THE EFFICACY OF AN ONLINE LEARNING TOOL IN IMPROVING EEG ANALYSIS AND INTERPRETATION SKILLS OF TECHNOLOGISTS, NEUROLOGY REGISTRARS AND NEUROLOGISTS

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DECLARATION

This dissertation is the original and independent work of the MMed Neurology candidate, Dr Melody T. Asukile. Neither the whole work nor any part of it has been or is to be submitted for another degree to another university. This work has not been reported or published prior to registration for this MMed degree.

This dissertation has been submitted to the Turnitin module and I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.

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ACKNOWLEDGEMENTS

I would like to acknowledge the guidance of my MMed supervisors, Dr Lawrence Tucker and Dr Charle Viljoen in conducting this study, analysing the data and drafting the manuscript. I would also like to acknowledge the EEG*online* tutors, Prof. Roland Eastman and Dr. Edward Lee Pan for their contributions to the study design, conduct and manuscript draft.

I am immensely grateful for the financial support provided by my sponsors, the Mandela Rhodes Foundation, and the Beit Trust in conjunction with the University of Cape Town, without whom I would not have had the opportunity to pursue this MMed.

I am eternally grateful to my husband Bulaya and my daughter Bukose for their patience and unwavering support during the process of completing this study.

ABSTRACT

Background

Scalp electroencephalography (EEG) remains an invaluable neurophysiological tool in supporting the diagnosis and management of epilepsy and encephalopathy, however, most sub-Saharan countries have very few neurologists per population for EEG analysis and training. Web-based, distance learning programs may provide effective electroencephalogram (EEG) training in resource-poor settings. EEG*online* is an interactive, web-based, 6-month multi-modality, learning program designed to teach basic principles and clinical application of EEG. This study aimed to determine the effectiveness of EEG*online* in improving EEG analysis and interpretation skills for neurologists, neurology residents and technologists, particularly in resource-limited settings.

Methods

Between June 2017 and November 2018, 179 learners were registered on the EEG*online* course. Of these, 128 learners originating from 20 African countries, Europe, the UK and USA participated in the study. Pre- and post-course multiple-choice question (MCQ) test results and EEG*online* user logs were analyzed. Differences in pre- and post-test performance were correlated with quantified exposure to various EEG*online* learning modalities. Participants' impressions of EEG*online* efficacy and usefulness were assessed through pre- and post-course perception surveys.

Results

Ninety-one participants attempted both pre- and post-course tests. Mean scores improved from 46.7% ± 17.6% to 64.1% ± 18% respectively ($p<0.001$, Cohen's *d* 0.974). Almost all participants improved regardless of the amount of course material used, however those who used more, tended to have higher scores. The largest percentage-improvement was in the correct identification of normal features (43.2% to 59.1%, $p<0.001$, Cohen's *d* 0.664) and artefacts (43.3% to 61.6%, $p<0.001$, Cohen's *d 0.836*). Improvement in competence was associated with improvement in subjective confidence in EEG analysis. Overall confidence among 72 survey respondents improved significantly from 25.3% to 64.8% ($p<0.001$). Lecture notes, end-of-module self-assessment quizzes and discussion forums were the most utilised learning modalities. The majority of survey respondents (97.2%) concluded that EEG*online* was a useful learning tool and 93% recommended that similar courses should be included in EEG training curricula.

Discussion

Almost all participants showed significant improvement in EEG analysis competence (MCQ test scores) and confidence (survey responses) following the educational intervention, regardless of the amount of course material used. Improved identification

of normal features and artefacts is particularly useful as it reduces the risk of misdiagnosis which can cause harm. The EEG*online* course employed several learning techniques, through its multi-modality format, that may have contributed to the improvement observed, including, self-directed learning, cognitivism, collaborative learning, contextual learning and reflective learning. Subjective confidence likely correlates with competence and may be useful to gauge learners' needs and levels of understanding about a subject. Learning preferences vary among adult learners, it is unclear if one learning modality (that is, video, audio, lecture notes, epoch activities, discussion forums) is superior to others, but it seems as though a multi-modal approach may be the most sensible.

Conclusions

This study demonstrated that a multi-modal, online EEG teaching tool was effective in improving EEG analysis and interpretation skills and may be a useful supplement for EEG teaching especially in resource-poor settings. Given the optimistic findings of this study, we encourage the development and evaluation of further online neurology teaching tools.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

Background

What is the EEG?

EEG (electroencephalography) is a neurophysiological investigation that utilises electrodes placed on the scalp or, occasionally, implanted surgically onto the surface of the cerebral cortex, to measure spontaneous electrical activity generated within the brain.(1) This electrical activity is processed and represented on a screen which allows for interpretation. More advanced EEG techniques may incorporate magnetic resonance imaging (MRI), called magneto-encephalography (MEG) but this is typically reserved for research purposes. Specific and non-specific EEG abnormalities are associated with neurological conditions including the various epilepsy syndromes, as well as infectious, metabolic, and immune-related encephalopathies.

Although the diagnosis of neurological diagnoses such as epilepsy and encephalopathy remain clinically-based, electroencephalography (EEG) is a very useful neurophysiological tool when used to support these clinical diagnoses.(2) It is helpful in identifying focal brain dysfunction which may not be detectable on brain imaging, and may also assist in grading the severity of encephalopathy arising from various infectious, inflammatory and metabolic causes. Furthermore, EEG is especially useful in differentiating specific inherited epilepsy syndromes from epilepsy caused by brain injury.(3) Prolonged Video-EEG monitoring is critical in the work up for epilepsy surgery(4,5) and may also be useful in the diagnosis of psychogenic non-epileptic seizures (PNES), a condition in which delayed diagnosis may be extremely disabling and costly for the patient.(6) Thus, in good hands, EEG can be of immense benefit but where used by inexperienced electroencephalographers, it may result in misdiagnosis and serious harm.(6,7) Misdiagnosis may result in a patient being incorrectly diagnosed with a chronic medical condition. Misdiagnosis of epilepsy, in particular, has serious negative consequences, as patients with this condition are subject to numerous restrictions, which include driving motor vehicles, piloting aeroplanes, operating heavy machinery, working at heights or near deep water, swimming and bathing. A diagnosis of epilepsy also commonly results in stigmatisation. Significantly, misdiagnosed patients are subjected to inappropriate,

chronic or even life-long anti-epileptic medication that may be associated with serious cognitive and physical side effects.

The interpretation of EEG traces is subject to human judgement and must be interpreted in the clinical context of the individual patient(8) and current automated seizure detection software has low sensitivity, especially for focal seizures. In a study on automated seizure detection by Gonzalez Otarula et al, electrographic seizures (seizures documented on EEG) were only detected in 53% of patients, with a higher detection rate for generalised seizures (70%) versus focal seizures (46%).(9) In some developed countries such as the UK, EEG interpretation is recognised as a specialty independent from clinical neurology.(10,11) In contrast, in Africa and other resource-poor regions, where the ratio of neurologists and neurophysiologists to the population is low (0.04 adult neurologists per 100 000 population)(12), EEG analysis and interpretation are regarded as essential skills for practicing neurologists. Although EEG machines are now more affordable and widely available in Africa and other resource-limited countries (13), there are few centres on the continent where the skills necessary to perform, read and clinically apply EEG can be learnt.(12,14) Thus innovative and sustainable methods of improving the access to quality EEG training is urgently needed in these resource-limited regions.

EEG training

There is little data regarding specialist neurology and EEG training in Africa and most information available is anecdotal. For instance, a survey of participants from 22 African countries attending a recent neurology training meeting in Sudan in 2015, revealed that only eleven of the nineteen countries represented had formal neurology training programs. Moreover, only six of those neurology training programs included formal training in practical EEG skills, while six included only basic EEG skills training and two had no EEG training at all.(15) It is clear that the need for EEG training in Africa currently far exceeds the capacity of EEG training centres on the continent.

Traditionally, EEG interpretation has been taught through didactic face-to-face lectures and tutorials, usually guided by an EEG expert, in which learners often analyse EEGs under supervision. This remains the most common form of EEG teaching in South Africa, but it is expensive in terms of instructor time. Furthermore,

there is little literature confirming the efficiency and effectiveness of this traditional method of instruction. Several learning theories may be incorporated in this traditional method of teaching. The **cognitivist model** encourages learners to acquire knowledge by understanding concepts and internally processing information presented to them.(16) Face-to-face tutorials allow learners to interact in real-time with their tutors and ask questions to clarify their understanding of concepts. However, the student-teacher interaction and outcomes are dependent on the individual learner.(17) Face-to-face teaching also incorporates the **behaviorist learning model**. This model uses a tutor-centered approach, as it is up to the teacher to create a learning environment suitable for learners to assimilate information and use that information to develop new competences and change their behavior.(17) Though beneficial for acquiring new skills, the disadvantage is that the learner is dependent on the teacher and may not be provided with much opportunity for self-direction and self-reflection.(18,19)

Alternative methods of EEG training

In recent years, a number of factors, including the need to train more medical professionals and increased student literacy in information technology, has led to the use of computer/ web-based or blended (traditional face-to-face and computer/web-based) methods of instruction in both undergraduate and postgraduate medical training programs.(20) Computer/ web-based learning employs the use of computer applications to aid in teaching. Web based learning, also referred to as e-learning or online learning, incorporates the use of teaching tools available via the Internet. These include discussion forums, live and recorded video and audio lectures, interactive tests and activities, and are usually available online for users to access at any time and from remote geographical locations.(21) In contrast, blended learning, typically refers to the use of a combination of traditional face-to-face teaching together with computer/ technology-assisted methods. However, in his article “Defining Blended Learning”, Friesen highlights several definitions of blended learning that have emerged over time including; a combination of various web-based applications (such as live virtual classrooms, interactive applications, discussion forums); a combination of different learning ideologies (such as cognitivism, behaviorism, constructivism) and a combination of teaching with applied work tasks, as in work-based training.(20)

Computer and web-based teaching programs tend to incorporate multiple teaching techniques in their delivery of information to learners, and this may be an advantage over conventional teaching. In their systematic review and meta-analysis interrogating the efficacy of computer-assisted ECG (electrocardiography) teaching versus face-to-face teaching, Viljoen et al summarize the various learning techniques and theories employed by both methods. These include: Instrumental learning theories comprising **cognitivism** and **constructivism**; Humanistic learning theories of **andragogy** and **self-directed learning**; Social learning theories comprising **collaborative** and **contextual** learning; and **reflective** models.(18) **Cognitivism** is a learning theory that focuses on learners grasping concepts mentally, and not especially on change of behavior resulting from learning. In computer-assisted learning, it is exemplified by the use of multimedia such as audio, video and cartoon animations to explain difficult concepts. **Constructivism** involves learners developing an individual framework of understanding about a concept through self-reflection and critical thinking, a method that may be employed in computer-based teaching through interactive, problem-solving tasks. **Andragogy** refers to adult education and this is closely tied to **self-directed learning** as teaching adults usually requires a degree of freedom and flexibility from the teaching program due to adults' numerous responsibilities. Such methods are ideal for computer/ web-based teaching as learning material is usually accessible to learners at any time, and they can structure their learning to suit their schedules. This type of teaching does not assume that all individuals can grasp concepts at the same pace and allows for self-paced learning and repetition where needed. Additionally, computer-assisted learning may provide various forms of self-assessment and reflection that employs the **reflective model**, a teaching method that may not be so easily adapted to face-to-face teaching. Finally, **collaborative** and **contextual learning** theories are social theories as they incorporate learning from peers and case scenarios respectively. These methods of learning are used during group discussions or team projects and such techniques can be utilized in computer-assisted programs through discussion forums and group projects conducted online. Each of these theories may be employed in both computer-assisted and face-to-face teaching but, as noted previously, it is easier in the computer-assisted approach to incorporate multiple techniques simultaneously.(16–18)

In recent years, web-based teaching tools have been developed for undergraduate and postgraduate medical training programs to teach practical skills, such as physical examination(22), ECG (electrocardiogram) analysis(23,24), surgical techniques(25), and basic and clinical sciences.(26,27) Similar tools have been applied for teaching EEG interpretation through the use of computer-based programs to teach neurology residents the key features of EEGs(28); simulations to demonstrate the effect of anesthesia on the EEG for anesthesiologists(29); and the use of podcasts as an alternative to traditional didactic EEG lectures for neurology residents.(30) These have proven useful supplementary resources in blended EEG teaching programs. The International League Against Epilepsy (ILAE) has also developed several globally accessible web-based tools for the teaching of EEGs and epilepsy.(31) Despite these developments, data evaluating the efficacy of web-based EEG-training of neurologists is sparse. Web-based teaching tools potentially allow for global distribution of medical education and training, which is easily accessible, flexible and geographically independent.(32) Recent meta-analyses support the benefits and non-inferiority of web-based and blended teaching methods, despite significant heterogeneity among studies.(18,33,34) Importantly, by extending faculty availability, web-based teaching tools may be especially useful in resource-limited settings where teachers and face-to-face learning resources are scarce. However, web-based learning remains vulnerable to computer access, availability, reliability and bandwidth of local internet(35), as well as inadequate infrastructure and electricity outages. One proposed solution is the development of mobile smartphone-based applications with minimal data requirements.(36)

EEG*online* course

With the aim of addressing the problems associated with teaching EEG interpretation and analysis skills in South Africa, and more broadly across Africa and other resource-poor geographic areas, the Division of Neurology at the University of Cape Town in collaboration with the World Federation of Neurology (WFN), constructed a comprehensive, web-based, part-time, distance EEG learning program (EEG*online*).

EEGonline consists of 9 teaching modules over 6-months which cover a wide range of subjects regarded as essential basic knowledge for electroencephalographers, including: the neurophysiological basis of electrical signal generation in the brain,

signal processing in EEG machines, electrical safety in the laboratory, normal EEG waveforms in human wakeful and drowsy states, abnormal epileptiform and non-epileptiform waveforms, artefacts, and the use of EEG in the clinical management of patients with epilepsy and encephalopathy.

Distance learning tools utilised by EEG*online* include concise relevant text, interactive EEG epoch activities during which an epoch (segment) of EEG wave activity is comprehensively analysed under direction, custom-made videos and audio-lectures, discussion forums, links to resources on the Internet, and end-of-module quizzes with immediate feedback, after submission of response, of model answers with explanations. Some of the strengths of EEG*online* include the large number of examples of normal and abnormal EEG waveforms, as well as artefacts presented in the learning material; and also its interactivity, regular communication with instructors on the discussion fora, and immediate feedback on frequent self-assessment quizzes.

The EEG*online* course employs several learning techniques, through its multi-modality format. **Self-directed learning**(16,37) is a key feature of this course as learning material is available for learners to access at any time, and past modules remain available throughout the course facilitating independent self-paced study, revision and repetition. The benefit of self-directed learning has been shown to be an advantage over conventional teaching in other domains of medicine where visual analysis plays an integral part in diagnosis, such as electrocardiography (ECG).(38) It also employs **cognitivism** (in which knowledge is acquired through explanation and demonstration)(16,17) through the multi-modal approach with video and audio lectures and also by participant-tutor interactions on discussion forums. The cognitivist theory focuses on helping the learner understand concepts in a way that is adapted to them.(17) **Collaborative learning** is achieved through discussion forums in which participants interact with each other and with tutors as they deliberate over EEG epochs presented to them. Moreover, learners may be divided into smaller groups and provided an EEG problem to solve. This provides the opportunity of learning not only from tutors but also from their peers. In collaborative learning, learners acquire knowledge through interactions with peers and appreciate diverse views on certain topics.(16,18,39,40) The interactive EEG epoch activities allow for **contextual learning**(18,40) as they provide a wide range of examples dealing with various

scenarios in which certain EEG features may be present; additionally in the last module of the course, participants are presented with a clinical scenario, including a patient's clinical history, EEG and ancillary investigation results. and they are then required to formulate an appropriate contextualized EEG report. These learning methods are likely beneficial as they provide learners with the opportunity to review the intricacies of numerous EEG epochs in their own time and at their own pace, which is typically not feasible during the traditional in-person EEG teaching. Finally, immediate-feedback quizzes within the course supported the **reflective model of learning**(16), which allows learners to evaluate themselves and identify areas of weakness as they review explanations for the correct answers. Notably, learners were permitted to repeat the quiz as many times as they wished. This method of learning has been shown, in other studies, to be useful for enhancing learning and improving knowledge acquisition and retention.(38,41) Rather than replacing traditional teaching methods such as face-to-face instruction and the regular use of textbooks and manuals, EEG*online* has been designed to augment these, resulting in a blended approach.

