Clinical EEG and Neuroscience
1–26

DOI: 10.1177/1550059420954054
journals.sagepub.com/home/eeg
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# Special Report on the Impact of the COVID-19 Pandemic on Clinical EEG and Research and Consensus Recommendations for the Safe Use of EEG

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**Abstract**

*Introduction*. The global COVID-19 pandemic has affected the economy, daily life, and mental/physical health. The latter includes the use of electroencephalography (EEG) in clinical practice and research. We report a survey of the impact of COVID-19 on the use of clinical EEG in practice and research in several countries, and the recommendations of an international panel of experts for the safe application of EEG during and after this pandemic. *Methods*. Fifteen clinicians from 8 different countries and 25 researchers from 13 different countries reported the impact of COVID-19 on their EEG activities, the procedures implemented in response to the COVID-19 pandemic, and precautions planned or already implemented during the reopening of EEG activities. *Results*. Of the 15 clinical centers responding, 11 reported a total stoppage of all EEG activities, while 4 reduced the number of tests per day. In research settings, all 25 laboratories reported a complete stoppage of activity, with 7 laboratories reopening to some extent since initial closure. In both settings, recommended precautions for restarting or continuing EEG recording included strict hygienic rules, social distance, and assessment for infection symptoms among staff and patients/participants. *Conclusions*. The COVID-19 pandemic interfered with the use of EEG recordings in clinical practice and even more in clinical research. We suggest updated best practices to allow safe EEG recordings in both research and clinical settings. The continued use of EEG is important in those with psychiatric diseases, particularly in times of social alarm such as the COVID-19 pandemic.

**Keywords**

COVID-19, psychiatry, resting state electroencephalography (rsEEG), event-related potentials (ERPs), event-related oscillations (EROs), quantitative EEG (qEEG)

Received July 27, 2020; accepted August 24, 2020.

## Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) that caused the corona virus disease outbreak in 2019 (COVID-19), was initially reported in December 2019 in Wuhan (China) and rapidly evolved into a global pandemic according to the World Health Organization (WHO). At this time, nearly 600 000 deaths due to the virus have been recorded worldwide, and severe lockdowns were imposed worldwide, given the public health risk. This affected several aspects of society, such as the economy, daily life, academic activities, and mental/physical health; presently, there is much work being conducted in an attempt to develop immediate priorities and longer-term strategies to face this situation.[1-4]

Previous data on the impact on mental health of the severe acute respiratory syndrome (SARS, which started in 2002) and the Middle East respiratory syndrome (MERS, which started in 2012) suggested that while most people will not suffer from a reactionary psychiatric disorder, clinicians must be aware of the possibility of depression, anxiety, fatigue, and posttraumatic stress disorder in the aftermath.[5] Undoubtedly, the acute effects of lockdowns, uncertainty about the future, and fear of death negatively affect the mental health of the global population. For these reasons, national health systems should carefully monitor those risk factors and mental health in both the general population and in those with a preexisting psychiatric illness. Accordingly, a key issue also concerns how *the treatment of current psychiatric outpatients, as well as inpatients of psychiatric care units, has been (and will be) managed during this pandemic*. Indeed, strict social/physical distancing measures and stay-at-home orders imply suspending many in-person medical consultations and clinic visits, or substituting these face-to-face consultations (eg, psychotherapy or social support) with remote interventions.

Clinical electrophysiology refers to the application of electrophysiology principles to medicine and is used throughout the world in neurology and psychiatry. Electroencephalography (EEG) is noninvasive, repeatable without significant learning effects, globally available, and cost-effective. EEG allows the investigation of neurophysiological mechanisms underlying cortical neural current and related voltages with low to moderate spatial resolution (ie, some centimeters) but better temporal resolution (ie, <1 ms) than other neuroimaging techniques (eg, functional magnetic resonance imaging on the order of seconds). In addition, EEG allows the investigation of dynamic features of brain activity, including neural oscillations and stimulus elicited neural responses, with millisecond sensitivity.[6] Two main facets can be described, one related to "testing" and another to "therapy."

First, different kind of *monitoring* tools exist. EEG is inexpensive and has low or no maintenance costs. This noninvasive method allows the recording of spontaneous electrical brain activity from multiple electrodes placed over the scalp (eg, see Biasiucci et al[7]). Despite limited spatial resolution, EEG is a valuable clinical tool for diagnosis due to its excellent temporal resolution, making it a first-line method to exclude diagnoses of epilepsy, drug intoxication, or sleep disorders in psychiatric patients. EEG can also be a helpful tool in the differentiation of delirium from a primary mood, anxiety, or psychotic disorder.[8] This "routine" and conventional EEG procedure is sometimes complemented by quantitative analyses of the digitized EEG

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(qEEG), a technique used for differential diagnosis and treatment response assessment. Sometimes semiautomated assessments of wakefulness regulation during prolonged resting state measurements is performed to estimate the usefulness of, for example, stimulant medication.[9,10] A derivative of the EEG technique includes event-related potentials (ERPs), referring to averaged EEG responses that are time-locked to the sensory or cognitive processing of stimuli.[11] As cognitive complaints are a key factor of mental diseases, cognitive ERP deficits have been widely reported in various psychiatric disorders.[12-15] Converging evidence shows that ERPs enrich our understanding of brain dysfunctions in sensory and cognitive systems in psychiatric patients, offering potential biomarkers to complement differential diagnosis, which is still mainly based on clinical evaluations. For instance, depressive symptoms are common in the general population[16] and have an overall pooled prevalence of 27% in outpatients.[17] Analysis of clinical psychiatric patients has demonstrated that, in order to follow the progress of a patient through time, the contingent negative variation (CNV) shows a different type of cumulative curve for the depressive and manic phase.[18] However, due to a lack of specificity, such ERP alterations have a poor diagnostic power in psychiatry, reflecting just an index of clinical severity—although, there are a few positive examples of the clinical utility of ERPs in some neurological conditions (eg, for coma monitoring[19]) or for assessing the efficacy of cochlear implants.[20] Therefore, if ERPs are often used in psychiatric care settings, their clinical relevance is still under debate. However, in research, recent work has tried to enhance their clinical applicability by fostering a longitudinal and intra-individual ERP approach in order to favor the individualized monitoring of cognitive abilities as a function of a treatment and the predictive power of ERPs regarding clinical trajectory.[10,21-26] Similarly, research also shows that qEEG-derived frequency bands, microstate analysis, and event-related oscillations (EROs; non–phase locked rhythmic pattern of neural activity) are highly modified in pathological brains.[27-30] Despite encouraging data, the relevance of such tools in daily psychiatric clinics is still under investigation.

