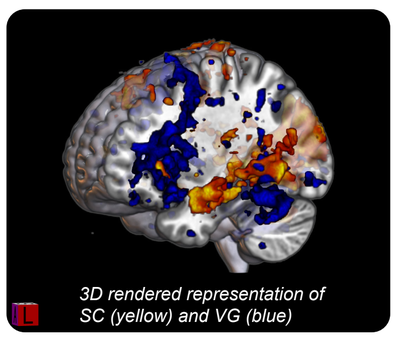
Discussion

Findings are consistent with previous studies which advocate the use of a sentence completion task in the fMRI protocol for pre-surgical language mapping.

By requiring integration of semantic and syntactic information at the sentence level, the SC task better engages the posterior temporal, parietal and occipital regions implicated in language comprehension compared to tasks limited to single-word processing. Whilst still activating frontal areas also seen in verb and antonym generation, these areas were not as strong in SC.

Results show that a protocol with all three tasks would potentially capture Broca's area (inferior/middle/superior frontal gryi) and Wernicke's area (middle/superior temporal gryi, and angular and supramarginal gryi of the parietal lobe). In this study, SC activated additional areas that have been associated with language processing, such as the lingual gyrus and precuneus (Heath et al.. 2012; Mashal et al, 2014).

This more complete mapping of language networks, especially posteriorly, highlights the utility of the SC task and the benefit of using a combination of tasks in pre-surgical language mapping.



3D rendered representation of SC (yellow) and VG (blue)

Future Impact

Studying complementary fMRI language tasks to establish functional neuroanatimical areas activated with each will allow us to curate **patient-specific paradigms** that will assist the planning of surgical intervention. Future research will explore other tasks such as story comprehension and rhyming. Furthermore, a bilingual fMRI study has been completed and will be developed for clinical application.

Limitations

This study was conducted with a limited sample of healthy participants.

Patients with brain tumours may exhibit altered patterns of language activation due to factors such as neurovascular uncoupling or functional reorganisation (Binding et al., 2022).

Further studies involving larger sample and the patient population are required to validate the clinical applicability of the sentence completion task in pre-surgical language mapping.

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