Rationale for study methods

For this study, pre- and post-intervention multiple choice question (MCQ) tests were used to assess learning and acquisition of EEG analysis competence during the course. Pre- and post-test assessments are frequently used in medical education to assess competence. Pre-intervention MCQ tests are recognized as a useful and efficient method of assessing learners' baseline knowledge prior to teaching and post-intervention tests determine how much knowledge has been acquired consequent to the teaching.(42,43) They help both learners and tutors identify strengths and weaknesses, and guide teaching focus areas. Additionally, a post-test will identify which areas need further attention. The presence of pre- and post-training tests may incentivize students to pay more attention to the learning material taught, so that they can perform better after the teaching. Thus, they may serve both as tools for assessment and for learning promotion. This point was demonstrated in a study by Mohanram *et al* in which medical students who received both a pre- and post-test performed better than those who received a post-test alone.(44) Though some studies have demonstrated delayed retention of acquired knowledge in post-tests, particularly

for ECG teaching(45,46), it would be useful to determine whether or not the knowledge and competencies acquired are reflected in daily clinical practice.

Participants were also asked to grade their levels of subjective confidence in EEG analysis using pre- and post-course opinion surveys. Subjective learner confidence may be a useful tool to gauge learner knowledge and serve as a guide for self-directed learning.(47) In a study by Favazzo et al, students who reported high confidence in a particular test question were more likely to get it right. However, they also noted that students' self-rated confidence was higher when they did not have to answer the test questions. Thus they concluded that both confidence rating and responses to test questions are important to accurately assess the level of student knowledge.(48) Another study by Luetsch and Barrows, utilized certainty rating of answers to questions in pre- and post-tests for an online clinical pharmacy course. They demonstrated that student's certainty ratings to questions correlated with correctness of the answers. They concluded that adding certainty ratings provided more comprehensive information about student learning and this could guide individual learning.(43) Therefore, the use of subjective confidence surveys to evaluate the EEGonline learners may be useful in providing holistic information about learners' EEG analysis competence.

An additional aspect of this study was to determine whether or not the amount of course material utilized correlated with final test results, and which learning modalities the learners preferred. There are few studies evaluating the effect that the amount of course material used has on test scores. One study showed that in students who had the option of either attending a face-to-face lecture versus an online video one, majority chose the face-to-face option. And interestingly, the students accessing the online video lectures had comparatively lower test scores.(49) Reviews on learning preferences of adult online learners highlight how individual learning styles and mode of instruction (online vs. in-person) play a role in preferred methods of learning. Moreover, the efficacy of any one particular learning modality (that is, video, audio, discussions etc.) in improving skills is likely dependent on individual learning-style preferences too(50,51). In a study interrogating learner perceptions of online continued professional development training for healthcare workers in sub-Saharan Africa, group discussions and case studies were the most popular, closely followed by

self-paced learning via computer or internet.(35) Others have argued that learning modalities should be selected based on the subject being taught and that a multimodal approach seems sensible in this regard.(19)

Aim

The primary aim of this study was to determine the effectiveness of a web-based learning tool (EEG*online*) in improving learners' (neurologists, neurology registrars and technologists) EEG pattern recognition, analysis and interpretation skills; and by implication, their effective and appropriate use of EEG in clinical practice. EEG*online* can be accessed at *www.studyeegonline.com*

Specific Objectives

The specific objectives of this study were to:

a. Determine whether or not the use of a 6-month, web–based, distance-learning tool (EEG*online*), significantly improved the EEG interpretation skills of learners using pre-intervention and post-intervention multiple choice question (MCQ) tests.
b. Establish whether or not learners who accessed the tool frequently, or spent more time using the tool, performed better than those who accessed the tool infrequently or not at all, as assessed by a pre- and post-intervention MCQ test.
c. Establish whether or not a significant correlation exists between any one or more of the various learning modalities utilised by EEG*online* (e.g. lecture notes, interactive EEG activities, videos, audio-lectures, discussion forums, immediate feedback quizzes) and learners' performance in post-intervention tests.
d. Establish whether or not learners prefer a particular learning modality from the teaching course by reviewing which modality was used the most and which was reported as being most preferred.
e. Determine the learners' competency and confidence in recognition and interpretation of EEG waveforms before and after using EEG*online*; and establish if there is a correlation between their competency and confidence before and after using this learning tool.

f. Determine learners' perceptions of:
   - The benefits and limitations of their pre-intervention EEG teaching and learning methods prior to using EEG*online* (e.g. lectures, supervision, tutorials, textbooks)
   - The usefulness of the EEG*online* course and its contribution, if any, to improving their competency and confidence in EEG pattern recognition, analysis and interpretation.

g. Determine the feasibility of using such a multimodal, web-based distance learning program for supplemental EEG teaching in resource-limited settings.

h. Use the outcomes from this study to improve the EEG*online* learning platform.

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CHAPTER 2: PUBLICATION-READY MANUSCRIPT

Cover letter

Division of Neurology,
Department of Medicine,
Groote Schuur Hospital,
Cape Town.

9th November 2020

Dear Prof. Merino (Editor-in-Chief),

RE: MANUSCRIPT SUBMISSION FOR CONSIDERATION OF PUBLICATION IN NEUROLOGY® JOURNAL

I am sending you our manuscript entitled "Evaluating the Efficacy of an Online Learning Tool for EEG Teaching" by Asukile et al. We would like to have the manuscript considered for publication in the Neurology® journal, under the section Contemporary Issues: Innovations in Education. This study was approved by the University of Cape Town Human Research Ethics committee (HREC 333/2017) as is stated in our methods section.

Our study interrogated the usefulness of an online tool for teaching EEG (electroencephalography) analysis and clinical interpretation for neurology residents, neurologists and technologists. We hoped such a program could be used to expand access to training in regions with very few neurologists such as sub-Saharan Africa.

The study utilized pre- and post-course multiple-choice-question tests and opinion surveys to assess competence and confidence in EEG analysis respectively. Information sheets were sent to all participants and opt-out consent was taken on the online learning platform. The results showed significant improvement in both competence and confidence in the majority of participants. Participants also reported high satisfaction with the course and recommended its use for supplemental EEG teaching.

We believe that this study will be beneficial for the readers of Neurology® as it emphasizes on alternative ways of advancing neurology education and maximizing the use of the limited neurology expertise in sub-Saharan Africa. Additionally, it encourages the use of virtual learning platforms, which is timely as a safe way of learning in light of the COVID-19 pandemic.

I, Dr Melody Asukile, take full responsibility for the data, the analysis, and interpretation and conduct of the research. I have full access to all the data, and the authority to publish it all or in part. All authors have agreed to the conditions noted on the Authorship Agreement Form.

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission to the Neurology®journal.

Your consideration will be highly appreciated, and we look forward to your response.

Sincerely,

Asukile

Dr Melody Asukile
BSC, MB.ChB, FCNeurol(SA)

Title

Evaluating the Efficacy of an Online Learning Tool for EEG Teaching.

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Word count:

Title: 11 words, 68 characters
Abstract: 250 words
Manuscript: 3499 words, 3 tables, 2 figures
Supplemental data: 1 figure, 2 tables
References: 39 references

ABSTRACT

Objective

To determine the effectiveness of a 6-month, interactive, multi-modal, web-based EEG teaching program in improving EEG analysis and interpretation skills for neurologists, neurology residents and technologists, particularly in resource-limited settings.

Methods

Between June 2017 and November 2018, 179 learners were registered on the EEG*online* course. Of these, 128 learners originating from 20 African countries, Europe, the UK and USA participated in the study. Pre- and post-course multiple-choice question (MCQ) test results and EEG*online* user logs were analyzed. Differences in pre- and post-test performance were correlated with quantified exposure to various EEG*online* learning modalities. Participants' impressions of EEG*online* efficacy and usefulness were assessed through pre- and post-course perception surveys.

Results

Ninety-one participants attempted both pre- and post-course tests. Mean scores improved from 46.7% ± 17.6% to 64.1% ± 18% respectively ($p<0.001$, Cohen's *d* 0.974). The largest improvement was in correct identification of normal features (43.2% to 59.1%, $p<0.001$, Cohen's *d* 0.664) and artefacts (43.3% to 61.6%, $p<0.001$, Cohen's *d 0.836*). Improvement in competence was associated with improvement in subjective confidence in EEG analysis. Overall confidence among 72 survey respondents improved significantly from 25.3% to 64.8% ($p<0.001$). Lecture notes, end-of-module self-assessment quizzes and discussion forums were the most utilised learning modalities. The majority of survey respondents (97.2%) concluded that EEG*online* was a useful learning tool and 93% recommended that similar courses should be included in EEG training curricula

Conclusions

This study demonstrated that a multi-modal, online EEG teaching tool was effective in improving EEG analysis and interpretation skills and may be useful in resource-poor settings.

KEY WORDS/ SEARCH TERMS

EEG – electroencephalography/ electroencephalogram, e-learning, medical education, resident training

GLOSSARY

EEG – electroencephalography/ electroencephalogram, MCQ – multiple choice question, ECG – electrocardiography/ electrocardiogram, sSA – sub-Saharan Africa

AUTHOR DISCLOSURES

Dr. Melody Asukile became a tutor on the EEG*online* course after completion of the study.

Dr. Charle Viljoen does not report any disclosures

Dr. Edward Lee Pan is a course tutor on the EEG*online* course.

Prof. Roland Eastman is a course tutor on the EEG*online* course.

Dr. Lawrence Tucker is the course convenor of the EEG*online* course.

INTRODUCTION

Scalp electroencephalography (EEG) remains an invaluable neurophysiological tool in supporting the diagnosis and management of epilepsy and encephalopathy(1). In Africa and other resource-constrained regions, where the ratio of neurologists and neurophysiologists to the population is low (median 0.04 adult neurologists per 100 000 population)(2–4), EEG analysis and interpretation are regarded as essential skills for practicing neurologists.(5)

EEG interpretation is traditionally taught through lectures and face-to-face tutorials by experienced electroencephalographers but there is little literature confirming the efficiency and effectiveness of this method of instruction. Web-based teaching tools potentially allow for medical education and training, which is easily accessible globally, flexible and geographically independent.(6) Recent meta-analyses support the benefits and non-inferiority of web-based and blended teaching methods, despite significant heterogeneity among studies.(7–9)

Recently, web-based teaching tools have been developed for training undergraduate and postgraduate practical skills, such as physical examination(10), ECG (electrocardiogram) analysis(11-13), surgical techniques(13), and basic and clinical sciences.(14,15) Similar tools have been applied to teach EEG interpretation through computer-based programs(16), simulations(17) and podcasts(18), which have proven useful in blended EEG teaching programs.(19)

There are little data evaluating the efficacy of web-based EEG training of neurologists(16), The primary aim of this study was to assess the effectiveness of an online learning tool in improving EEG analysis and interpretation skills of neurologists, neurology residents and technologists.

METHODS

Study design

This was a prospective cohort study of learners registered on EEG*online* (Figure 1), a 6-month, web-based, part-time, distance EEG learning program developed by the University of Cape Town, with World Federation of Neurology (WFN) support. It can be accessed at www.studyeegonline.com.

Participants

All individuals registered on the EEG*online* course were invited to participate in the study. Inclusion criteria were: 1) All neurologists, neurology residents, other medical doctors or medical technologists enrolled on EEG*online* between June 2017 and December 2018; 2) Completion of both pre- and post-course multiple-choice question (MCQ) tests. Data was collected from participants registered on the course during June to December 2017 (Cohort 1); and May to November 2018 (Cohort 2).

After completing a web-based, pre-course MCQ test to establish their baseline EEG analysis knowledge, participants were exposed to course material for six months. Within two weeks of completing the course, they completed a similar post-course MCQ test to assess acquisition of EEG analysis skills. Data collected and contained in EEG*online* participant user logs were used to assess participant use of EEG*online* learning resources, and correlate this with acquisition of EEG analysis and interpretation skills as determined by the two MCQ tests. Additionally, participants completed a pre-course survey regarding EEG teaching resources available to them prior to the course, and a post-course survey concerning their opinions on the usefulness of EEG*online* as an EEG teaching tool and its effectiveness in improving their confidence of EEG interpretation in clinical practice.

The tests

Pre- and post-course MCQ tests were administered electronically and accessed online using a password protected personalized user ID. These consisted of 30 single best-answer MCQs comprising one or more EEG waveforms of interest requiring identification and followed by a stem-question with four answer options, one of which was “I am unsure”. Both tests comprised the same questions presented in a random order for each participant. To test the internal consistency of the test,

two questions were repeated in their exact form, and two additional questions had a stem that was repeated, but with a different EEG epoch. These four questions carried a half mark each. The total MCQ test score was 28 points. EEG waveforms included normal physiological features of wakefulness, sleep and benign variants (nine questions), abnormal non-epileptiform (five questions); and epileptiform (eight questions) waveforms, as well as biological and non-biological artefacts (ten questions) (Figure e-1)**.** EEGs included in the tests were selected as appropriate and representative of the waveforms of interest by five neurologists experienced in EEG analysis. Participants had 60 uninterrupted minutes within which to complete each test on one attempt and were required to complete the applicable test within two weeks of starting and ending the course respectively.

The surveys

Pre-course (survey 1) and post-course (survey 2) opinion surveys were administered electronically. Survey 1 collected basic demographic and EEG competency information of participants using six matrix-type questions. These interrogated participant utilizations of different EEG learning methods and experience in EEG analysis prior to the course, as well as subjective pre-course participant confidence in EEG analysis of various waveforms. Survey 2 comprised three matrix-type questions and asked participants to rate their perceptions of various elements of the course and their post-course confidence in analyzing various EEG waveforms.

The course

The EEG*online* learning platform was constructed and run on a Moodle open-source online-learning management system. The course comprised nine modules of progressively increasing complexity. Topics included: the neurophysiological basis of electrical brain signal generation; signal processing in EEG machines; electrical safety in the EEG laboratory; normal EEG waveforms in wakeful and drowsy states; abnormal epileptiform and non-epileptiform waveforms; biological and non-biological artefacts, and the use of EEG in the clinical management of patients with epilepsy and encephalopathy. Each module lasted between two and four weeks, during the last week of which participants completed an end-of-module, self-assessment quiz with immediate feedback. Access to modules was made available sequentially. Each module comprised lecture notes, custom-made audio and video lectures, interactive

EEG epoch activities, and a discussion forum to which the instructors posted EEG epochs for interpretation and comment by the participants. Three neurologists with EEG experience replied to questions raised by participants, corrected errors, and provided detailed and reasoned interpretation for each epoch. Links were also provided to useful external internet resources where appropriate. Course materials from all completed modules, except end-of-module self-assessment quizzes, remained available to participants throughout the 6-month course. After the last module, participants had one week for revision followed by three end-of-course examinations. The EEG*online* application automatically recorded user log details which were used to analyze frequency of use, and correlated to post-course test outcomes, as well as participants' preferred aspects of the course.

Statistical analysis

All statistical analyses were performed using STATA Version 15.0 (StataCorp, College Station TX) and Microsoft Excel. The Shapiro-Wilk test was used to assess if data were normally distributed. Data were reported using means ± standard deviation (normally distributed continuous variables) or median with interquartile range (non-normally distributed continuous variables), or frequencies and percentages for categorical data. Paired and unpaired t-tests were used to assess within group and between group differences in test scores respectively. Effect size (practical significance) of the differences in pre- and post-test scores was calculated using Cohen's *d,* with values of 0.2, 0.5 and 0.8 indicating small, moderate and large effect sizes respectively. Chi square tests were used to analyze group differences for categorical variables. To measure internal consistency, within group change for the repeat questions was analyzed using the McNemar's test. Significance levels were set at $p < 0.05$.

Standard protocol approvals, registration, and consent from participants

An information sheet was emailed to all prospective EEG*online* users. Opt-out consent was obtained at registration on the EEG*online* website. The University of Cape Town Faculty of Health Sciences Human Research Ethics Committee approved this study (HREC REF: 333/2017).

Data availability

Anonymized study data will be shared with any qualified investigator on reasonable request.