Second, at a therapeutic level, it is worth noting that noninvasive brain stimulation (NIBS) that utilizes neuroelectric principles to modulate brain activity (such as transcranial direct current stimulation [tDCS], transcranial alternating current stimulation [tACS], or transcranial magnetic stimulation [TMS]) have been successfully established for the treatment of a wide range of psychiatric disorders (for a review, see Lefaucheur et al[31]). These tools are currently used as unique nonpharmacological treatment methods in severely impaired patients unresponsive to conventional therapies.[32,33]

However, the present restrictions that limit person-to-person contact have affected clinicians and researchers using EEG and other electrophysiological tools. Depending on regional restrictions, and whether electrophysiology is considered a major asset in the clinical evaluation of mental diseases in a particular jurisdiction, electrophysiological recordings in both mental health clinics and research centers were disrupted through the suspension of all activities to limited new enrollments. *As we consider electrophysiological measures an important and fundamental tool in the understanding and clinical management of psychiatric disorders*, their reestablishment in the current COVID-19 pandemic, as well as during future epidemics, is vital. Moreover, as a "second wave" of COVID-19 infections is likely to occur.[34,35] a roadmap of how to resume these activities in the face of the current circumstances is urgently needed, as well as plans for how to proceed in future pandemics.

A recent expert consensus paper provided recommendations for a rapid, prudent, and coordinated reestablishment of operations at institutions providing NIBS treatments or using NIBS in research.[36] *However, such recommendations still do not exist at the international level for EEG, qEEG, ERPs, EROs, and microstates for clinical or research applications*. Therefore, in the present article, a large multidisciplinary expert panel reviewed the state of electrophysiological recordings in clinical applications and research in patients with psychiatric disorders in several countries. By collecting data through a global survey, the main aims of the present article were (*a*) to highlight the impact of COVID-19 on electrophysiology in different countries around the world; (*b*) to provide an overview on the different strategies that have been introduced to mitigate the spread of the virus, along with general guidelines and checklists; and (*c*) to highlight the need to develop new opportunities for our community and prepare for future epidemics and pandemics.

## Method

A survey was created in order to (*a*) assess the challenges in responding to the COVID-19 pandemic in terms of EEG recordings in psychiatric units and in research, (*b*) highlight the strategies used in various clinics/labs to address or mitigate these challenges, and (*c*) investigate potential opportunities the pandemic is making for EEG practices in labs/clinics (see Table 1). Following a similar article recently published for NIBS tools,[36] 3 main phases were considered to drive data collection: (*a*) phase 0 refers to the challenges that affected clinical or research activities with respect to COVID-19, (*b*) phase 1 refers to the activities that have been implemented in response to the pandemic, and (*c*) phase 2 refers to the precautions planned or already implemented during the reopening of EEG research activities. The survey was sent by email to members of 2 main EEG societies working with psychiatric populations: the WPA Psychiatric Electrophysiology Section (https://www.wpanet.org/psychiatric-electrophysiology) and the EEG and Clinical Neuroscience Society (ECNS; http://www.ecnsweb.org/). This represents around 30 members, who were asked to forward the survey to colleagues (eg, members of the International Pharmaco EEG Society [IPEG; http://www.ipeg-society.org/], the International Federation of Clinical Neurophysiology [IFCN; https://www.ifcn.info/], Electrophysiology Professional Interest Area of ISTAART, and the Alzheimer's Association [https://action.alz.org/personifyebusiness/Membership/ISTAART/PIA/Electrophysiology.aspx]). We collected 15 reports from 8 different countries (Belgium, China, Czech Republic, Germany, Italy, Japan, Switzerland, and Turkey) with regard to clinics, as

**Table 1.** Illustration of the Questions Used in the Survey to Investigate the Impact of COVID-19 on Various Electrophysiological Measures for Clinical and/or Research Purposes.

| |
|---|
| Short survey on the EEG recordings labs/clinics in the era of COVID-19 for psychiatry departments<br>Your name and affiliation: |
| Main aim<br>• Challenges in responding to COVID-19 in EEG recordings labs/clinics<br>• Strategies your clinic/lab is using to address or mitigate these challenges<br>• Opportunities the pandemic is making for EEG practices/research in labs/clinics<br>General questions<br>• Which country are you currently working in?<br>• What is your role?<br>• Which is your main activity related to EEG settings? (research, clinic, both).<br>Precise questions<br>• What type EEG technologies (EEG eyes opened/closed, qEEG, ERPs [event-related potentials], EROs [event-related oscillations], microstates, polysomnography, neurofeedback, tDCS [transcranial direct current stimulation], . . .) are you using in your clinic? In your lab for research? What kind of psychiatric patients are you following with EEG tools for clinic? For research? What are the main purposes of these exams?<br>• When did your lab shut down in responding to COVID-19?<br>• How many people are involved in your clinic? In your lab?<br>• When is your clinic planning to reopen? Did your clinic consider EEG exams as a priority in the clinical assessment of your psychiatric patients?<br>• When is your lab planning to reopen?<br>• Has the COVID-19 affected your clinic/lab? If yes, in which way?<br>• How do you handle data coming from ongoing clinical studies?<br>• How do you handle ongoing clinical protocols?<br>• What changes in clinic/lab activity have you made in response to the COVID-19 pandemic?<br>• What changes have you made to sustain your clinical/research activity as a result of the COVID-19 pandemic?<br>• What precautions have you undertaken to prevent COVID-19 when you reopen/ed your clinic/lab?<br>• What are the opportunities that this pandemic might bring for your EEG protocols in the future?<br>• Any other practices/experiences in your EEG clinic/lab that might be interesting for your professional colleagues? |

well as 25 reports from 13 different countries (Belgium, Canada, China, Czech Republic, Germany, Hungary, Italy, Japan, Portugal, Spain, Switzerland, Turkey, and the United States) for research (see Tables 2 and 3).

