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Summary

The human brain weighs approximately 3 lbs and consumes 40–60%

of blood glucose. This disproportionate amount of energy is used to create electricity in

approximately 100 billion interconnected neurons. Quantitative EEG is a real-time movie of

the electrical activity of the preconscious and conscious mind at frequencies of approximately

1–300 Hz. Numerous studies have cross-validated electrical neuroimaging by structural MRI,

functional MRI and diffusion spectral imaging and thereby demonstrated how quantitative

EEG can aid in linking a patient’s symptoms and complaints to functional specialization in the

brain. Electrical neuroimaging provides an inexpensive millisecond measure of functional

modules, including the animation of structures through phase shift and phase lock. Today,

neuropsychiatrists use these methods to link a patient’s symptoms and complaints to

functional specialization in the brain and use this information to implement treatment via

brain–computer Interfaces and neurofeedback technology.

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Review

Robert W Thatcher

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Neuropsychiatry and quantitative

EEG in the 21st Century

Practice points



Use conventional clinical evaluation to derive a diagnosis and identify patient symptoms.



Measure eyes open and eyes closed artifact-free quantitative EEG.



Calculate auto- and cross-spectra to identify scalp locations and network deviations from normal.



Use EEG tomography to link the patient’s symptoms and complaints to functional systems in the brain.



Identify and separate the ‘weak’ systems from compensatory systems.



Use Z-score biofeedback to target the deregulated brain subsystems to reinforce optimal and homeostatic

states of function while the clinician monitors the patient’s symptom reduction.



Use quantitative EEG to evaluate pre- versus post-treatment and follow-up evaluations to determine

treatment efficacy (e.g., medications, repetitive transcranial magnetic stimulation, electroconvulsive therapy,

brain–computer interfaces and biofeedback, among others).

Neuropsychiatry

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eview

Thatcher

EEG is the measurement of the brain-gener

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ated electrical potential between locations on

the scalp and/or with respect to a reference.

Quantitative EEG (qEEG) invovles the use

of computers to precisely quantify electrical

potentials of approximately 1–300

Hz, repre

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senting subsecond measures of summated local

field potentials generated in groups of cortical

pyramidal neurons

[1]

. In the last 40

years, over

90,000 qEEG studies have been listed in the

National Library of Medicine’s database

[201]

.

To review this vast literature, it is best to use the

search terms ‘EEG and x’ where ‘x’ is a topic such

as schizophrenia, dyslexia, attention deficit, reli

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ability, validity, obsessive–compulsive dis

orders,

evidenced-based medicine, anxiety or phobia,

among others. A reading of the studies and

abstracts shows that the vast majority of these

studies are qEEG studies involving computer

analyses (e.g., spectral analyses, ratios of power,

coherence or phase, among others). The search

term ‘EEG’ and not ‘qEEG’ is necessary because

the National Library of Medicine searches arti

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cle titles/abstracts, and these rarely if ever use

the term ‘qEEG’ in the title (e.g., this author

has published six books and over 200 total

publications and never used the term ‘qEEG or

QEEG’ in the title or abstract). This is why a

small ‘q’ is used in this paper to emphasize that

the summation of electrical potentials generated

by pyramidal neuron synapses are the sources of

the EEG and the ‘q’ designates quantification

as opposed to ‘eye-ball’ or visual examination

of the EEG traces or squiggles without quanti

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fication as used in clinical routine. This article

is written with a special emphasis on the use of

qEEG after visual examination by psychiatrists,

neuropsychiatrists, clinical psychologists, psy

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chologists, neuro

psychologists and neuroscien-

tists who are the primary users and publishers of

psychiatric-related articles using qEEG.

Historically, visually recognized EEG pat

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terns and other electrophysiological measures

(evoked potentials and event-related potential)

were used to discern etiological aspects of brain

dysfunction related to psychiatric disorders

with reasonable success, but not at the level that

qEEG can be used as a standalone diagnostic

method for psychiatric disorders

[2]

. Instead,

qEEG was used as an indicator of organicity or a

physiological etiology of unknown origin similar

to how a clinical blood test is used as well as an

objective evaluation of treatment efficacy upon

follow-up. In the 1960s and 1970s, prior to the

advent of MRI or PET scans or modern knowl

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edge of brain function, it was speculated that the

development of large qEEG databases of patients

with different clinical disorders will result in the

development of qEEG diagnostic measures that

provide indications of psychiatric disorders

[3]

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However, it was quickly shown that only a sta

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tistical approach is feasible due to the number of

measures and the fact that the EEG changes with

age. As a consequence, age regression and strati

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fied reference normative databases were devel

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oped by Matousek and Petersen in 1973

[4,5]

and

later by John

[3,6–8]

, Duffy

[9]

, Thatcher

[10]

and

Congedo and Lubar

[11]

, among others

[12–17]

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The Stockholm, Sweden, norms of Matousek

and Petersen were independently replicated by

John and collaborators in New York, USA

[3,6]

.

Subsequent replications of different qEEG nor

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mative databases demonstrated the statistical

stability and value of using reference normative

databases to aid in identifying deviant EEG fea

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tures and in linking the location of deviant fea

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tures to symptoms and complaints

[2–8,12,16,18]

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The reference database provides a statistical

match to reliable quantitative features available

in the 1970s and 1980s. However, the spectral

methods in the 1970s relied upon the Fourier

transform that did not have sufficient temporal

resolution to measure high-speed dynamics such

as rapid shifts in phase differences and phase

lock. This problem was solved in the late 1980s

with the application of joint time–frequency

analysis (JTFA), where a time series of real-

time measures of phase differences is produced.

JTFA provided precise measures of phase shift

and lock durations across the human lifespan

for all combinations of the ten- or 20-electrode

systems and normative JTFA databases that were

soon developed

[12,19]

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Efforts are still being undertaken in a few labo

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ratories to record and classify qEEG from thou

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sands of patients with the belief that a standalone

diagnosis can be developed for different psychiat

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ric disorders. However, as explained by John

[2,3]

and Duffy

[9]

, it is unlikely that qEEG can serve

as a standalone diagnostic measure no matter how

large the databases. For example, meta-analyses

of evidenced-based medicine criteria only show

moderate to strong effect sizes for particular EEG

features in schizophrenia

[4]

and obsessive–com

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pulsive disorder, post-traumatic stress disorder,

panic disorder, generalized anxiety disorder and

phobias

[2,20–22]

. This scientific literature shows

that there are a wide variety of different changes