RESULTS

Study population

A total of 179 learners were registered on the EEG*online* course between June 2017 and November 2018, originating from 20 African countries, Europe, the UK and USA of which 128 learners agreed to participate in the study (82 from sub-Saharan Africa). These learners included 53 qualified neurologists, 46 neurology residents, 20 medical technologists, and eight other medical doctors comprising psychiatrists, general physicians and pediatricians. Ninety-one participants (71%) completed both pre- and post-course MCQ tests and were included in the analysis, 37 participants (28.9%) did only one of the tests and were excluded (Table 1). Both cohorts (cohort 1 with 42 (46.2%) participants and cohort 2 with 49 (53.8%) had similar characteristics. Sixteen participants re-enrolled for the course during the second year of this study and only results relating to their first registered course were included.

Prior EEG experience and learning

Study participants' EEG experience varied widely. All technologists reported at least five years' experience in neurophysiology practice including EEGs. Of 67 survey respondents, eight technologists (61.5%) reported analysing EEGs at least once a week compared to 24 (32.4%) qualified and trainee neurologists. This difference did not reach significance (p=0.162) (Table 1).

EEG analysis under expert guidance was the commonest method of EEG learning prior to the course, with 35 of 67 respondents (52.2%) reporting use of this method at least once a month. The second most common method was self-teaching, used at least once a month in 49.2% of respondents. Small group tutorials (38.8%), formal EEG lectures (34.3%), and EEG handbooks (25.4%) were less common methods. The majority of participants (88.1%) reported never using online EEG teaching resources.

EEG analysis competence and confidence

Test scores are presented in Table 2. There was a significant overall improvement in test scores between the pre and post-tests, from 46.7% ± 17.6% to 64.1% ± 18% respectively ($p<0.001$, Cohen's *d* 0.974). The largest improvement was noted amongst neurology residents (44.5% ± 18.4% to 65.8% ± 17.2%, $p<0.001$, Cohen's

d 1.195). Qualified EEG technologists obtained the highest pre and post-test scores (61.3% ± 14.9% to 72.6% ± 11.7%, p=0.006, Cohen's *d* 0.842) (Figure 2).

There was an overall, significant improvement in the identification of specific EEG features between the pre- and post-course tests. The largest percentage-improvement was in the correct identification of normal features (43.2% ± 22.7% to 59.1% ± 25%, p<0.001, Cohen's *d* 0.664) and artefacts (43.3% ± 22.7% to 61.6% ± 21.2%, p<0.001, Cohen's *d* 0.836).

Improvement in competence (test scores) was associated with improvement in subjective confidence in EEG analysis. Overall confidence amongst 72 survey respondents improved significantly from 25.3% before the course to 64.8% (p<0.001). Neurologists and neurology residents reported the largest improvement in confidence from 29% to 68.4% (p=0.006) and from 19.4% to 61.1% (p<0.001) respectively. Improvement amongst technologists and other doctors was non-significant (Figure 2). Improvement in confidence was greatest for abnormal non-epileptiform waveforms (13.2% to 60.4%, p<0.001) and normal EEG variants (19.8% to 60.4%).

We did not specifically measure delayed retention of knowledge. However, some learners chose to re-enrol on EEG*online* for extended access to course material. Five of seven participants, who re-enrolled on the course, and repeated a pre-course test 6 months after completing the post-course test, showed sustained improvement in their scores (p=0.008) from their base-line pre-course test scores (Mean score Pre-test 44.6%, Post-test 66.8%, Repeat pre-test 57.1%).

Internal consistency

In both the pre- and post-tests, there was no statistically significant difference between the answers provided for the repeat questions, which confirmed internal consistency.

Use of EEG*online* learning modalities

Of the EEG*online* learning modalities, lecture notes were most utilised with 95.6% of participants accessing at least half this learning material. End-of-module self-

assessment quizzes were the next most frequently utilised, followed by discussion forums, although only 53.8% of participants actually contributed to the discussions. Approximately half the participants accessed 50% or more of the interactive EEG epoch activities and audio lectures, and 39.6% of the video lectures, while 91% of the participants completed the end-of-course examinations (Table 3). There were no significant differences of patterns of use of the various learning modalities between qualified participants (neurologists + technologists) and trainees (neurology residents). No participants accessed all resources of the course, and only 29.7% of participants accessed more than 50% of all the learning material.

Total use of EEG*online* course materials was crudely measured using “hits” made on the various learning resources throughout the course. The participants were divided into very infrequent (<500 hits), infrequent (500-999), frequent (1000 – 1999) and very frequent (>2000) users. The majority of participants (63.7%) were frequent and infrequent users (Table 3). All participants, regardless of the number of their hits on the course, showed improvement in test scores. Frequent users showed the largest percentage improvement between the two tests. However, the difference between the various user groups did not reach significance. A more significant improvement was noted in participants who accessed at least 50% of any particular learning modality, demonstrated by larger effect size, Cohen’s *d* values. Those who attempted at least one final examination showed a higher percentage-improvement than those who did not (69.4% vs 2.9%, p=0.016). Seven participants (four qualified neurologists, two neurology residents and one technologist) did not attempt any of the three final examinations.

Of those who attempted the final course examinations (n=84), a significant difference (p=0.001) in examination scores was noted between participants who had covered at least 50% of all learning material (mean score 67.2% ± 14.08) versus those who had not (mean score 54.7% ±16.1). Similar findings were noted for individual learning modalities, with better exam scores for participants who utilised at least 50% of lecture notes (59.1% vs 41%, p=0.15), audio lectures (62.1% vs 54.1%, p=0.022), videos (63.8% vs 55.2%, p=0.02), epoch activities (63.3% vs 52.2%, p=0.002) and in-course quizzes (61.4% vs 43.7%, p=0.001).

Mean final examination scores of study participants (58.85% ± 16.20, n=84) were not significantly different (p=0.517) from those of non-participants (61.30% ± 16.22, n=24).

Perceptions of the course

Of 72 survey respondents, 94.4% reported subjective improvement in their EEG analysis and interpretation, 93.1% reported reduced EEG misinterpretation and 87.5% reported improved ability to differentiate normal from pathological waveforms. Out of 71 respondents, 87.3% reported a change in their approach to EEG interpretation, 85.9% reported improvement in their ability to interpret EEGs independently and approximately 70% (69% and 71.8% respectively) reported that the course had improved their ability to manage patients clinically and teach EEG analysis to others.

Lecture notes were graded as the most useful teaching tool on a scale of 1 to 9 (69.3% graded these 8 or 9), closely followed by quizzes (65.3%), epoch activities (64%) and audio/video lectures (both 62.7%).

Most survey respondents (97.2%) concluded that EEG*online* was a useful learning tool and 93% recommended that courses like EEG*online* should be included in EEG training curricula and considered for other aspects of neurology training such as electromyography and neuroradiology.

DISCUSSION

This study evaluated the effectiveness of an online learning tool in improving EEG analysis and interpretation skills of neurologists, neurology residents and technologists by comparing the results from pre- and post-course MCQ tests. Almost all participants showed significant improvement in EEG analysis competence (MCQ test scores) and confidence (survey responses) following the educational intervention, regardless of the amount of course material used. However, those who utilized the course more showed a larger improvement in test scores. Improvement was largest in the identification of normal EEG features and artefacts. The majority of participants reported subjective improvement in EEG analysis competence and felt that these skills would positively impact their clinical practice and recommended the course as an adjunct to traditional EEG teaching.

This EEGonline course employed several learning techniques that may have contributed to this improvement. **Self-directed learning**(20,21) was a key feature, as learning material was accessible to learners at any time. Past modules remained available throughout the course facilitating independent self-paced study and allowing for revision and repetition. Benefits of self-directed learning have been shown to be advantageous over conventional teaching in domains of medicine where visual analysis plays an integral role in diagnosis, such as electrocardiography (ECG).(9) In this course, **cognitivism** (in which knowledge is acquired through explanation and demonstration)(20,22) was employed through video, audio lectures and participant-tutor interactions on discussion forums. **Collaborative learning**(9,20,23,24) was achieved through discussion forums in which participants interacted with each other and with tutors as they considered EEG epochs presented to them. This provided learning opportunities from both tutors and peers. Interactive-epoch activities allowed for **contextual learning**(9,24) by providing a wide range of examples involving different scenarios in which certain EEG features may present. Finally, frequent immediate-feedback quizzes within the course supported the **reflective model of learning**(20), in which learners could evaluate themselves, identify areas of weakness with explanations provided and chose to repeat the quiz to improve scores. This method of learning was preferred by many of the participants in our study, and previous studies have shown it to enhance learning and improve knowledge acquisition and retention.(9,26)

Participants made most use of lecture notes, immediate feedback quizzes and discussion forums. A review on learning preferences of adult online learners has highlighted how individual learning styles and mode of instruction (online vs. in-person) play a role in preferred methods of learning(27). In our study, improvement in participant test scores was greatest in those who accessed the course material more often. However, we found that any exposure to the course resulted in improved scores. The study was not powered to determine which learning modality was most effective but this, too, may be dependent on individual learning-style preferences.(28) Others have argued that learning modalities should be selected based on the subject being taught and a multimodal approach seems sensible(29). Differences in baseline and post-course scores per modality could be due to individual biases to certain modalities and thus reflect the performance of particular groups of individuals rather than the effectiveness of the learning modality. It is also possible that once participants were registered on the course, they increased their exposure to EEGs in their practice, thus improving their analysis abilities. It would be useful to further interrogate which methods of instruction are most effective or preferred in delivering online EEG teaching.

In the pre-course MCQ tests, most participants identified abnormal epileptiform waveforms more easily than normal features and artefacts. In some instances, the latter were incorrectly interpreted as abnormal, which highlights a major challenge faced by electroencephalographers: the misinterpretation of normal variants, physiological waveforms and artefacts as epileptiform or evidence of encephalopathy. This may result in serious harm such as long-term, inappropriate, anti-epilepsy treatment and social restrictions.(30) Poor EEG training is often cited as an important reason for EEG misinterpretation(31) and it is reassuring that correct identification of normal variants, physiological waveforms and artefacts improved significantly in the study participants. Especially as pre-course surveys indicated that they were least confident about identifying these waveforms. This confidence significantly improved after the course and was associated with correspondingly improved test scores. Our comparison of subjective confidence levels vs. test scores suggested that learners were fairly accurate judges of their individual strengths and weaknesses. One study found that students who reported high confidence in a particular test question were more likely to get it right(32).

Another study suggested that subjective confidence of learners could be used as a useful guide for self-directed learning.(33) Although our study did not directly assess delayed retention of acquired knowledge after the course, previous studies into online ECG training have shown sustained retention(34,35) and it seems likely that EEG, which requires comparable aptitude for pattern recognition, would show similarly sustained knowledge retention.

The majority participation from Sub-Saharan Africa provided a good distribution of participants from lower-, middle- and upper-income regions enabling us to gauge the feasibility and usefulness of an online EEG teaching tool especially for resource-limited regions with reduced access to neurophysiology laboratories and experienced EEG teachers. Other studies have supported the use of virtual learning platforms to increase access to specialist teachers in these settings.(36,37) Additionally, almost equal participation from neurology residents and qualified neurologists suggested that even qualified neurologists perceived the need to improve EEG skills, although we did not directly interrogate the reasons for this observation. A recent study evaluating perceptions of online learning for continued professional development in sub-Saharan Africa among health-care workers concluded that the majority preferred internet-based learning.(37) Some of the benefits reported by this and other studies include self-direction, self-pacing, flexibility and self-reflection through assessments and discussions.(37–39)

Limitations

Learners who chose not to participate in the study may have altered the outcomes. We did not further analyse these non-participants' utilisation of learning materials and whether this may have played a role in their decision not to complete the tests. However, it was noted that final examination scores of both study participants and non-participants were similar. Similarly, not all participants responded to the surveys and it is possible that those who did not comment may have had negative perceptions about the course.

This study was internally controlled with no control group receiving conventional teaching alone for comparison. Furthermore, there may have been performance bias as we could not control for exposure to EEG teaching independent of the EEGonline

learning intervention during the study period. Therefore, we cannot comment on whether EEGonline is inferior, non-inferior or superior to conventional teaching, and if supplemental EEG analysis or teaching during the course may have contributed to the improved test scores. Our goal was to propose an online teaching tool to supplement, rather than replace, conventional EEG teaching.

CONCLUSION

This study has demonstrated that a multi-modal, online EEG teaching tool is effective in improving EEG analysis test scores of neurologists, neurology residents and medical technologists. Such a tool is likely to be a useful supplement for EEG teaching, especially in resource-limited settings. Given the optimistic findings of this study, we encourage the development and evaluation of further online neurology teaching tools.

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Table 1: Baseline characteristics

	All [a] n (%)	Qualified n (%)	Trainee n (%)	p Value[b]
Profession				
Neurologist[c]	74 (81.3)	38 (51.4)	36 (48.6)	
Technologist	13 (14.3)	13 (100)	0	0.001
Other medical practitioner[d]	4 (4.4)	4 (100)	0	
Region of practice or training				
Sub-Saharan Africa	82 (90.1)	48 (58.5)	34 (41.5)	
Northern Africa	2 (2.2)	2 (100)	0	
Europe	4 (4.4)	3 (75)	1 (25)	0.328
North America	1 (1.1)	0	1 (100)	
Participants who analysed EEGs at least once a week prior to course				
Neurologist[c]	24 (32.4)	14 (58.3)	10 (41.7)	
Technologist	8 (61.5)	8 (100)	0	0.162
Other medical practitioner[d]	0	0	0	
Learning modalities used				
All modalities				
All material	0	0	0	-
At least 50% of material	27 (29.7)	18 (66.7)	9 (33.3)	0.430
Lecture notes				
All	58 (63.7)	38 (65.5)	20 (34.5)	0.189
At least 50% of material	87 (95.6)	52 (59.8)	35 (40.2)	0.542
Audio lectures				
All	26 (28.6)	16 (61.5)	10 (38.5)	0.892
At least 50% of material	49 (53.8)	31 (63.3)	18 (36.7)	0.552
Video lectures				
All	10 (11)	7 (70)	3 (30)	0.512
At least 50% of material	36 (39.6)	24 (66.7)	12 (33.3)	0.326
Discussion forums				
All	49 (53.8)	30 (61.2)	19 (38.8)	0.869
Some	88 (96.7)	53 (60.2)	35 (39.8)	-
Discussion forum comments	49 (53.8)	30 (61.2)	19 (38.8)	0.869
Interactive EEG-epochs				
All	0	0	0	-
At least 50% of material	49 (53.8)	29 (59.1)	20 (40.8)	0.791
Intra-module quizzes				
All	35 (38.5)	22 (62.8)	13 (37.1)	0.709
At least 50% of quizzes	75 (82.4)	43 (57.3)	32 (42.7)	0.190
End of course exams[e]				
All	83 (91.2)	50 (60.20)	33 (39.8)	0.901
At least one exam	84 (92.3)	50 (59.5)	34 (40.5)	0.536

[a]Total number = 91, [b]chi-square, [c]Neurologist comprised both adult (33) and paediatric (5) neurologists respectively, [d]Other medical practitioner included 3 psychiatrists and 1 unknown medical specialty, [e]Comprised three exams.