This article was not designed to suggest revisions to diagnostic criteria but to reach consensus recommendations on the next steps for the safe use of EEG measures in the current COVID-19 circumstances and during future epidemics/pandemics. For this reason, the present review of the literature was not based on standard procedures typically adopted by international biomedical societies for the evidence-based revision of medical interventions and practices (e.g., the "GRADE" Handbook to address the so-called "PICO" health care questions, https://gdt.gradepro.org/app/handbook/handbook.html).

## Results

### *Clinical Data: What Is Used and Why*

#### *Reported Main Electrophysiological Measures*

- Standard resting EEG recording starting with eyes opened/closed condition (around 15 minutes), followed by hyperventilation (6 minutes maximum), and finally with photic stimulation (from 2 to 20 Hz for 6 minutes maximum).[37] This is used as a monitoring tool for psychiatric inpatients (and, when indicated, outpatients) to exclude epilepsy, organic (structural) disorder, drug side effects or intoxication, and/or consciousness disorder. Indeed, in the clinical workup EEG is required to detect delirium, which is the most common psychiatric syndrome found in the general hospital setting with a prevalence that surpasses most commonly known and determined psychiatric disorders. The incidence of delirium varies depending on the medical setting, which can range from 4.4% up to 73% for surgical interventions and 25% to 85% in cancer patients. Furthermore, several potential resting state markers exist for predicting treatment outcome in major depression, such as frontal alpha asymmetry,[38] prefrontal theta cordance,[39] pretreatment rostral anterior cingulate theta activity,[40] antidepressant treatment response (ATR) index,[41] and EEG functional connectivity.[42] Other resting-state EEG-based biomarkers are promising for the identification of patients at risk of mild cognitive impairment due to Alzheimer's and Lewy body disease,[43] and for subtyping subjects with attention deficit hyperactivity disorder (ADHD).[44] EEG is also used to monitor the effects of certain drugs, like lithium carbonate used in the treatment of bipolar disorder.[45] However, the use of EEG as a predictive biomarker to inform the choice of interventions has still not made its way into clinical practice due

**Table 2.** Data Gathered Concerning the COVID-19 Impact on Electrophysiological Monitoring Tools in Psychiatric Clinic.[a]

| Country | Name of the institution (contact person/s) | EEG tools used for clinical practice | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Belgium | CHU Brugmann, Brussels (Kajosch) | EEGs, ERPs, tDCS | March 15, 2020 | Still not clear | EEGs, ERPs, tDCS cancelled | Teleconference contacts, phone calls with patients | To be decided | Not clear |
| Germany | University Hospital Munich (Pogarell) | EEGs, tDCS, rTMS | No shutdown | Not applicable | Number of clinical EEGs decreased | Pandemic contingency plan was developed: hygiene plans and face masks (both patients and technicians) | Face masks, hygiene procedures and disinfection | Protocols how to safely run electrophysiology measures |
| Belgium | Private practice, Ghent (Otte) | EEG, qEEG, ERPs | March 13, 2020 | End of May? | All exams cancelled | Teleconference contacts, phone calls with patients | Hand washing, masks and UVC [ultraviolet-C] devices (lamps) to disinfect all material | Promote remote patients consultations |
| Switzerland | University Hospital Zurich (Olbrich) | Resting EEG, hyperventilation photic stimulation | No shutdown | Not applicable | Number of clinical EEGs decreased | Stricter indications for EEG recordings and strict hygienic regime | Rotating teams, isolation of patients on wards, social distancing, disinfection | Nothing |
| China | Sichuan Normal University (Yuan) | EEG, qEEG, ERPs | January 23, 2020 | Early July 2020 | All exams cancelled | All activities have been stopped | Cleaning of EEG material, social distance, hands washing, facial masks | Nothing |
| Japan | Osaka University (Ishii) | Resting EEG, hyperventilation photic stimulation | March 27, 2020 | Still not clear | All exams cancelled | All activities have been stopped | Cleaning of EEG material, social distancing, hands washing, facial masks; test only COVID-19 negative patients | Develop tools to measure EEG by using wearable EEG sensors without EEG technologists |

