TECHNICAL COMMENTARY

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Magnetoencephalography

Introduction

Magnetoencephalography (MEG) uses a helmet-shaped device containing MEG sensors (gradiometers) to noninvasively measure the magnetic fields produced by neural activity of the brain. MEG is able to localise the source of neural activity to particular brain regions, represented as positive and negative charges (dipoles), with greater accuracy than EEG, which is a measure of the electrical fields produced by neural activity. MEG can be used to measure continuous resting-state brain activity (spontaneous MEG), but also to assess event-related changes in brain activity (ERP). The evidence included in this summary relates only to spontaneous MEG, as there are not yet any reviews available that assess the ERP response.

Spontaneous MEG reflects neural activity in particular brain regions and across a range of frequencies: delta activity (up to 4 Hz) is slow wave activity normally seen during deep sleep only in healthy individuals; theta activity (4 to 7 Hz) is often seen during drowsiness and early stages of sleep; alpha activity (8 to 12 Hz) commonly occurs during a state of relaxed wakefulness in healthy adults, particularly when eyes are closed; beta activity (13 to 30 Hz) of low amplitude occurs during intense concentration and mental activity; and gamma activity (30 to 80+ Hz) occurs during certain cognitive and motor functions. Change in activity is assessed as a dipole density, which measures the representation of each type of wave within a particular region.

MEG may be used to identify patterns of neural activity in people with schizophrenia, as well as identify locations of functional abnormalities based on topographical organization and frequency bands.

Method

We have included only systematic reviews (systematic literature search, detailed methodology with inclusion/exclusion criteria) published in full text, in English, from the year 2000 that report results separately for people with a diagnosis of schizophrenia, schizoaffective disorder, schizophreniform disorder or first episode schizophrenia. Reviews were identified by searching the databases MEDLINE, EMBASE, CINAHL, Current Contents, PsycINFO and the Cochrane library. Hand searching reference lists of identified reviews was also conducted. When multiple copies of reviews were found, only the most recent version was included. Reviews with pooled data are prioritised for inclusion.

Review reporting assessment was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, which describes a preferred way to present a meta-analysis[1]. Reviews with less than 50% of items checked have been excluded from the library. The PRISMA flow diagram is a suggested way of providing information about studies included and excluded with reasons for exclusion. Where no flow diagram has been presented by individual reviews, but identified studies have been described in the text, reviews have been checked for this item. Note that early reviews may have been guided by less stringent reporting checklists than the PRISMA, and that some reviews may have been limited by journal guidelines.

Evidence was graded using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group approach where high quality evidence such as that gained from randomised controlled trials (RCTs) may be downgraded to moderate or low if review and study quality is limited, if there is inconsistency in results, indirect comparisons, imprecise or sparse data and high probability of reporting bias. It may also be downgraded if risks associated with the intervention or other matter under review are high. Conversely, low quality evidence such as that gained from observational studies may be upgraded if effect sizes are large or if there is a dose dependent

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response. We have also taken into account sample size and whether results are consistent, precise and direct with low associated risks (see end of table for an explanation of these terms)[2]. The resulting table represents an objective summary of the available evidence, although the conclusions are solely the opinion of staff of NeuRA (Neuroscience Research Australia).

Results

We found one systematic review that met our inclusion criteria[3].

- Moderate to low quality evidence suggests increased bilateral delta and theta wave activity in the frontal, temporo-parietal and occipital cortices of people with schizophrenia, which appear to be particularly associated with positive symptom severity. Beta activity was reportedly increased in frontal and temporo-parietal regions, and changes in alpha and gamma activity were unclear.

Siekmeier PJ, Stufflebean SM

Patterns of spontaneous magnetoencephalographic activity in patients with schizophrenia

Journal of Clinical Neurophysiology 2010; 27(3): 179-190

View review abstract online

Comparison	**Comparison of spectral wave activity (delta, theta, beta and gamma waves) across different brain regions in people with schizophrenia vs. controls.**
Summary of evidence	**Moderate to low quality evidence (small to medium-sized samples, unable to assess consistency or precision, direct) suggests increased bilateral delta and theta activity in the frontal, temporo-parietal and occipital cortices of people with schizophrenia, which appears to be particularly associated with positive symptom severity. Beta activity was reportedly increased in frontal and temporo-parietal regions, though changes in alpha and gamma activity were unclear.**

Spectral dipole density

Delta and theta (slow wave) dipole density;

Ten studies (N = 346) reported increased delta and theta activity in the temporo-parietal cortex of both medicated and unmedicated schizophrenia compared to controls. One study (N = 70) also reported a dose-dependent relationship between dipole density and medication dose.

Three studies (N = 112) reported increased delta and theta activity in the frontal lobe (including prefrontal cortex) in schizophrenia compared to controls, though one additional study (N = 40) reported reduced delta and theta activity in frontal cortex.

One study (N = 48) reported increased delta and theta activity in the occipital cortex.

Increased delta and theta activity (in either temporal or frontal lobe regions) was correlated with increased general symptom severity (measured by PANSS) in two studies (N = 19), particularly positive symptoms in six studies (N = 114) and negative symptoms in one study (N = 30).

Alpha, beta and gamma dipole density;

Two small studies (N = 36) reported significantly reduced alpha activity in the temporo-parietal cortex; though one larger study (N = 40) reported a trend for increased alpha activity across the brain.

Four studies (N = 154) reported increased beta activity in the temporo-parietal cortex, and three of these (N = 130) also reported increased beta in the frontal cortex.