Table 2: Results of pre and post course confidence (based on survey responses) and competence (based on MCQ test scores)

	Confidence[a] (subjective measurement, as self-rated in surveys)			Competence (objective measurement, as assessed in MCQ tests)			
	Pre-course n (%)	Post-course n (%)	p Value[b]	Pre-test % mean (SD)	Post-test % mean (SD)	p Value[c]	Cohen's *d* [d]
Overall scores							
All	23 (25.27)	59 (64.84)	<0.001	46.70 (17.58)	64.06 (17.98)	<0.001	0.974
Neurology[e]	18 (24.32)	48 (64.86)	<0.001	44.5 (17.18)	63.74 (18.10)	<0.001	1.090
Normal EEG features							
Normal – wakeful state	36 (39.56)	65 (71.43)	<0.001	51.65 (32.68)	64.83 (33.10)	0.001	0.401
Normal - drowsiness	27 (29.67)	61 (67.03)	<0.001	36.54 (25.63)	53.30 (31.23)	<0.001	0.587
Normal – EEG variants	18 (19.78)	55 (60.44)	<0.001	46.89 (34.06)	62.27 (31.51)	0.0002	0.469
Abnormal epileptiform waveforms							
	31 (34.07)	57 (62.64)	<0.001	50.41 (21.53)	66.21 (23.46)	<0.001	0.702
Abnormal non - epileptiform waveforms							
	12 (13.19)	55 (60.44)	<0.001	56.70 (26.88)	72.09 (22.48)	<0.001	0.621
Artefacts – biological and non-biological							
	29 (31.87)	54 (59.34)	<0.001	43.30 (22.71)	61.65 (21.15)	<0.001	0.836

[a]Confidence n refers to the number of those who answered "agree" or "strongly agree" on survey questions about EEG analysis confidence, [b]McNemar's chi square, [c]t-test, [d]Cohen's *d* coefficient for effect size, [e]Neurology – qualified neurologists and neurology residents

Table 3: Use of course material and corresponding MCQ test performance

	n (%) Total = 91	Pre-test score % mean (SD)	Post-test score % mean (SD)	p Value[a]	Cohen's *d* [b]
Very infrequent (<500)	18 (19.78)	40.56 (14.96)	49.07 (14.50)	0.013	0.578
Infrequent (500 – 999)	28 (30.77)	49.52 (19.00)	65.59 (19.54)	<0.001	0.834
Frequent (1000 – 1999)	30 (32.97)	46.22 (16.94)	69.11 (13.36)	<0.001	1.500
Very frequent (>2000)	15 (16.48)	50.00 (18.64)	69.11 (18.45)	0.0003	1.030
All modalities					
>=50% of material	27 (29.67)	50.49 (19.23)	74.94 (13.84)	<0.001	1.459
<50% of material	64 (70.33)	45.16 (16.74)	59.48 (17.62)	<0.001	0.833
Lecture notes					
>=50% of material	87 (95.6)	47.01 (17.51)	64.56 (18.00)	<0.001	0.988
<50% of material	4 (4.40)	40.83 (20.79)	53.33 (15.63)	0.427	0.679
Audio lectures					
>=50% of material	49 (53.8)	48.10 (18.34)	68.37 (18.14)	<0.001	1.111
<50% of material	42 (46.2)	45.16 (16.73)	59.05 (16.61)	<0.001	0.833
Video lectures					
>=50% of material	36 (39.60)	48.24 (17.83)	70.00 (16.56)	<0.001	1.265
<50% of material	55 (60.44)	45.76 (17.51)	60.18 (17.94)	<0.001	0.814
Discussion forum[c]					
Some	88 (96.7)	47.12 (17.70)	64.73 (17.66)	<0.001	0.996
None	3 (3.30)	35.56 (9.62)	44.44 (19.53)	0.270	0.577
Interactive EEG activities					
>=50% of material	49 (53.8)	48.03 (19.42)	68.84 (17.74)	<0.001	1.119
<50% of material	42 (46.15)	45.23 (15.25)	58.49 (16.79)	<0.001	0.826
Intra-module quizzes					
>=50% of quizzes	75 (82.4)	48.80 (17.87)	67.51 (16.74)	<0.001	1.080
<50% of quizzes	16 (17.6)	37.08 (12.58)	47.92 (14.80)	0.0125	0.789
Course examinations					
All	83 (91.2)	46.58 (17.77)	65.02 (18.03)	<0.001	1.030
At least one exam	84 (92.3)	46.19 (18.03)	64.84 (17.99)	<0.001	1.035
No exam	7 (7.69)	53.33 (9.23)	54.76 (16.08)	0.390	0.109

[a]t-test, [b]Cohen's *d* for effect size, [c]Discussion forums – "all" means commented, viewed and posted on forums, whereas "some" meant did one or two out of the three actions.

Table e-1: Distribution of participants according to cohorts

Profession	All n (%)	Cohort 1 n (%)	Cohort 2 n (%)
All	91 (100)	42 (46.1)	49 (53.8)
Neurologist	38 (41.8)	14 (33.3)	24 (49)
Neurology resident	36 (39.6)	23 (54.8)	13 (26.5)
Technologist	13 (14.3)	5 (11.9)	8 (16.3)
Other medical practitioner[a]	4 (4.4)	0 (0)	4 (8.16)

[a]Other medical practitioner included 3 psychiatrists and 1 other unspecified medical doctor

Note: Breakdown of participants according to profession and cohort. Cohort 1 – 2017, Cohort 2 – 2018.

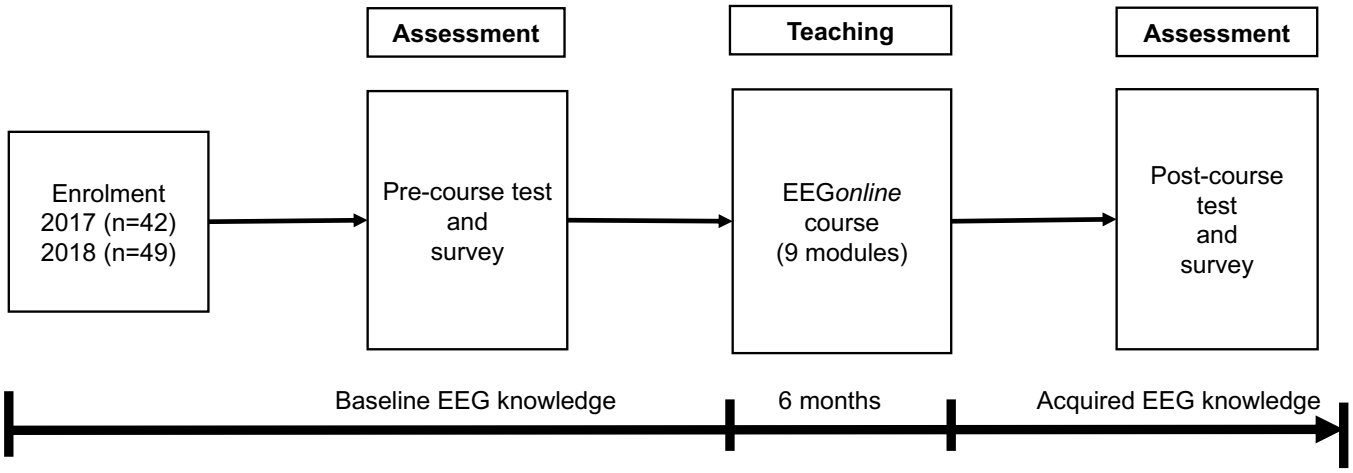
Table e-2: Pre and Post-test results by profession

	Confidence[a]			Competence			
	Pre-course n (%)	**Post-course n (%)**	**p Value[b]**	**Pre-test % mean (SD)**	**Post-test % mean (SD)**	**p Value[c]**	**Cohen's *d*[d]**
Overall confidence in EEG analysis				**Total score**			
All	23 (25.27)	59 (64.84)	<0.001	46.70 (17.58)	64.06 (17.98)	<0.001	0.974
Neurologist	11 (28.95)	26 (68.42)	0.0006	44.47 (16.19)	61.75 (18.91)	<0.001	0.982
Neurology resident	7 (19.44)	22 (61.11)	0.001	44.53 (18.40)	65.83 (17.21)	<0.001	1.195
Technologist	5 (38.46)	8 (61.54)	0.317	61.28 (14.89)	72.56 (11.72)	0.006	0.842
Other medical practitioner[e]	0	3 (75)	0.083	40.83 (11.01)	42.50 (15.48)	0.406	0.124

[a]Confidence n refers to the number of those who answered "agree" or "strongly agree" on survey questions about EEG analysis confidence
[b]McNemar's chi square, [c]t-test, [d]Cohen's *d* coefficient for effect size, [e]Other medical practitioner included 3 psychiatrists and 1 unknown medical specialty

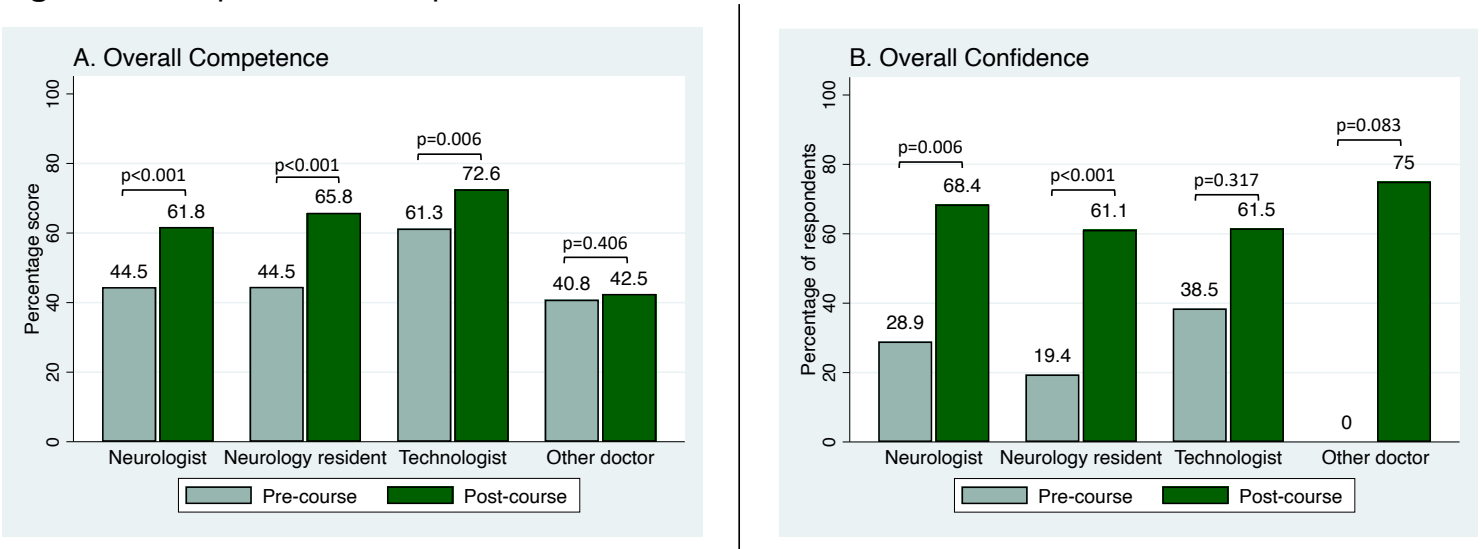
Note: Pre- and Post-test confidence and competence scores of participants according to profession. Significant improvement in test scores was noted in all groups except the small group of other medical practitioners. Similarly, confidence improved significantly for all neurologists and neurology residents but was non-significant for technologists and other medical practitioners.

Figure 1: Study flow diagram



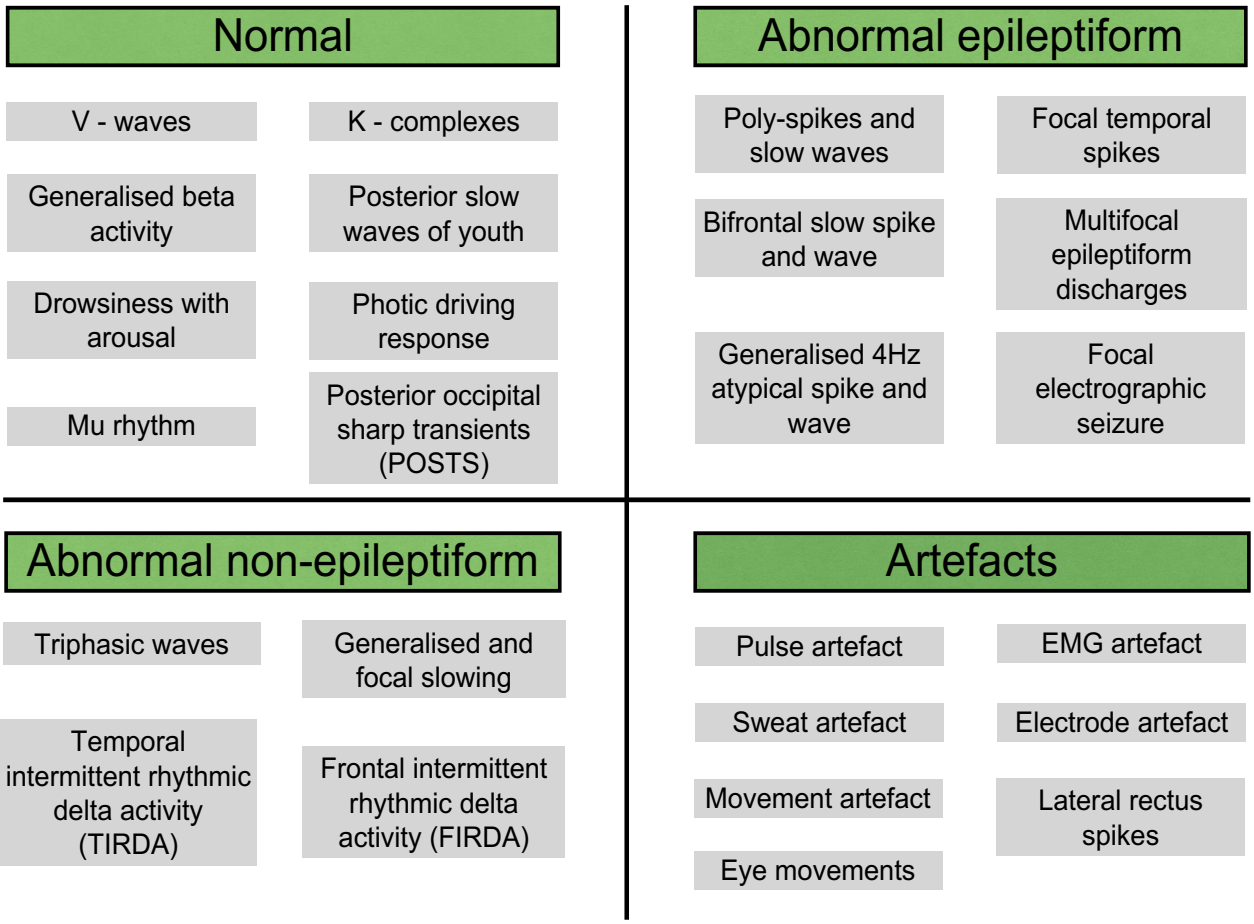
Note: Diagram showing the study design and methods.

Figure 2: Comparison of competence and confidence



A) shows improved overall competence by profession through mean percentage scores in pre- and post-tests and B) shows improved self-reported confidence in EEG analysis between pre and post-course surveys.

Figure e-1: EEG patterns assessed in pre- and post-tests



APPENDICES

Appendix 1: Author information

Name	Location	Role	Contribution
Melody Asukile BSc, MB.ChB, FCNeurol (SA)	University of Cape Town	Author	Study concept and design, collection and analysis of data, critical revision of the manuscript
Charle A Viljoen MB.ChB, MMed, FCP (SA)	University of Cape Town	Author	Study concept and design, analysis of data, critical revision of the manuscript
Edward Lee Pan MB.ChB, MMed	University of Cape Town	Author	Study concept and design, critical revision of the manuscript
Roland Eastman MRCP, FCP (SA)	University of Cape Town	Author	Study concept and design, critical revision of the manuscript
Lawrence Tucker MMed, FCNeurol (SA), PhD			Study concept and design, analysis of data, critical revision of the manuscript

Appendix 2: Information sheet and consent form

DEPARTMENT OF Neurology

ACTIVE IN CLINICAL SERVICE, HEALTH EDUCATION AND RESEARCH

INFORMATION SHEET
EEGonline Study

Dear Colleague,

We hope you will consider participating in our study to assess the usefulness of EEG*online* as a distance learning tool for the acquisition of EEG interpretation skills. Your contribution will be invaluable!

The information provided below explains what the study involves and what your participation would mean, so that your choice to participate or not is well informed. Your participation is also voluntary

What is the nature and purpose of the study?

This is a prospective cohort study involving medical technologists, neurology registrars and specialist neurologists participating in the EEGonline learning program starting in May of this year. The aim is to determine whether or not the use of an online learning tool, EEGonline, significantly improves participants' electroencephalogram (EEG) pattern recognition, analysis and interpretation skills and therefore, by implication, also their effective and appropriate use of EEG in clinical practice.

Who are the investigators?

The investigators are Lawrence Tucker (principal investigator and the director of undergraduate and postgraduate neurology training at the University of Cape Town), Charle Viljoen (investigator and cardiology research fellow at the University of Cape Town) and Melody Asukile (investigator, neurology registrar and MMed student, University of Cape Town).

What role will you play in this study?