*(continued)*

**Table 2. (continued)**

| Country | Name of the institution (contact person/s) | EEG tools used for clinical practice | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Czech Republic | National Institute of Mental Health, Klecany (Brunovsky) | EEG, hyperventilation, photic stimulation, polysomnography, TMS, ERPs | March 16, 2020 | May 18, 2020 | All exams cancelled | All activities have been stopped | Patient checked for temperature and corona negativity disinfection, social distance, strict hygienic rules | Don't know |
| Germany | University of Tübingen (Fallgatter) | EEG; polysomnography | No shutdown | Not applicable | Number of clinical EEGs decreased | Safety distance, controls with regard to infection symptoms, face masks, disinfection protocols | Maximal safety measures | Don't know |
| Italy | Sapienza University of Rome (Buttinelli, Tisei) | EEG, hyperventilation, photic stimulation, ERPs, EMG | March 10, 2020 | Early June 2020 | All exams cancelled | All activities have been stopped | Patient checked for temperature and corona negativity disinfection, social distance, strict hygienic rules | Don't know |
| Italy | University of Campania, Naples (Mucci, Giordano, Perrottelli) | EEG, hyperventilation | March 9, 2020 | Still not clear, possibly in September 2020 | All EEG activities stopped | All activities have been stopped | Safety distance, controls with regard to infection symptoms, face masks, disinfection protocols | Promote development of telemedicine devices allowing accurate clinical EEG assessment |
| China | Shanghai Jiao Tong University School of Medicine (Wang) | ERPs (CNV, P300, visual evoked potential, auditory brainstem response, somatosensory EP) | January 31, 2020 | April 7, 2020 | All exams cancelled | All activities have been stopped; smooth restart: EEG exams only for inpatients hospitalized since 2 weeks | Temperature check, history of traveling and living asked; disinfection by ultraviolet light, strict hygienic rules | Nothing |
| Belgium | Hospital Sint-Jan Brugge-Oostende | qEEG, ERPs | March 30, 2020 | May 4, 2020 | All exams cancelled | All activities have been stopped | Face masks, frequent hands washing, room/material disinfection; test only COVID-free patients | Maintain the current cleaning/disinfecting of caps by sterilization department. Stimulate the development of remote EEG monitoring |

*(continued)*

**Table 2. (continued)**

| Country | Name of the institution (contact person/s) | EEG tools used for clinical practice | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| | (Dumalin) | | | | | | | |
| Italy | University of Rome Tor Vergata (Di Lorenzo) | EEG, qEEG, polysomnography, tDCS | No shutdown | Not applicable | numbers of clinical EEGs decreased | Only "urgent," at the clinician's judgment, examinations were performed | Face masks, surgical gloves, room/material disinfection; test only COVID-free patients | |
| Switzerland | University of Fribourg (Missonnier) | EEG, ERPs, EROs, polysomnography, neurofeedback | March 9, 2020 | May 18, 2020 | All exams cancelled | All activities have been stopped | Cleaning of EEG material, social distancing, hands washing, facial masks | Stimulate the development of remote EEG monitoring (use of 2 separate rooms) |
| Turkey | Kemal Arıkan Psychiatry Clinic, Istanbul (Arikan) | EEG eyes opened/ closed, qEEG, rTMS | March 17, 2020 | June 1, 2020 | All exams cancelled | The clinic has prioritized telepsychiatry and online therapy during COVID-19 pandemic | Disinfection company, masks for clinicians and patients, social distance rules will be followed in the waiting room | Nothing |

Abbreviations: qEEG, quantitative EEG; ERP, event-related potential; ERO, event-related oscillation; rTMS, repetitive transcranial magnetic stimulation; tDCS, transcranial direct current stimulation; CNV, contingent negative variation; EMG, electromyography; EP, evoked potential.

[a]Phase 0 refers to the challenges that affected clinical activities with respect to COVID-19. Phase 1 refers to the activities that have been implemented in response to the pandemic. Phase 2 refers to the precautions planned or already implemented during the reopening of EEG clinics.

**Table 3.** Data Gathered Concerning the COVID-19 Impact on Electrophysiological Monitoring Tools in Psychiatric Research.[a].

| Country | Name of the institution and contact persons | EEG tools used in research | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Belgium | CHU Brugmann, Brussels (Campanella) | Cognitive ERPs; tDCS; neurofeedback | March 15, 2020 | Still not clear | All studies suspended | Researchers and participants under lockdown<br>Implementation of tele-working/conferencing | To be decided | Strengthening of national and international collaborations? |
| Germany | University Hospital Munich (Pogarell) | Cognitive ERPs; neurofeedback | March 16, 2020 | May 3, 2020 | All studies suspended | Home working, process/writing existing data tele-conferencing | Face masks, hygiene procedures and disinfection | Protocols how to safely run electrophysiology measures |
| Turkey | Istanbul Medipol University (Guntekin) | EEG; EROs | March 16, 2020 | Around June-September 2020 | All studies suspended | Lab reopening around June 15 for EEG analysis and paper writing | Social distancing, hand-hygiene and wearing chirurgical masks and disinfecting the all equipment | Nothing |
| Portugal | University of Minho (Lopez-Caneda/Pinal) | EEG; qEEG; EROs; ERPs; tDCS | March 9, 2020 | Still not clear; September 2020? | All studies suspended | Tele-working on previously collected data | BioSemi recommendations for cleaning and disinfecting all materials<br>Social distancing, hand-hygiene and wearing chirurgical masks | Nothing |
| Switzerland | University Hospital Zurich (Olbrich) | EEG; ERPs; TMS | March 15, 2020 | May 4, 2020 | All studies suspended | Focus shifted to data analyses | Reduce time of contact; strict hygiene rules | Outsourcing EEG lab from hospital, try new approaches of data processing |
| China | Sichuan Normal University (Yuan) | EEG, qEEG, ERPs, EROs | January 23, 2020 | Early July 2020 | All studies suspended | Analysis of previously recorded data<br>Online questionnaires for behavioral data | Cleaning of EEG material, social distance, hands washing, facial masks; test COVID-19 positivity before inclusion in the study | Nothing |