Magnetoencephalography

One small study investigated gamma activity (N = 30) and reported decreased gamma-1 (30 – 45Hz) in *left* frontal and temporal cortices and increases in gamma-2 (46 – 60Hz) and 3 (61 – 71Hz) in *right* frontal and temporal cortices. Increased beta activity (in either temporal or frontal lobe regions) was correlated with increased negative symptom severity (thought disorder) in one study (N = 20), but no association was reported with positive symptoms in one study (N = 20).	
Consistency in results‡	No measure of consistency is reported.
Precision in results§	No confidence intervals are reported.
Directness of results‖	Direct

Explanation of acronyms

MEG = magnetoencephalography, N = number of participants, *p* = statistical probability of obtaining that result ($p < 0.05$ generally regarded as significant), PANSS = Positive and Negative Syndrome Scale, vs = versus

Explanation of technical terms

* Bias has the potential to affect reviews of both RCT and observational studies. Forms of bias include; reporting bias – selective reporting of results; publication bias - trials that are not formally published tend to show less effect than published trials, further if there are statistically significant differences between groups in a trial, these trial results tend to get published before those of trials without significant differences; language bias – only including English language reports; funding bias - source of funding for the primary research with selective reporting of results within primary studies; outcome variable selection bias; database bias - including reports from some databases and not others; citation bias - preferential citation of authors. Trials can also be subject to bias when evaluators are not blind to treatment condition and selection bias of participants if trial samples are small[4].

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† Different effect measures are reported by different reviews.

Prevalence refers to how many existing cases there are at a particular point in time. Incidence refers to how many new cases there are per population in a specified time period. Incidence is usually reported as the number of new cases per 100,000 people per year. Alternatively some studies present the number of new cases that have accumulated over several years against a person-years denominator. This denominator is the sum of individual units of time that the persons in the population are at risk of becoming a case. It takes into account the size of the underlying population sample and its age structure over the duration of observation.

Reliability and validity refers to how accurate the instrument is. Sensitivity is the proportion of actual positives that are correctly identified (100% sensitivity = correct identification of all actual positives) and specificity is the proportion of negatives that are correctly identified (100% specificity = not identifying anyone as positive if they are truly not).

Weighted mean difference scores refer to mean differences between treatment and comparison groups after treatment (or occasionally pre to post treatment) and in a randomised trial there is an assumption that both groups are comparable on this measure prior to treatment. Standardised mean differences are divided by the pooled standard deviation (or the standard deviation of one group when groups are homogenous) which allows results from different scales to be combined and compared. Each study's mean difference is then given a weighting depending on the size of the sample and the variability in the data. Less than 0.4 represents a small effect, around 0.5 a medium effect, and over 0.8 represents a large effect[4].

Odds ratio (OR) or relative risk (RR) refers to the probability of a reduction (< 1) or an increase (> 1) in a particular outcome in a treatment group, or a group exposed to a risk factor, relative to the comparison group. For example, a RR of 0.75 translates to a reduction in risk of an outcome of 25% relative to those not receiving the treatment or not exposed to the risk factor. Conversely, a RR of 1.25 translates to an increased risk of 25% relative to those not receiving treatment or not having been exposed to a risk factor. A RR or OR of 1.00 means there is no difference between groups. A medium effect is considered if RR > 2 or < 0.5 and a large effect if RR > 5 or < 0.2[5]. lnOR stands for logarithmic OR where a lnOR of 0 shows no difference between groups. Hazard ratios

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measure the effect of an explanatory variable on the hazard or risk of an event.

Correlation coefficients (eg, *r*) indicate the strength of association or relationship between variables. They can provide an indirect indication of prediction, but do not confirm causality due to possible and often unforseen confounding variables. An *r* of 0.10 represents a weak association, 0.25 a medium association and 0.40 and over represents a strong association. Unstandardised (*b*) regression coefficients indicate the average change in the dependent variable associated with a 1 unit change in the independent variable, statistically controlling for the other independent variables. Standardised regression coefficients represent the change being in units of standard deviations to allow comparison across different scales.

‡ Inconsistency refers to differing estimates of effect across studies (i.e. heterogeneity or variability in results) that is not explained by subgroup analyses and therefore reduces confidence in the effect estimate. I^2 is the percentage of the variability in effect estimates that is due to heterogeneity rather than sampling error (chance) - 0% to 40%: heterogeneity might not be important, 30% to 60%: may represent moderate heterogeneity, 50% to 90%: may represent considerable heterogeneity and over this is considerable heterogeneity. I^2 can be calculated from Q (chi-square) for the test of heterogeneity with the following formula[4];

$$I^2 = \left(\frac{Q - df}{Q}\right) \times 100\%$$

§ Imprecision refers to wide confidence intervals indicating a lack of confidence in the effect estimate. Based on GRADE recommendations, a result for continuous data (standardised mean differences, not weighted mean differences) is considered imprecise if the upper or lower confidence limit crosses an effect size of 0.5 in either direction, and for binary and correlation data, an effect size of 0.25. GRADE also recommends downgrading the evidence when sample size is smaller than 300 (for binary data) and 400 (for continuous data), although for some topics, these criteria should be relaxed[6].

‖ Indirectness of comparison occurs when a comparison of intervention A versus B is not available but A was compared with C and B was compared with C, which allows indirect comparisons of the magnitude of effect of A versus B. Indirectness of population, comparator and/or outcome can also occur when the available evidence regarding a particular population, intervention, comparator, or outcome is not available and is therefore inferred from available evidence. These inferred treatment effect sizes are of lower quality than those gained from head-to-head comparisons of A and B.

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