This research will involve your participation in 2 multiple choice question (MCQ) tests and 2 user opinion surveys on EEG learning and teaching. It will also include analysis of data contained in your EEG*online* user log regarding your use of the EEGonline learning resources. ***Importantly, all information used for the study will be made ANONYMOUS, remain unknown to your EEGonline course conveners and will in no way influence your academic assessments on the EEGonline course.*** It will be password protected and remain completely confidential at all times.

- **MCQ tests**
  You will be asked to do two 30-question MCQ tests: a *pre-intervention test*, written before you access any of the EEGonline course material and a *post-intervention test*, written within a week of completing the EEGonline course. These tests will be used to assess, respectively, your baseline EEG knowledge and the knowledge you acquire during the course. It is important to stress again that the results of these study-related MCQ tests will remain ***anonymous and in no way influence your assessments on the EEGonline course***.

- **Opinion surveys**
  You will also be asked to complete 2 user opinion surveys, respectively at the same time as the two MCQ tests 1 and 2. These surveys will collect information regarding your opinions on EEG teaching, and provide us with feedback regarding several aspects of the EEGonline program.

- **User log information**
  As mentioned, we will also collect information regarding the amount of time you spend on EEGonline and what type of course material you access most (e.g. videos, lecture notes, quizzes, discussion forums). This information will help us to assess whether specific learning modalities are more useful or preferred over others. Again, the information collected will remain anonymous will have no effect on your course progress.

Why have you been chosen for this study?

You are being invited to participate in this study because you have enrolled for the EEGonline course and it is important for us to confirm the usefulness of this learning program. It is likely that the findings of this study will result in improvements to the course, and also influence the development of additional teaching resources for the future.

What choices do you have?

Participation in this study is entirely voluntary. There will be no repercussions if you decide not to participate.

How long will the study last?

The study will commence in June 2017 and end in December 2018. Your participation will be required from May to November 2018 (length of EEGonline course).

What are the risks, benefits and reimbursements of the study?

There are no risks to you associated with this study. The UCT Human Research Ethics Committee approved this study (HREC ref# 333/2017)

There is no direct benefit to you from this study, but your participation is very important as it is likely to provide insights on how best to improve the EEGonline course and determine whether or not it is an effective EEG training tool.

You will not receive any reimbursement or remuneration for participating in this study.

What will happen to the information collected?

All personal and contact information collected will be kept strictly confidential and will only be accessible to the investigators. MCQ test and survey results will be made anonymous and remain confidential.

What will happen when the study is over?

The results of the study will be made available to you and may be published and used to guide EEG training curriculum development in resource limited countries.

Who do you contact if you have questions about the study?

You can contact Dr. Melody Asukile by email (tunsu1asukile@gmail.com) or phone (+277 3729 0610) regarding any concerns about the study. If you have any ethical concerns about our study, please contact the Human Research Ethics Committee (HREC) at the Faculty of Health Sciences at the University of Cape Town. The contact person at the HREC is Ms. Sumaya Ariefdien (sumaya.ariefdien@uct.ac.za), at room E52-24 Old Main Building, Groote Schuur Hospital, Observatory, 7925. Her office telephone number is 021 406 6338.

Thank you so much for choosing to be a part of this very important study.

Dr Lawrence Tucker, Dr Charle Viljoen, Dr Melody Asukile

Appendix 3: Ethics approval letters

3a) 2017 Ethics approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone (021) 406 6626
Email: shureita.thomas@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

14 June 2017

HREC REF: 333/2017

Dr L Tucker
Neurology
E8, NGSH

Dear Dr Tucker

PROJECT TITLE: THE EFFICACY OF AN ONLINE LEARNING TOOL IN IMPROVING EEG ANALYSIS AND INTERPRETATION SKILLS OF TECHNOLOGISTS, NEUROLOGY REGISTRARS AND NEUROLOGISTS (Master's candidate-Dr M Asukile)

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee.

It is a pleasure to inform you that the HREC has **formally approved** the above-mentioned study.

Approval is granted for one year until the 30 June 2018.

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.
(Forms can be found on our website: www.health.uct.ac.za/fhs/research/humanethics/forms)

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please note that for all studies approved by the HREC, the principal investigator **must** obtain appropriate institutional approval before the research may occur.

The HREC acknowledge that the student, Dr Melody T Asukile will also be involved in this study.

Yours sincerely

Signature Removed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE
Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

3b) 2018 Ethics approval letter

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Human Research Ethics Committee

Room E53-46 Old Main Building
Groote Schuur Hospital
Observatory 7925
Telephone [021] 406 6492
Email: sumayah.ariefdien@uct.ac.za
Website: www.health.uct.ac.za/fhs/research/humanethics/forms

16 November 2018

HREC REF: 333/2017

Dr L Tucker
Department of Neurology
E-8
NGSH

Dear Dr Tucker

PROJECT TITLE: THE EFFICACY OF AN ONLINE LEARNING TOOL IN IMPROVING EEG ANALYSIS AND INTERPRETATION SKILLS OF TECHNOLOGISTS, NEUROLOGY REGISTRARS AND NEUROLOGISTS (master's candidate-Dr M Asukile)

Thank you for your letter to the Human Research Ethics Committee (HREC) dated 1 November 2018.

It is a pleasure to inform you that the HREC has **approved** the following amendments made to the protocol: -

1. Data collection was extended from December 2017 to December 2018;
2. Narrowing the exclusion criteria;
3. Additional questions added to the opinion survey;
4. Benefits: Study participants who completed both quizzes were granted extended access to the EEGonline course materials.

Please quote the HREC REF in all your correspondence.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Yours sincerely

Signature Removed

PROFESSOR M BLOCKMAN
CHAIRPERSON, FHS HUMAN RESEARCH ETHICS COMMITTEE

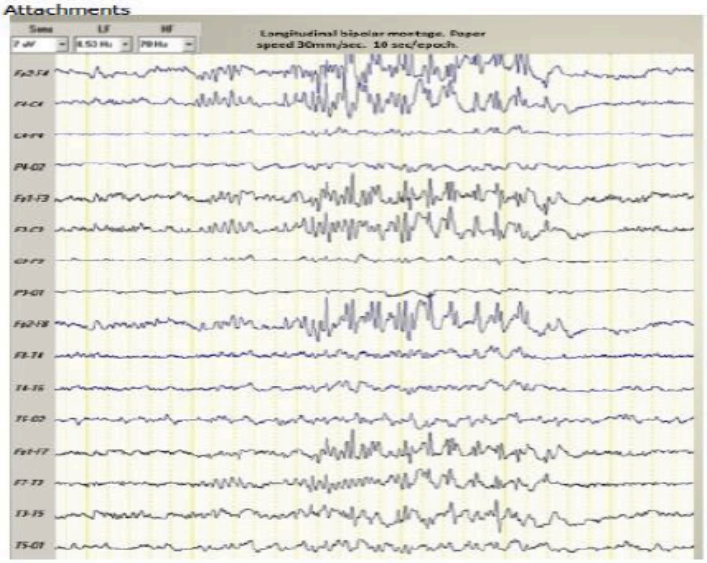
Appendix 4: MCQ test – pre- and post-course test

Note: The test comprised 30 questions which were presented randomly and were shuffled each time a participant took the test. Thus the order of question presentation was different for each participant.

Q1

Which statement best describes the waveform of interest in this epoch?

Attachments

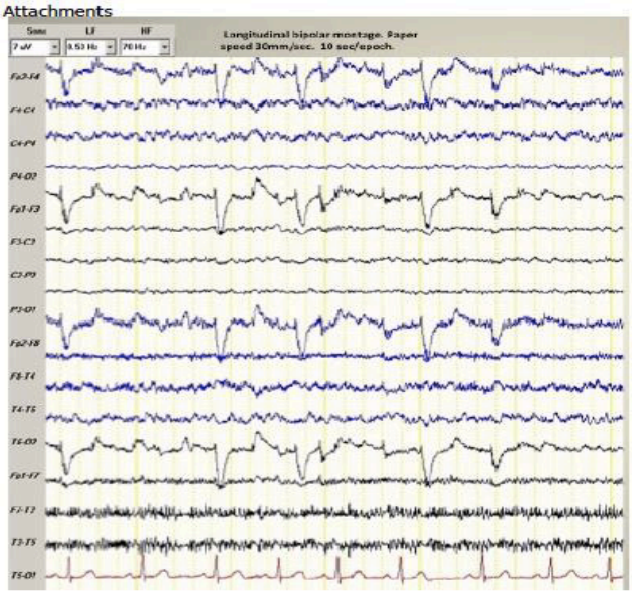


- A. Artefact, likely related to the operation of medical equipment.
- B. A run of generalised epileptiform polyspikes and spike-&-slow wave discharges.
- C. Unsure
- D. EMG artefact

Q2

Which statement best describes the waveforms of interest in this epoch?

Attachments

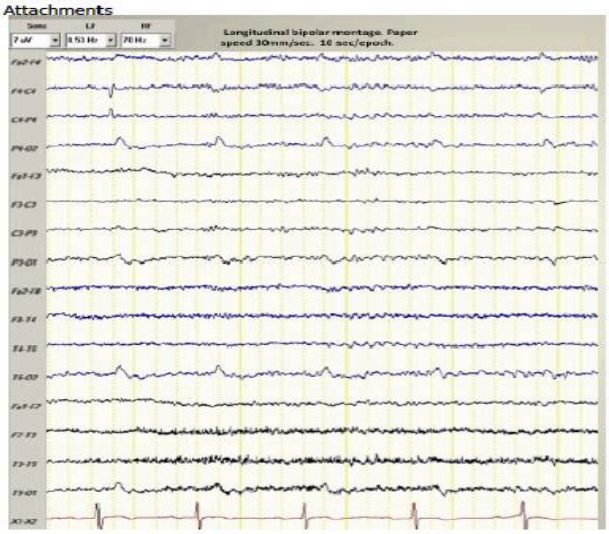


- A. Epileptiform spike-&-slow wave activity and EMG artefact.
- B. Unsure
- C. Normal eye movements, EMG artefact and epileptiform discharges.
- D. Normal eye movements, lateral rectus spikes and EMG artefacts.

Q3

Which statement best describes the features of interest in this epoch?

Attachments

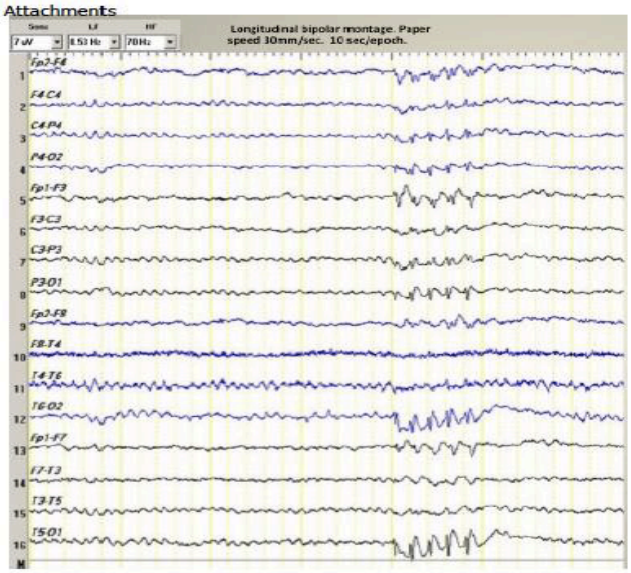


- A. Unsure
- B. Electrode, EMG and pulse artefacts
- C. Electrode and EMG artefacts, as well as POSTS (posterior occipital slow transients of sleep)
- D. Electrode and EMG artefacts, as well as occipital epileptiform sharp waves

Q4

Which statement best describes the possible clinical implication of the waveform of interest in this epoch?

Attachments

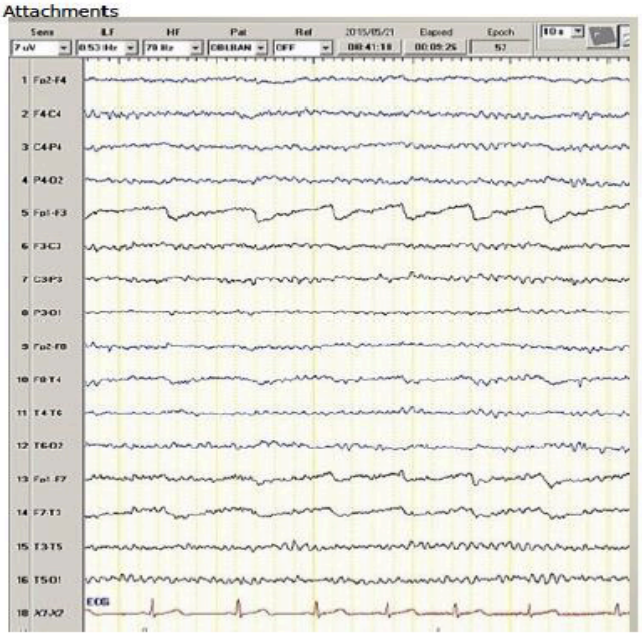


- A. A secondary generalised form of epilepsy
- B. A run of focal bifrontal epileptiform discharges
- C. A primary generalised epilepsy syndrome.
- D. Unsure

Q5

Which statement best describes the waveform of interest in this epoch?

Attachments

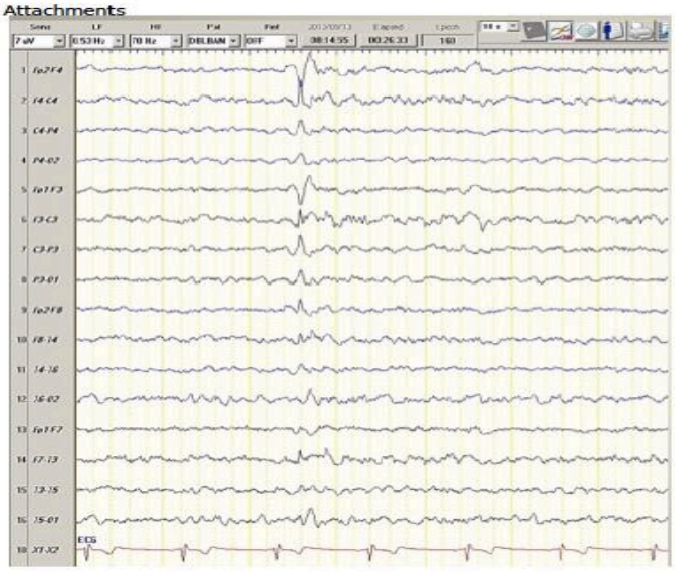


- A. Artefact
- B. Unsure
- C. Abnormal frontal delta slowing (Zeta waves)
- D. Triphasic waves

Q6

Which statement best describes the waveform of interest in this epoch?

Attachments

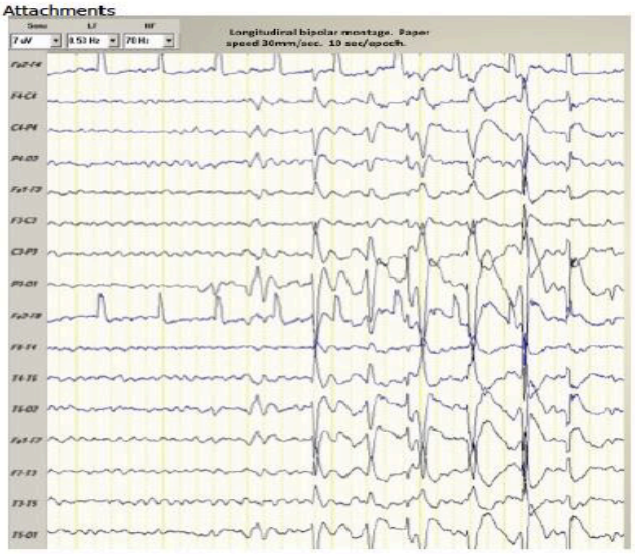


- A. An epileptiform discharge
- B. Unsure
- C. An artefact
- D. A normal physiological discharge

Q7

Which statement best describes the feature/s of interest in this epoch?