*(continued)*

**Table 3. (continued)**

| Country | Name of the institution and contact persons | EEG tools used in research | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Italy | Catholic University of Milan (Balconi) | ERPs, EROs, qEEG, neurofeedback, TMS, tDCS | March 15, 2020 | Lab reopening since May 11 for material consultation and software usage | All studies suspended | Smart working at home, previously collected data analyses, teleconferencing | Room and material disinfection, rules of social distancing, hand-hygiene and wearing chirurgical masks | Develop new research themes on COVID-19 impact |
| Italy | University "G. d'Annunzio" Chieti-Pescara (Bertollo/Comani) | qEEG, neurofeedback, tDCS | March 6, 2020 | June 2020 at the earliest | All studies suspended | Smart working at home, teleconferencing, analyses of previous data, literature reviews | Body temperature below 37.5 °C, surgical mask, gloves, hands washing, social distancing, open windows at least for 10 minutes every 4 hours, local/material disinfection | Nothing |
| Japan | Osaka University (Ishii) | ERPs, EROs | March 27, 2020 | Still not clear | All studies suspended | Data analyses and paper writing, teleconferencing | Cleaning of EEG material, social distancing, hands washing, facial masks; test only COVID-19 negative patients | Development of remote rehabilitation system using wearable sensors, motion analysis, 3D holograms and virtual reality |
| Hungary | Research Center for Natural Sciences, Budapest (Winkler) | EEG/ERP, NIRS, eye tracking | March 1, 2020 | June 15, 2020 | All studies suspended | Home working, process/writing existing data | Select participants based on questionnaire and temperature measurement; room and material disinfection, social distancing, hand hygiene, masks, gloves | Planning new ERP studies on patients who recovered from COVID-19 |
| Italy | European University of Rome (Imperatori) | Resting state EEG, qEEG | March 12, 2020 | Still not clear; October 2020? | All studies suspended | Home working and tele-conferencing | Still waiting for department dispositions | Don't know |
| Czech Republic | National Institute of Mental Health, Klecany (Brunovsky) | 256-/128-/32-channel EEG; ERPs, tDCS, tACS | March 16, 2020 | May 18, 2020 | All studies suspended | Home working and tele-conferencing | Participants checked for temperature and corona negativity disinfection, social distancing, strict hygienic rules | Don't know |

*(continued)*

**Table 3. (continued)**

| Country | Name of the institution and contact persons | EEG tools used in research | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Germany | University of Tübingen (Fallgatter) | ERPs, tDCS, neurofeedback | March 15, 2020 | May 18, 2020 | All studies suspended | Home working and teleconferencing | Safety distance, controls with regard to infection symptoms, face masks, disinfection protocols | More time for writing papers and proposals Analysis of old data |
| Italy | Sapienza University of Rome (Babiloni, Betti) | EEG; ERPs; resting state; source reconstruction; connectivity; graph theory | March 10, 2020 | Early June 2020 | All studies suspended | Home working, process/writing existing data | Participants checked for temperature and corona negativity disinfection, social distance, strict hygienic rules | Planning new EEG studies on COVID-19 impact on cognition Development of easy-to-use virtual reality experiments combined with EEG dry electrodes technology |
| Spain | University of Barcelona (Escera) | EEG; ERPs; EROs | March 13, 2020 | Still not clear; September 2020? | All studies suspended | Home working: data analysis, analysis protocol development, manuscript preparation, project management | Only negative coronavirus participants allowed; restricted access to the lab; only one user in contact with participant; disinfection; strict hygiene measures; addendum to inform consent form | Nothing |
| Italy | University of Campania, Naples (Mucci, Giordano, Perrottelli) | ERPs; resting-state EEG (microstate analysis, peak and dipole analyses) | March 9, 2020 | Still not clear; September 2020? | All studies suspended | Home working | Safety distance, controls with regard to infection symptoms, face masks, disinfection protocols | Promote development of telemedicine devices allowing accurate research EEG assessment |
| China | Shanghai Jiao Tong University School of Medicine (Tang) | EEG, ERPs, TMS, mECT | January 31, 2020 | April 7, 2020 | All studies suspended | Home working (data analysis) | Subjects who have not been to/ in Hubei province or have been in Shanghai more than 14 days without any symptom can perform research EEG examinations | Nothing |
| United States | University of Pittsburgh School of Medicine (Salisbury) | rsEEG, ERPs, EROs | March 17, 2020 | Still not clear; July 2020? | All studies suspended | Home working (data analysis, writing papers, and grants funding proposals) | To be decided | Maybe get extra funding to finish work? |

*(continued)*

**Table 3. (continued)**

| Country | Name of the institution and contact persons | EEG tools used in research | Start date of restrictions | (Planned) date of easing the restrictions | Phase 0 | Phase 1 | Phase 2 | Opportunities for the future |
|---|---|---|---|---|---|---|---|---|
| Belgium | Hospital Sint-Jan Brugge-Oostende (Dumalin) | qEEG; ERPs | March 30, 2020 | Still unclear | All studies suspended | Home working and data analysis | Face masks, frequent hands washing, room/material disinfection; test only COVID-free participants | Maintain the current cleaning/disinfecting of caps by sterilization department |
| Canada | Mount Saint Vincent University, Halifax (Fisher) | EEG, ERPs, microstates | March 19th 2020 | Still unclear | All studies suspended | Home working, papers writing, data analysis (but slowed without access to lab computers and specialized software) | Heightened infection control procedures, still to be decided | Protocols how to safely run electrophysiology measures |
| Italy | University of Rome Tor Vergata (Di Lorenzo) | (rs)EEG, ERPs, qEEG, tDCS, tACS/tRNS | March 9, 2020 | Last week of June 2020 | All studies suspended | Home working: overall, data analysis through remote control of lab workstations | Face masks, face shields, gloves during EEG procedures; frequent hand washing, room/(EEG) material disinfection; body temperature (BT) monitoring of the laboratory staff and of the participants on entering the laboratory (BT $<$37.5 °C is mandatory to enter the university) | Stimulate the development of remote EEG processing |
| Italy | University of Rome Tor Vergata 2 (Bianchi) | ERPs, neurofeedback | March 8, 2020 | Last week of June 2020? | All studies suspended | Home working: data analysis and software development | Still waiting for department dispositions | Nothing |
| Switzerland | University of Fribourg (Missonnier) | EEG; EROs; ERPs | March 9, 2020 | May 11, 2020 | All studies suspended | Home working, data analysis | Heightened infection control procedures | Stimulate the development of remote EEG monitoring (use of 2 separate rooms) |
| Canada | University of Toronto (Kiang) | ERPs | March 20, 2020 | Still unclear | All studies suspended | Home working, some follow-up longitudinal studies by phone | Still waiting for department dispositions | Don't know |
| Turkey | Kemal Arıkan Psychiatry Clinic, Istanbul (Arikan) | qEEG, TMS | March 17, 2020 | June 1, 2020 | All studies suspended | Home working, teleconferencing | Heightened infection control procedures | Research on the psychological impact of COVID-19 |

Abbreviations: qEEG, quantitative EEG; rsEEG, resting state EEG; ERP, event-related potential; ERO, event-related oscillation; rTMS, repetitive transcranial magnetic stimulation; tACS, transcranial alternating current current stimulation; tDCS, transcranial direct current stimulation; tRNS, transcranial random noise stimulation; NIRS, near-infrared spectroscopy; mECT, modified electroconvulsive therapy.

[a]Phase 0 refers to the challenges that affected research activities with regard to COVID-19. Phase 1 refers to the activities that have been implemented in response to the pandemic. Phase 2 refers to the precautions planned or already implemented during the reopening of EEG labs.

to the small amount of evidence,[46] even if some recent studies showed promising results of EEG-based prediction in refractory status epilepticus,[47] and antidepressant response.[48] Results from qEEG research in schizophrenia have not yet led to the implementation of a clinical test for the diagnosis of this complex disorder[49]; for instance, the mere presence of increased delta and theta activity would not be sufficient on its own to provide a diagnosis of schizophrenia.[50] Also, patients presenting with treatment resistant borderline personality disorder often present EEG abnormalities.[51]

- ERPs (sensory evoked: P50, N100, P200, or cognitive elicited: CNV, mismatch negativity [MMN], P300) are used mainly for subjects presenting with cognitive disorders[52] (see de Tommaso et al[53] for recent review). Traditionally CNV amplitude is related to a combination of attention and arousal. However, analysis of hospitalized psychiatric patients has demonstrated that the use of the cumulative curve of the CNV is indicated for bipolar disorders where it can illustrate whether the patient is in a depressive and manic phase.[54] For the oddball P300, the focus is predominantly on the waveforms of average responses to the nonstandard stimuli (ie, deviant and/or target stimuli). The average waveforms to the standard stimuli, which are similar to the auditory long latency response (ARL) can also be of use for psychiatric disorders. Data analysis of hospitalized patients has shown that substance abuse will affect the ARL differently in case there is abuse of a single substance. Chronic alcohol abuse will show reduced amplitudes of the N100 and P200 components, while occasional alcohol abuse will show normal amplitude. In cases of abuse of benzodiazepines, the frontal amplitudes will show (marked) increased amplitudes of the N100 and subsequent components. For opiate abuse, the standard average waveform can show frontal and parietal increased amplitudes most pronounced for the N100 and less for the P200 component, which can occur in combination with an increase of latencies.[54] N100 and P200 are reduced in first-episode schizophrenia,[55] although the N100 reduction is present only in first-episode schizophrenia individuals who hallucinate, showing a specific association with a psychotic symptom.[56] Among other sensory ERPs, an inhibition deficit of the P50 may represent a central neurophysiological dysfunction characteristic of schizophrenia (the sensory gating deficit[57]). Although ERPs abnormalities have been robustly reported in subjects with schizophrenia, their use as diagnostic biomarkers has still not been clearly established. This is due to the fact that alterations in these EEG indexes are often found across different psychiatric disorders. For instance, many studies support MMN and P300 amplitude reduction as feasible biomarkers of schizophrenia, but the same abnormalities have also been found in subjects with bipolar disorder and depression.[58-60] These findings suggest the presence of relationships between neurophysiological abnormalities and transdiagnostic psychiatric symptoms, rather than associations to a specific disorder.[61] More promising are results of studies conducted in subjects with schizophrenia, concerning the use of EEG abnormalities as potential predictors of illness course and outcome.[62-65] For example, the degree of MMN impairment increases in the first few years after the onset of psychosis, in concert with the amount of left auditory cortex reduction, thus serving as a biomarker of progressive gray matter loss.[66]
- Polysomnography (PSG) is useful for examining the neural regulation of sleep/wake patterns and test for their disturbances, including sleep apnea, periodic leg movements in sleep and the restless legs syndrome, which are highly prevalent in mild cognitive impairment (MCI) and many types of dementia. Sleep disturbances are also associated with psychological distress and depression, with a consequent significant impact on the cognitive and physical functions of the patients.[67] PSG can be an important part in the diagnostic evaluation of severe sleep disturbances in psychiatric disorders, as well as in primary insomnia and parasomnias. Moreover, whole-night PSG has an irreplaceable role to confirm isolated REM (rapid eyemovement) sleep behavioral disorder that is considered to be an early biomarker of α-synucleinopathic neurodegeneration in Parkinson's disease, dementia with Lewy bodies, and multiple system atrophy.[68,69] A few years ago, the Italian Dementia Research Association (SINDem) prepared recommendations for the diagnosis and treatment of sleep disorders in individuals with MCI and dementia, where the use of PSG, or of alternative similar methods to monitor sleep/wake patterns, was recommended for diagnostic purposes.[70]

*Phase 0: Start date of restrictions and main consequences.* Among the 15 reports we received, 11 clinical centers reported a total stoppage of all clinical EEG activities, starting January 23, 2020 at Sichuan Normal University (China) and around March 9, 2020 in Europe (University of Campania, Naples, Italy; University of Fribourg, Switzerland). Only 4 centers reported "no complete shutdown," with the main consequence of COVID-19 on the clinical EEG procedures being a decreased number of recordings.