Attachments

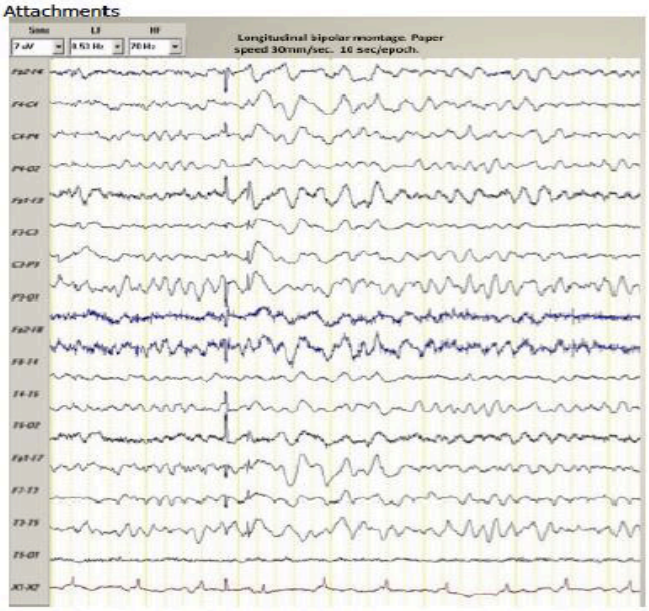


- A. Evolving seizure activity with focal onset
- B. Artefact
- C. Evolving seizure activity with generalised onset, as well as an Fp2 electrode artefact
- D. Unsure.

Q8

Which statement best describes the features of interest in this epoch?

Attachments

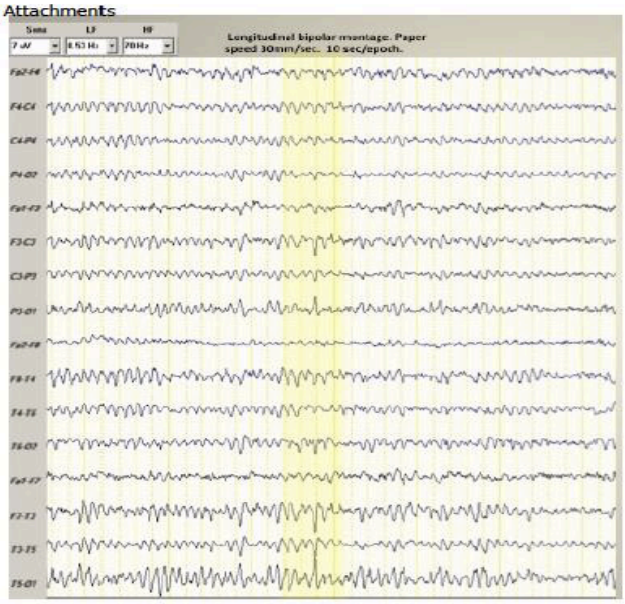


- A. Two epileptiform discharges with background theta slowing.
- B. An epileptiform discharge, and a spike-like artefact, with background theta slowing.
- C. Two spike-like artefacts and a run of generalised delta waves with background theta slowing.
- D. Unsure

Q9

Which clinical condition is probably associated with the highlighted waveform in this epoch?

Attachments

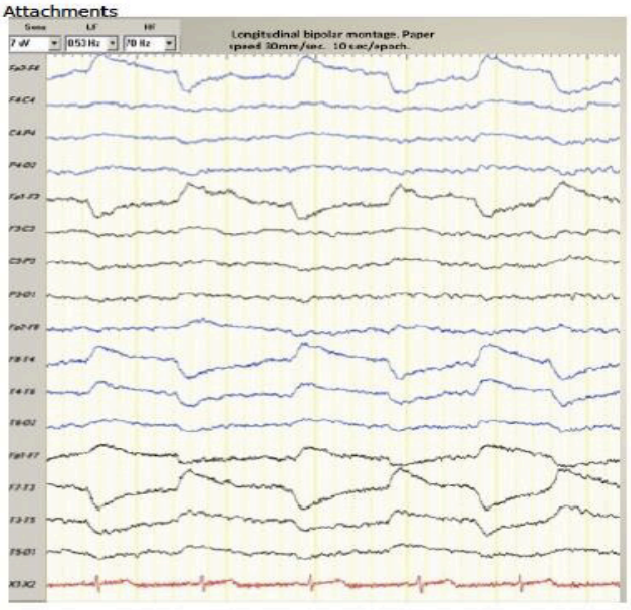


- A. Unsure
- B. The highlighted waveform is probably normal.
- C. Metabolic derangement (e.g. renal failure)
- D. Temporal Lobe Epilepsy.

Q10

Which statement best describes the features of interest in this epoch?

Attachments

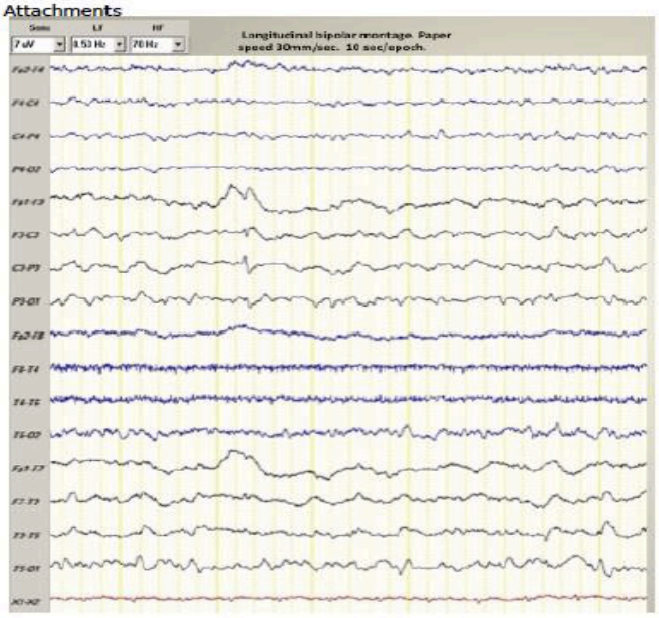


- A. Up gaze eye movement artefacts
- B. Unsure
- C. Lateral eye movement artefacts
- D. FIRDA (frontal intermittent rhythmic delta activity)

Q11

Which one of the following waveforms is NOT present in this epoch?

Attachments

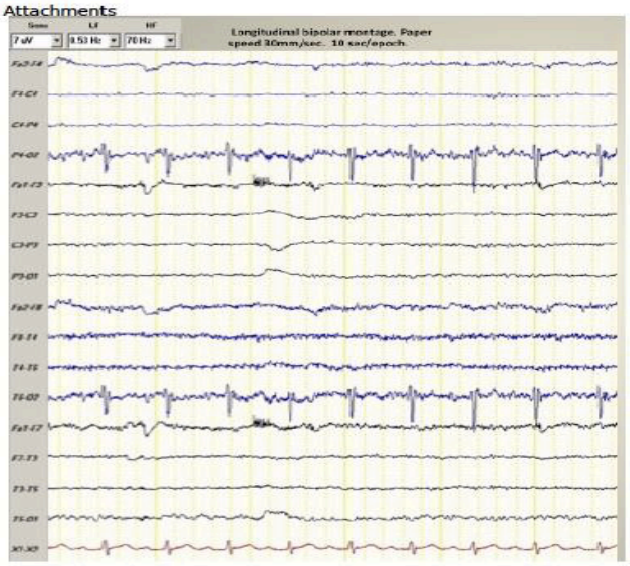


- A. EMG artefact
- B. Left, mid-temporal epileptiform discharge.
- C. Unsure
- D. Focal slowing

Q12

Which one of the following waveforms is NOT present in this epoch?

Attachments

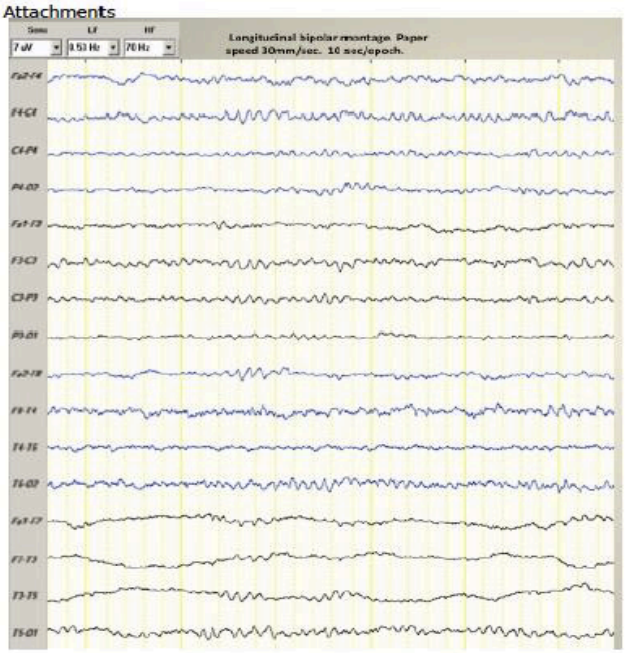


- A. Fp1 electrode artefact
- B. Unsure
- C. C3 electrode artefact
- D. Pulse artefact

Q13

Which statement best describes the features of interest in this epoch?

Attachments

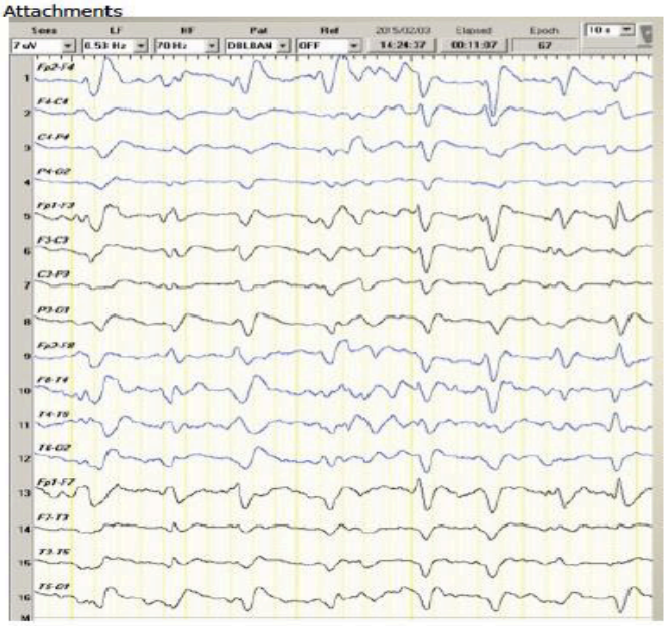


- A. Sweat artefacts affecting the left temporal leads
- B. Unsure
- C. Focal slowing which indicates non-specific dysfunction involving the left temporal lobe
- D. TIRDA (temporal intermittent rhythmic delta activity)

Q14

Which term best describes the features of interest in this epoch?

Attachments

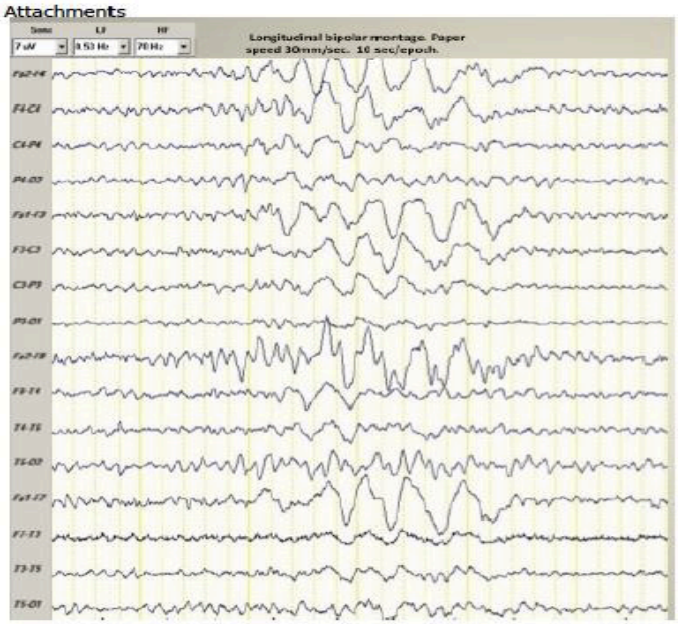


- A. Slow wave sleep
- B. Unsure
- C. V-waves
- D. Triphasic waves

Q15

Which statement best describes the features of interest in this epoch?

Attachments

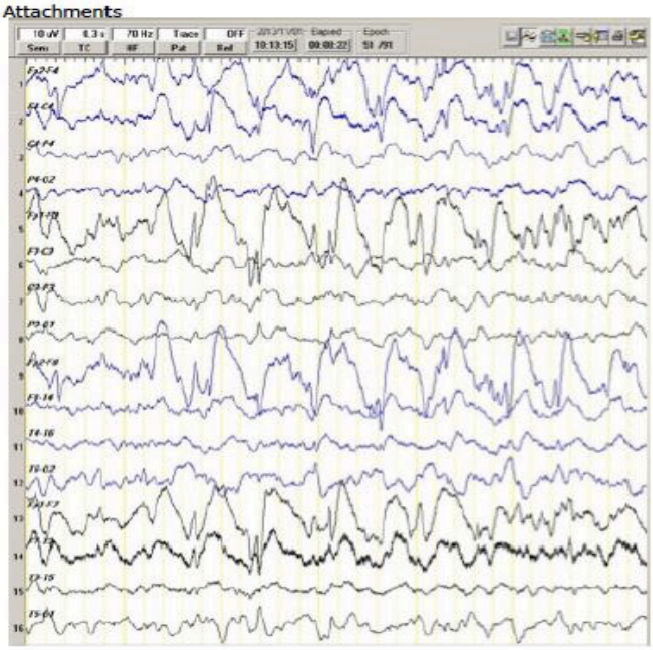


- A. Epileptiform, frontally predominant, larval spike and slow wave discharges
- B. Eye movement artefacts
- C. Unsure
- D. FIRDA (frontal intermittent rhythmic delta activity)

Q16

Which statement best describes the feature of interest in this epoch?

Attachments

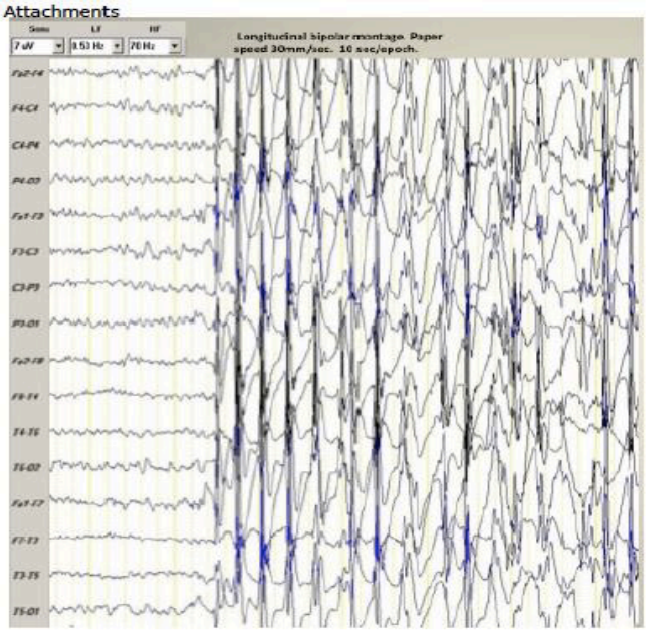


- A. Unsure
- B. Hypsarrhythmia
- C. Rapid eye blink artefacts with EMG artefact
- D. Bifrontal spike and slow wave activity

Q17

Which statement best describes the features of interest in this epoch?

Attachments

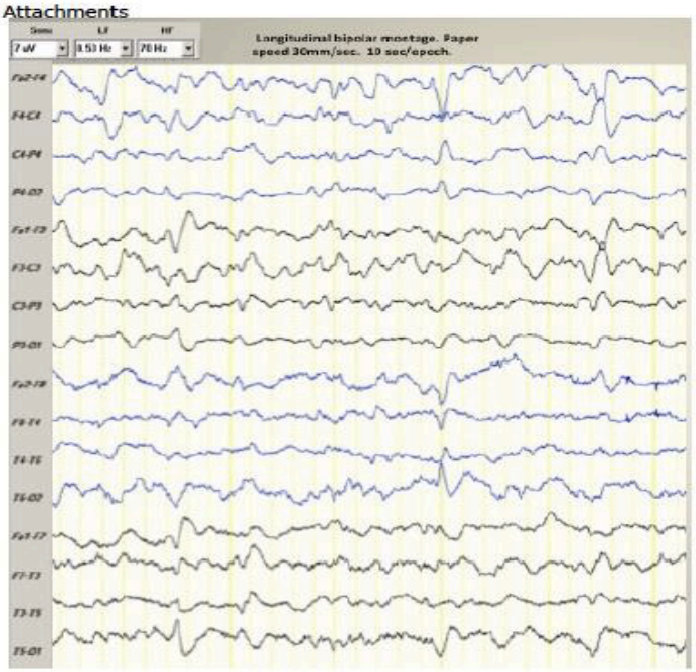


- A. Movement artefact
- B. Primary generalised epileptiform discharge.
- C. Unsure
- D. Hypnogogic hypersynchrony

Q18

Which statement best describes the features of interest in this epoch?

Attachments

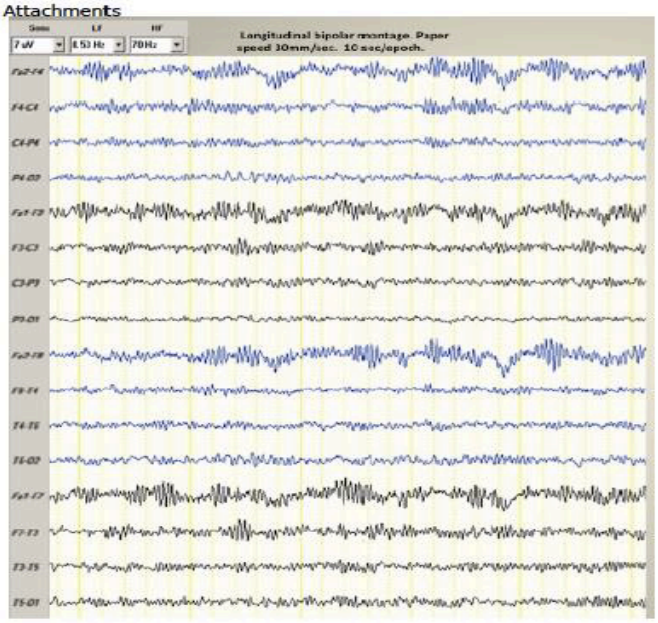


- A. PEDS (periodic epileptiform discharges)
- B. PLEDS Periodic lateralised epileptiform discharges.
- C. Unsure
- D. Multifocal epileptiform discharges

Q19

Which statement best describes the features of interest in this epoch?

Attachments

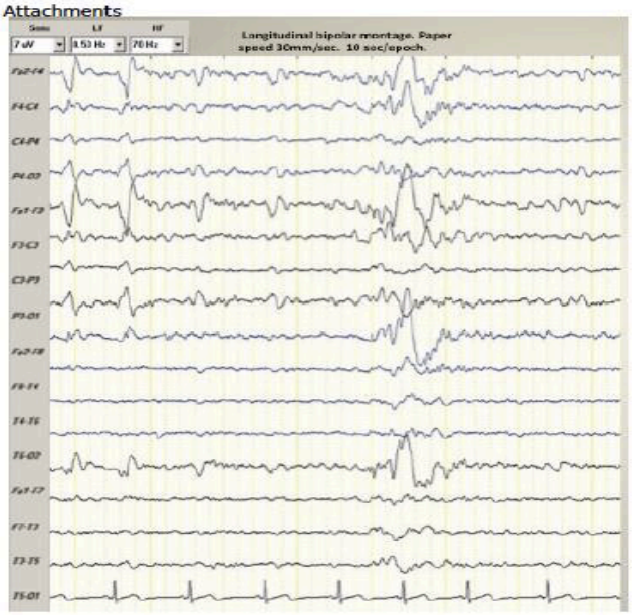


- A. Widespread EMG artefact
- B. Unsure
- C. Generalised beta activity which may be normal or related to benzodiazepine use
- D. Widespread 50Hz mains artefact

Q20

Which statement best describes the features of interest in this epoch?

Attachments

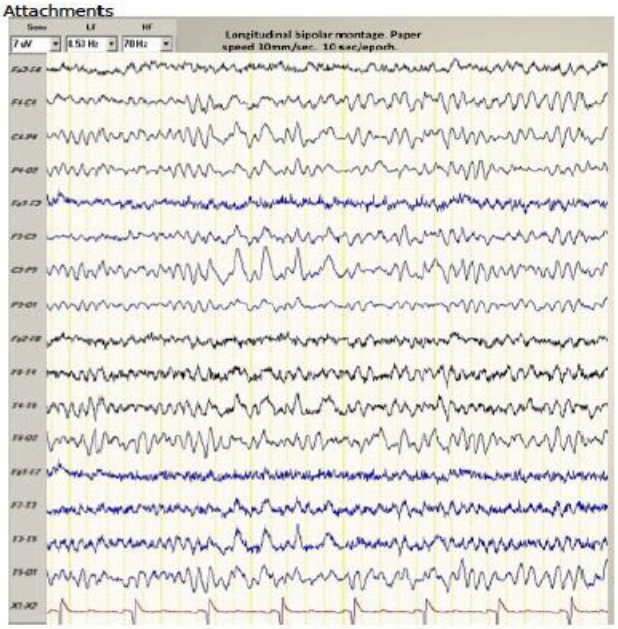


- A. Normal physiological
- B. Unsure
- C. Abnormal epileptiform
- D. Abnormal non-epileptiform

Q21

Which statement best describes the feature of interest in this epoch?

Attachments

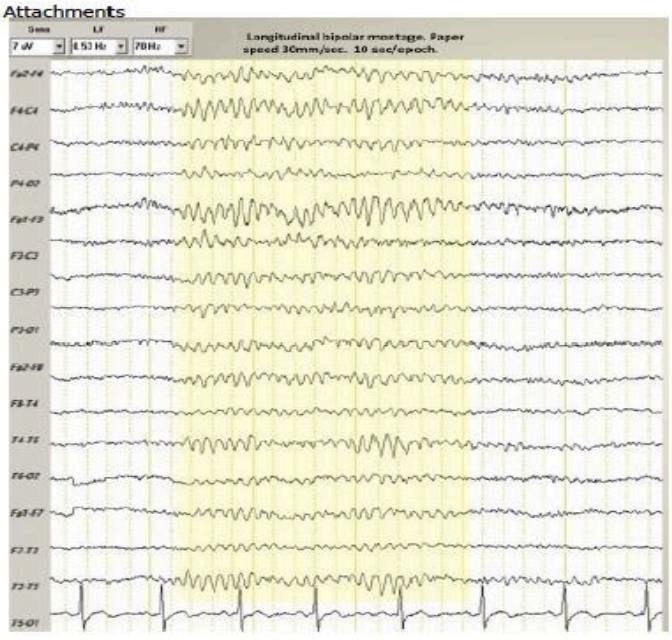


- A. Abnormal non-epileptiform
- B. Abnormal epileptiform
- C. Unsure
- D. Normal

Q22

Which statement best describes the highlighted waveform in this epoch?

Attachments

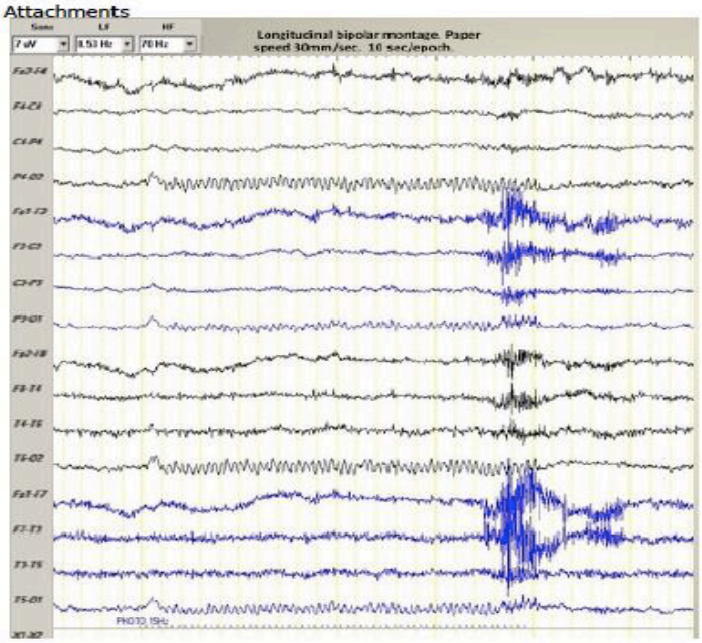


- A. A period of drowsiness
- B. A period of arousal
- C. Unsure
- D. A run of generalised rhythmic epileptiform activity

Q23

Which statement best describes the feature of interest in this epoch?

Attachments

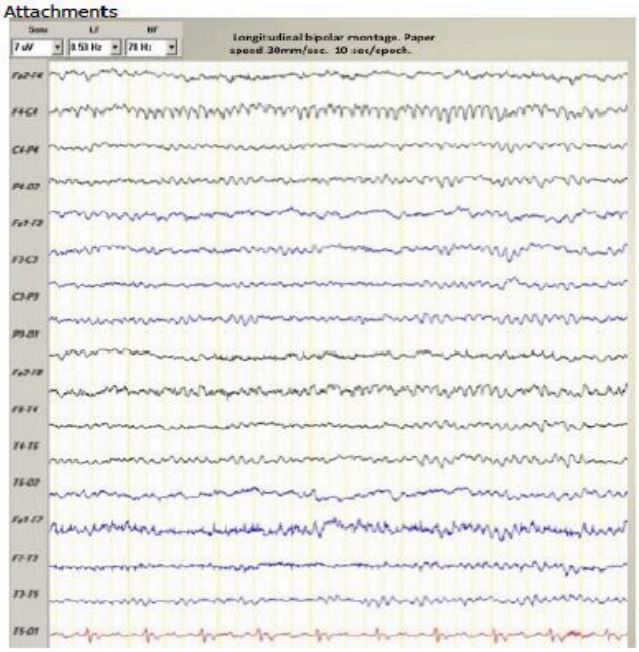


- A. Normal photomyogenic response
- B. Unsure
- C. Abnormal photoparoxysmal response.
- D. Physiological photic driving response

Q24

Which statement best describes the feature of interest in this epoch?

Attachments

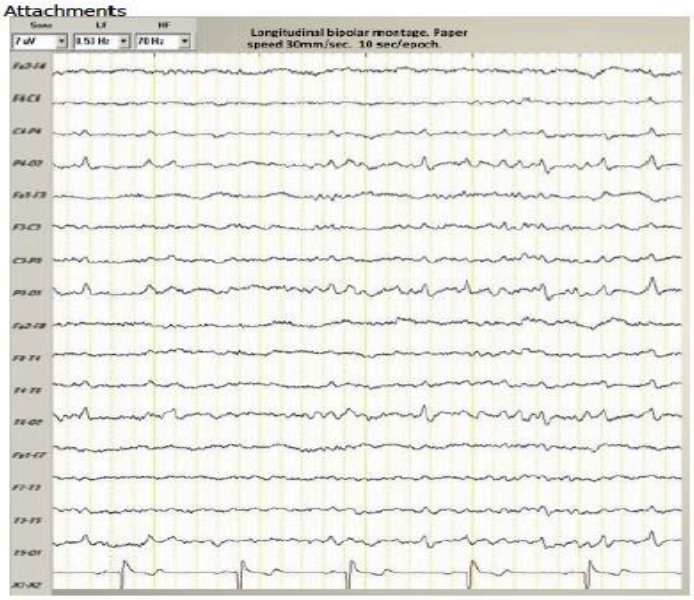


- A. Unsure
- B. RMTD (rhythmic mid-temporal discharge)
- C. Sleep spindle
- D. Mu

Q25

Which statement best describes the features of interest in this epoch?

Attachments

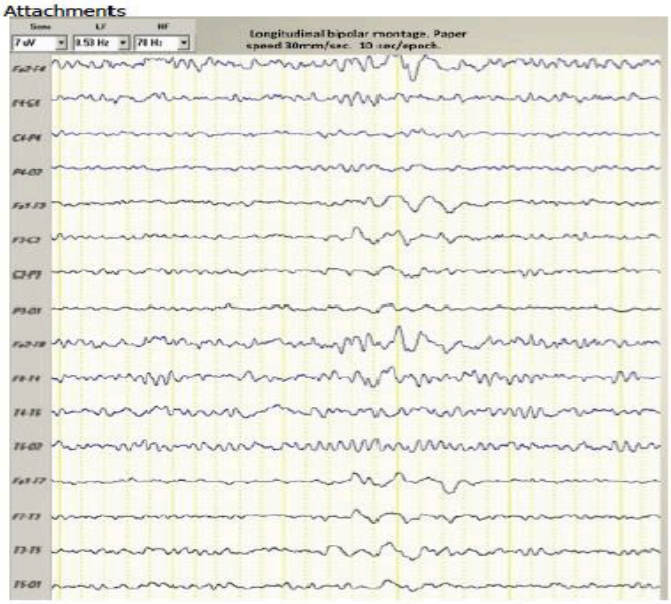


- A. Epileptiform occipital spikes/sharp waves
- B. Unsure
- C. POSTS (posterior occipital slow transients)
- D. Lambda waves

Q26

Which statement best describes the features of interest in this epoch?

Attachments

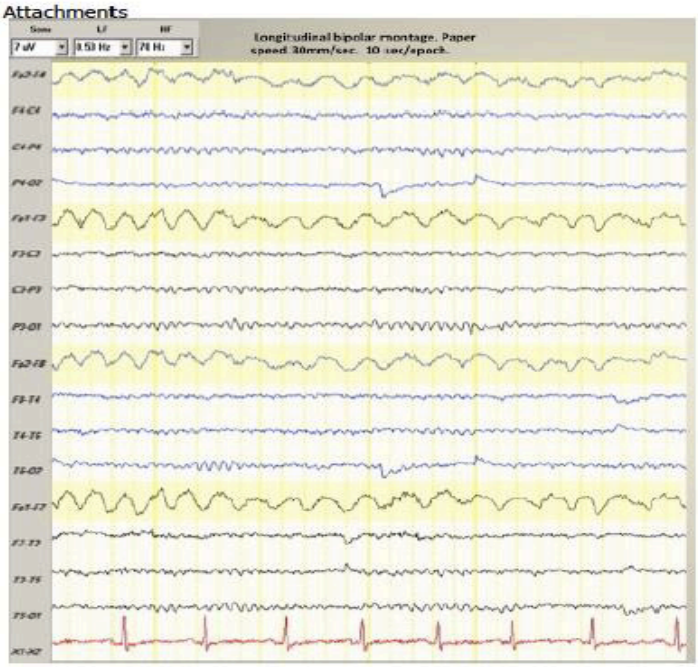


- A. TIRDA (temporal intermittent rhythmic delta)
- B. Wicket Waves
- C. Unsure
- D. RMTD (rhythmic mid temporal discharges)

Q27

Which statement best explains the highlighted feature of interest in this epoch?

Attachments

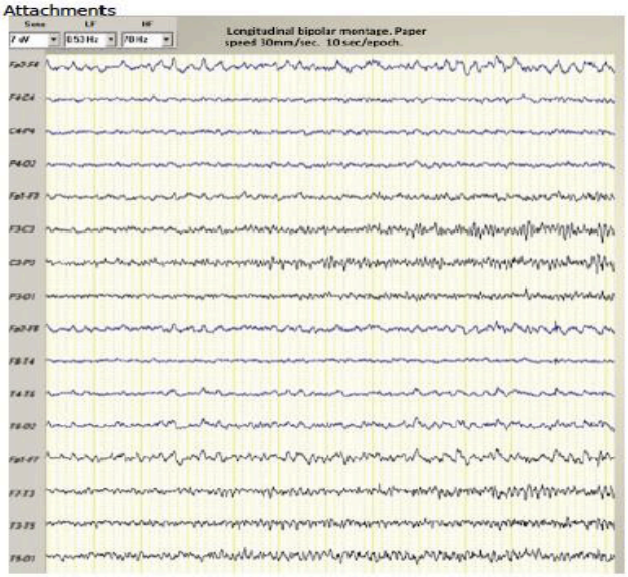


- A. Movement/tremour-related artefact
- B. Rhythmic bi-frontal delta activity
- C. Unsure
- D. Eye-related artefact

Q28

Which statement best describes the features of interest in this epoch?