*Phase 1: Activities implemented in response to the pandemic and planned date of restarting.* The University Hospital of Munich (Germany), University Hospital of Tübingen (Germany), the University Hospital of Zurich (Switzerland), and the University Hospital of Rome "Tor Vergata" (Italy) responded to the COVID-19 pandemic by decreasing, not halting, the number of electrophysiological recordings. Updated procedures included routine screening of all patients before entering the hospital, including recording of temperature. Patients with signs of respiratory infections were not assessed with EEG. In all other cases, urgent EEG recordings (eg, exclusion of epilepsies, encephalopathies, drug toxicity) were performed. Both patients and technicians were required to wear face masks, while technicians used gloves and face shield during the placement of scalp electrodes. Importantly, at this time no COVID-19 infections among EEG staff have been reported in any of these centers despite the continuation of electrophysiological measures. However, after the cancellation of all electrophysiological measures in the 11 other centers, one (Shanghai Jiao Tong University School of Medicine, China) reported a smooth restart of the EEG activity on April 07th 2020, while others reopened in early May (Hospital Sint-Jan Brugge-Oostende, Belgium; National Institute of Mental Health, Klecany, Czech Republic; University of Fribourg, Switzerland). In these clinics, only "urgent" examinations have been (or will be) performed at the clinician's judgment (including the medical director of the hospital). All other centers reported that all electrophysiological activities have been stopped, and that clinical contact with patients has been maintained only through teleconference and phone calls. Future resumption of EEG recordings among responding centers are planned for later in June (Kemal Arikan Psychiatry Clinic, Istanbul, Turkey; Sapienza University of Rome, Italy) or later in July (Sichuan Normal University, China). Conversely, dates for resumption of testing are still not clear for EEG recordings related to the clinical activities at the University of Campania (Naples, Italy), where urgent routine clinical EEG patients are referred to the neurological department; Osaka University (Japan); University Hospital, CHU Brugmann (Brussels, Belgium); and a private practice center (Ghent, Belgium).

*Phase 2: Precautions planned or implemented during reopening.* Several precautions have been planned and implemented to deal with the pandemic. These include (from most to least used):

- Strict hygiene procedures: surgical mask, frequent hand washing, disposable gloves, single-use syringe and blunt needle, frequent room ventilation (via open windows or air conditioning for a couple of minutes for a complete change of air in the lab), testing patient in a separate room from the EEG technician where possible. After each patient, room and material disinfection includes desks, lab surfaces, plastic keyboard covers (with 70% ethanol), response pads, and computer screens, as appropriate (with 70% isopropyl alcohol), as well as procedure chairs and EEG equipment (eg, via disinfectant wipes). At one center, EEG caps are washed to remove the gel and then placed into a plastic box that can be closed. After a few caps have been used, the box is sent to the sterilization department where a 3 step process takes place: (*a*) the caps are soaked for 15 minutes in an Aniosyme XL3 solution, (*b*) thoroughly rinsed, and (*c*) machine dried. All preparatory and application materials are placed behind the patient and any procedures requiring close contact, such as putting on the EEG cap, is carried out behind or on the side of the patient to avoid face-to-face positioning.
- Safety measures: testing only COVID-19 free patients (test SARS-CoV-2 negativity if possible; if not, before the admission to the in-clinic visit, the clinician administers a questionnaire to the patient to exclude the presence of symptoms related to the COVID-19 and the potential risk exposure in the past 2 weeks to COVID infection, such as close contact with a suspected or confirmed case of COVID-19). If all the aforementioned criteria are negative, the patient can attend the EEG laboratory/clinic. When the patient does arrive for testing, the clinician will record the patient's temperature at the start of the visit. Testing procedures to employ physical distancing as much as possible, including limiting test session to one patient with only one technician, and rotating teams.
- Isolation of patients on wards.
- Material disinfection by deep ultraviolet light (UVC in the range of 200-300 nm).
- For polysomnography, it is policy to (*a*) clean cup electrodes properly after each study using mild soap and water—a toothbrush with soft bristles may be used to remove paste and then be disinfected using bleach in water; (*b*) dispose of sticking electrodes/button electrodes after every use; (*c*) change cannulae used to measure respiratory flow after every use; (*d*) wipe respiratory belts using a cloth dampened with alcohol after every use; (*e*) clean oximeter probe with alcohol wipes after every use; (*f*) clean the thermistor with alcohol wipes after every use; (*g*) wash chin straps with warm water after every use; and (*h*) clean continuous positive airway pressure (CPAP) masks, hoses, and straps with lukewarm water after every use and then send them for ethylene oxide sterilization.[71]

*New opportunities brought by the pandemic situation.* Probably the most relevant modification required and accelerated by COVID-19 was the development of best practice protocols to safely run electrophysiological measures (notably in case of future pandemics). Besides typical safety and hygiene guidelines, the current circumstances highlight the utility of recording electrophysiological measures in 2 separate rooms (even if shielded EEG rooms are often limited). The current situation can also promote the development of new tools, such as remote devices allowing accurate clinical EEG assessment by using wearable EEG sensors without EEG technologists (even if, of course, the quality and comparability without a technician guided procedure is questionable). New EEG recording systems often involve small, lightweight amplifiers alongside wireless transmission, which contribute to increased practicality and portability of the devices.[72] These new tools, in some cases, reduce or potentially eliminate the need of contact between technician and subject due to easier set up procedures. An example of a possible application is the MONARCA project in Europe,[73] which has developed a mobile technology for subjects with bipolar disorder with the aim to assess early warning signs and eventually predict the occurrence of episodes. This technology allows monitoring physiological and behavioral information through four elements:

a sensor enabled mobile phone, a wrist worn activity monitor, a stationary EEG system and novel sock-integrated electrodermal activity sensor. Finally, temporary tattoo electrodes (TTEs) directly laminated onto the skin also show promise for clinical use and offer advantages compared with the current wet and dry electrodes used. Apart from removing the need for cleaning/disinfecting they are perforable, such that hair can grow through them without impairing the quality of recorded signals, and do not show formation of sweat with time.[74]