Attachments

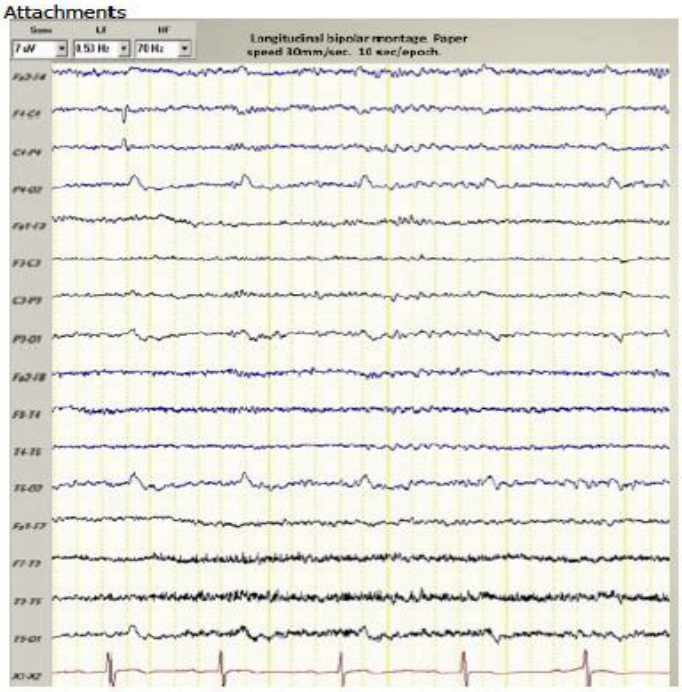


- A. EMG artefact
- B. Seizure activity
- C. Unsure
- D. 50 Hz mains artefact

Q29

Which statement best describes the features of interest in this epoch?

Attachments

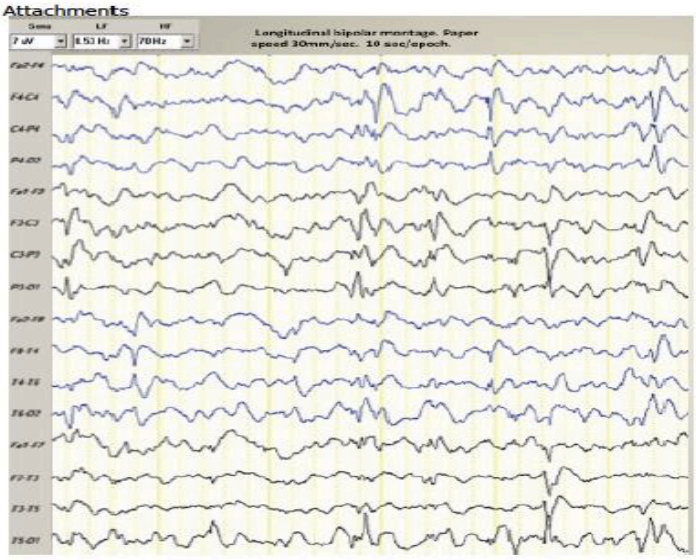


- A. Electrode and EMG artefacts, as well as POSTS (posterior occipital slow transients of sleep)
- B. Electrode, EMG and pulse artefacts
- C. Unsure
- D. Electrode and EMG artefacts, as well as occipital epileptiform sharp waves

Q30

Which statement best describes the features of interest in this epoch?

Attachments



- A. Unsure
- B. PLEDS Periodic lateralised epileptiform discharges.
- C. PEDS (periodic epileptiform discharges)
- D. Multifocal epileptiform discharges

Appendix 5: Pre-course survey (Survey 1)

Appendix 6: Pre-course survey (Survey 1)

Part 1: Personal background information

Highest Academic Qualification

- A. College Certificate
- B. Diploma
- C. Bachelors Degree
- D. Masters degree
- E. PhD or higher

Current occupation

- A. Medical technologist
- B. Neurology registrar/ resident in training
- C. Qualified specialist Neurologist
- D. Other (Please specify in question 3)

If you selected "Other" in question 2. please state your occupation here. Otherwise you may skip this question.

For Medical technologists, kindly state duration of practice (years):

For Neurology registrars/ residents, kindly state:
1. Current year of study
2. Duration of Neurology training at your institution (years)

For qualified Neurologists, kindly state:
1. Duration of neurology training (years)
2. Duration of practicing as specialist (years)

Country of origin (citizenship/ permanent residence):

Current location (country):

For how long have you been at your current location (years)?

To what University are you affiliated, if any?

Sex:

- A. Female
- B. Male
- C. Do not wish to disclose

Age:

Part 2: EEG training

How is/was EEG analysis and interpretation taught in your location?

	Never	Several times a year (but not every month)	Several times a month (but not every week)	At least once a week
Formal EEG lectures	○	○	○	○
Small group tutorials	○	○	○	○
EEG analysis under expert supervision	○	○	○	○
EEG Workshops	○	○	○	○
EEG Handbooks	○	○	○	○
Online EEG courses	○	○	○	○
Self taught	○	○	○	○

Feedback:

How often do you analyse and interpret EEGs in your daily work/ training?

	Never	Several times a year (but not every month)	Several times a month (but not every week)	At least once a week	Everyday
Under expert supervision	○	○	○	○	○
Independently (without expert supervision)	○	○	○	○	○

Feedback:

How many EEGs do you analyse and interpret in your daily work/ training? (average number per month)

	None	1 - 5 per month	6 - 10 per month	More than 10 per month
Under expert supervision	○	○	○	○
independendly	○	○	○	○

Feedback:

How often do you use the following resources for EEG learning?

	Never	Maybe once or twice	About once a week	Regularly/ several times a week
Textbooks	○	○	○	○
EEG Handbooks	○	○	○	○
Online tutorials (podcasts)	○	○	○	○
Websites (explaining EEG)	○	○	○	○
Smart phone or tablet applications	○	○	○	○

Feedback:

How confident are you in the interpretation of EEGs in general?

	Strongly Disagree	Disagree	Undecided	Agree	Strongly agree
I find EEG interpretation very difficult	○	○	○	○	○
I would like to improve my EEG interpretation skills	○	○	○	○	○

How strongly do you agree with the following statements regarding EEG analysis and interpretation?

	Strongly Disagree	Disagree	Undecided	Agree	Strongly agree
I am confident in the analysis/ interpretation of normal physiological waveforms associated with drowsiness	○	○	○	○	○
I am confident in the analysis/ interpretation of normal physiological waveforms associated with a wakeful state	○	○	○	○	○
I am confident in the analysis/ interpretation of abnormal non–epileptiform waveforms	○	○	○	○	○
I am confident in the analysis/ interpretation of abnormal epileptiform waveforms	○	○	○	○	○
I am confident in the analysis/ interpretation of artefacts	○	○	○	○	○
I am confident in the analysis/ interpretation of normal EEG variants	○	○	○	○	○

Appendix 6: Post-course survey (Survey 2)

Part 1: Overall impression of EEGonline

On a scale of 1- 9 rate the following aspects of the EEGonline learning program?
(1 = very poor, 9 = excellent)

	1	2	3	4	5	6	7	8	9
User-friendliness	○	○	○	○	○	○	○	○	○
Screen layout	○	○	○	○	○	○	○	○	○
Quality of Epochs presented	○	○	○	○	○	○	○	○	○
Quality of EEGonline videos	○	○	○	○	○	○	○	○	○
Internet accessibility	○	○	○	○	○	○	○	○	○
Technical support provided by EEGonline	○	○	○	○	○	○	○	○	○
Overall score/ general impression of EEGonline	○	○	○	○	○	○	○	○	○

Feedback:

On a scale of 1- 9 rate the usefulness of the following teaching modalities utilised by the EEGonline learning program?
(1 = not at all useful, 9 = extremely useful)

Lecture notes	○	○	○	○	○	○	○	○	○
Interactive EEG epoch activities	○	○	○	○	○	○	○	○	○
EEGonline teaching videos	○	○	○	○	○	○	○	○	○
EEGonline audio lectures	○	○	○	○	○	○	○	○	○
Discussion forums	○	○	○	○	○	○	○	○	○
EEGquizzes	○	○	○	○	○	○	○	○	○
Links to internet resources	○	○	○	○	○	○	○	○	○
Content covered by EEGonline	○	○	○	○	○	○	○	○	○
Overall usefulness of EEGonline program	○	○	○	○	○	○	○	○	○

Part 2: Evaluation of confidence in EEG analysis and interpretation after EEGonline

I am more confident about EEG analysis and interpretation since I completed the EEGonline program

- ○ Strongly Disagree
- ○ Disagree
- ○ Undecided
- ○ Agree
- ○ Strongly agree

How strongly do you agree with the following statements regarding EEG analysis and interpretation since your completion of the EEGonline program?

	Strongly disagree	Disagree	Undecided	Agree	Strongly agree
I am confident in the analysis/ interpretation of normal physiological waveforms associated with a wakeful state	○	○	○	○	○
I am confident in the analysis/ interpretation of normal physiological waveforms associated with drowsiness	○	○	○	○	○
I am confident in the analysis/ interpretation of abnormal non-epileptiform waveforms	○	○	○	○	○
I am confident in the analysis/ interpretation of abnormal epileptiform waveforms	○	○	○	○	○
I am confident in the analysis/ interpretation of artefacts	○	○	○	○	○
I am confident in the analysis/ interpretation of normal EEG variants	○	○	○	○	○

Part 3: Evaluation of usefulness of EEGonline in clinical practice

Please rate the usefulness of EEGonline in your clinical practice

	Strongly disagree	Disgree	Undecided	Agree	Strongly agree
EEGonline has improved my EEG analysis and interpretation skills	○	○	○	○	○
EEGonline has improved my ability to accurately recognise and differentiate normal physiological EEG waveforms from pathological waveforms	○	○	○	○	○
EEGonline has reduced my misinterpretation of EEG waveforms when analysing EEGs	○	○	○	○	○
EEGonline has changed my approach to EEG analysis and interpretation	○	○	○	○	○
EEGonline has improved my ability to manage patients clinically	○	○	○	○	○
EEGonline has improved my ability to interpret EEGs independently	○	○	○	○	○
EEGonline has improved my ability to teach EEG analysis to others	○	○	○	○	○
Online distance learning platforms such as EEGonline should be part of EEG training curricula	○	○	○	○	○
Web-based tools such as EEGonline should be designed for other aspects of neurology training such as EMG (electromyography) and neuroradiology	○	○	○	○	○
EEGonline is a useful learning tool	○	○	○	○	○

Appendix 7: Neurology® journal instructions to authors

Note: A detailed description of instructions to authors can be accessed at: https://www.neurology.org/writing-your-paper/

Neurology® Author Checklist

This form should be used as a reference tool. It does not replace the full information provided in the Author Center.

Cover letter

- ☐ Include title of manuscript
- ☐ Include classification (e.g. Article) of the manuscript.
- ☐ Notify editor of any possible redundant or duplicate publication.
- ☐ Notification of pre-publication on a preprint server (e.g., bioRxiv) and doi number, if applicable.
- ☐ Include declaration that all authors and contributors agree to the conditions outlined in the Authorship and Contributorship section of the Information for Authors.
- ☐ Include statement of responsibility for clinical trial data and include date that clinical trial data must be deposited in clinical trial database (if applicable)
- ☐ Include statement that authors take full responsibility for the data, the analyses and interpretation, and the conduct of the research; full access to all of the data; and the right to publish any and all data. (If study is sponsored, add: separate and apart from the guidance of the sponsor.)
- ☐ Indicate that the Methods section includes a statement that an IRB or regional review board has approved the use of human subjects for this study
- ☐ Indicate that that the author has received permission to cite any personal communications (if applicable).
- ☐ Indicate that the author has received and submitted to *Neurology* a Patient Consent-to-Disclose Form for any figure or video of a recognizable patient.

Title Page

- ☐ Provide a clinically interesting and informative title (96 characters or less, including spaces punctuation, and subtitle).
- ☐ Use Widely Accepted Abbreviations in title.
- ☐ Include word counts for Abstract and text and character count for the title.
- ☐ Include number of references, tables and figures.
- ☐ Include all authors with highest degrees and institutions.
- ☐ Provide full contact information
- ☐ If applicable, authors should indicate study sponsorship or funding information for the corresponding author and email addresses of all co-authors.
- ☐ Specify who completed the statistical analysis and list affiliation(s).
- ☐ Notification of pre-publication on a preprint server (e.g., bioRxiv) and doi number, if applicable.
- ☐ Provide a word count for the paper and abstract and a character count for the title (including spaces and punctuation).
- ☐ Indicate if there are "supplementary data" to the manuscript (Teaching Slides, Videos).
- ☐ Provide five or fewer Search Terms accompanied by their corresponding numbers.

Methods

In a subsection on **Standard Protocol Approvals, Registrations, and Patient Consents**, include the following (if applicable):

- ☐ A statement that approval was received by an ethical standards committee on human experimentation (institutional or regional) for any experiments using human subjects.
- ☐ A statement that written informed consent was obtained from all patients (or guardians of patients) participating in the study.
- ☐ Indicate that a signed Patient Consent-to-Disclose Form has been obtained for photos/ videos of any recognizable patient.
- ☐ If reporting a clinical trial, provide the identity of the public trials registry and the clinical trial identifier number.

In a subsection underneath Standard Protocol Approvals, Registrations, and Patient Consents, include the following section titled **Data Availability Statement**:

- ☐ Authors will be required to include a data availability statement specifying that any data not published within the article is available in a public repository and include digital object identifiers (doi) or accession numbers to the datasets or to state that anonymized data will be shared by request from any qualified investigator.

Body of Manuscript

- ☐ Use 12 pt. font size.
- ☐ Use a default typeface (e.g. Times, Times New Roman, Courier, Helvetica or Arial).
- ☐ Set the left margin at one inch and the right margin at one-half inch or more.
- ☐ Do not justify the right margin; leave it unaligned.
- ☐ Place the page number and lead author's last name in the upper right corner of each page (including the reference, tables, and figure legend(s) pages).

Results

- ☐ Evidence-based medicine statistics (if applicable) must be included for the manuscript to be forwarded for editorial review including confidence intervals, numbers needed to treat, and absolute risk reduction

Appendix 1 - Authors

- ☐ Provide names, locations, roles, and contributions of all authors in a tabular format.

Appendix 2 - Coinvestigators

- ☐ Provide co-investigator names, locations, roles, and contributions.

Page 2

- ☐ List disclosures for all authors.
- ☐ Indicate if study is industry-sponsored; if so, list sponsors.
- ☐ If one or more authors have no disclosures, include the following: "Dr. Doe reports no disclosures."

Forms and Checklists

- ☐ Upon request for revisions, each author must complete an interactive Authorship Agreement Form, Disclosure Agreement Form, and Publication Agreement Form.
- ☐ For randomized, controlled clinical trials, submit a completed Consolidated Standards for Reporting Trials (CONSORT) checklist.
- ☐ For studies on diagnostic accuracy, submit a completed Standards for Reporting of Diagnostic (STARD) checklist.
- ☐ For meta-analyses of randomized controlled trials, submit a completed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.
- ☐ For case-control, cohort, and cross-sectional observational studies, submit a completed STROBE checklist. (For items that do not apply to your study, indicate "N/A".)

Abstract

- ☐Abstracts should not exceed 250 words.
- ☐A structured Abstract is mandatory for Articles. (Clinical/Scientific Notes do not have Abstracts).
- ☐Include Classification of Evidence for therapeutic papers.

Drugs and Devices

- ☐ State generic name with proprietary name, city, & state of manufacturer in parentheses at first mention, generic name thereafter.

References

- ☐ The references (check classification for maximum number) should be numbered and listed in the order cited.
- ☐ If references include more than six authors, cite only the first three and add et al.
- ☐ If there are six or fewer authors, cite all of them.
- ☐ Use continuous pagination (e.g., 33-37, not 33-7).

Figures

- ☐ If submitting a randomized clinical trial (CONSORT) or a study reporting diagnostic accuracy (STARD), or a meta-analysis of randomized controlled trials (PRISMA), the flow chart should be figure 1.
- ☐ JPG , PPT, PDF, and GIF files may be submitted for review purposes only.
- ☐ Digital files must be saved at the size authors would like them to appear in print.
- ☐ Keys should be within the confines of the figure or included in the figure legend.
- ☐ The figure legend and a title of no more than 15 words should be placed on a separate page of the manuscript document.
- ☐ Indicate figures that are to be published online-only.

Supplemental Data (Upload as supplemental files)

- ☐ Cited 'in press' articles
- ☐ Videos and video legends
- ☐ CONSORT, STARD, STROBE, PRISMA checklists
- ☐ Patient Consent-to-Disclose Form for recognizable patients

Videos

- ☐ Videos must be 20MB or less. Preferred video formats include
- ☐ .wma, .mpg and .mov files.