## Research Data: Main Protocols and Aims

### Reported Main Electrophysiological Measures

- An important amount of research is devoted to ERPs, such as P50, MMN, event-related negativity (ERN), and P300.[75] A highly valuable aspect of cognitive ERPs is that they permit the inference of impaired cognitive stages.[76] In other words, by using a well-characterized task and analyzing which ERPs show decreased amplitude and/or delayed latency compared to normal values, it is possible to deduce which processing stage is associated with the deficit.[22] In this view, by allowing the evaluation of the entire information processing stream, ERPs can help pinpoint the specific neurocognitive functions that should be targeted in each patient through specific and individualized cognitive remediation procedures (through cognitive training and NIBS tools, for instance[22]). Moreover, because cognitive symptoms are closely linked to the onset and maintenance of clinical symptoms (eg, a lack of inhibition can support negative intrusive thoughts or ruminations in depressive disorders as well as relapse in alcohol dependence[23,77]), ERPs can also be used as biological markers of the progression of a brain-based disease.[66] Accordingly, the oddball P300 and the No-Go P300 components (ERP waveforms typically elicited in classical paradigms such as the oddball and the Go/No-Go tasks) have been recently shown to predict abstinence vs. relapse at three months in recently detoxified alcoholic patients,[25] while MMN deficits have been shown to differ between early and chronic schizophrenia.[78-81] However, despite decades of research, ERPs have yet to be implemented in the clinical management of psychiatric patients. A main limitation of this approach is surely "technical," as many complex methodological challenges arise when applying the ERP technique to clinical populations.[82] Yet the use of passive paradigms, which requires minimal effort from patients also holds promise; for example, the MMN has been used to assess coma severity and prognosis, and in phoneme training in dyslexia.[15]
- Assessment of EEG-vigilance regulation during eyes-closed resting conditions using semiautomated procedures: Decreased wakefulness during the resting state and before sleep onset can be assessed quantitatively using the Vigilance Algorithm Leipzig (VIGALL[9]) It is a method to screen for different functional brain states in patients and healthy subjects and has diagnostic[83] and predictive power.[84] Following the electrophysiological patterns of wakefulness regulation,[85-87] the vigilance algorithm allows for the identification of short shifts of arousal (with a resolution of 1 second) during wakefulness. Since the regulation of brain arousal is crucial for many different neuropsychiatric disorders such as ADHD and major depression, it is important to be able to objectively assess alterations of wakefulness regulation. The vigilance framework helps identify these patterns. Within the clinical context, this information could be used to improve the choice of therapeutic interventions, although independent validation of VIGALL is still missing.[46]
- EROs: The study of EROs enables the measurement of frequency-specific brain electrical oscillations in neural circuits that are related to the sensory and cognitive processing of stimuli.[88] EROs are commonly classified according to the "natural frequencies" of the brain,[89] that is, delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30-70 Hz). The analysis of EROs yields several measures such as event-related power, event-related phase locking (intertrial coherence), event-related coherence, and cross-frequency coupling. Event-related power increases in comparison with prestimulus activity are commonly referred to as event-related synchronization (ERS),[90] while event-related power decreases in comparison to pre-stimulus activity are known as event-related desynchronization (ERD).[6,90] Different frequency bands have been associated with a myriad of cognitive functions such as perception, attention, memory, inhibitory control, and decision making.[91-94] For example, the gamma ERO elicited by 40 Hz click trains is used frequently to assess circuit function in schizophrenia,[95] is reduced in first-episode psychosis,[96] and is impaired in the prepsychosis prodromal stage as well.[97] Other EROs in the alpha (~12 Hz) and theta (~6 Hz) range are examined as measures of information transfer between distributed cortical areas, and are impaired in psychiatric disorders. For instance, alpha connectivity was impaired in several dynamic brain networks in first-episode schizophrenia, including deficits in right inferior frontal gyrus, anterior and posterior cingulate, and left posterior superior temporal gyrus, all areas associated with psychotic symptoms.[98] Steady-state visual alpha responses were also reduced in schizophrenia patients.[99,100] Schizophrenia patients had a reduced late gamma response (220-350 ms) compared with healthy controls during an auditory oddball paradigm, while there was no difference between patients and healthy in the early time window (20-100 ms).[101] The early auditory gamma-band response is reduced in first-episode schizophrenia.[102] On the other hand, increased gamma power in schizophrenia patients over frontal electrodes has been reported.[103] Increases of delta and theta power and phase locking, especially over

frontal-central areas, has been shown during different working memory processes in healthy subjects and is an essential sign of a healthy brain. Several authors showed that both schizophrenia patients and bipolar disorder patients had reduced delta and theta responses during different working memory paradigms. Reduced delta phase locking during the auditory oddball paradigm,[104,105] as well as reduced evoked delta power during both a visual oddball paradigm[106] and a Go/No-Go paradigm[107,108] were found in schizophrenia patients. Theta power and phase locking were reduced in schizophrenia patients during memory tasks,[109,110] auditory oddball paradigms,[104,105] and Go/No-Go paradigms.[107,108] Reduced delta and theta responses were also reported in bipolar disorder patients during oddball paradigms.[111-113] Overall, reductions of delta and theta responses are thought to be a general indicator of pathological brains; reductions of these EEG bands are found not just found in schizophrenia and bipolar patients but also in dementia patients. Patients with MCI,[114,115] patients with Alzheimer's disease,[116,117] and dementia patients with Parkinson's disease[118,119] have also been shown to exhibit reduced delta and theta responses. Similar to those with schizophrenia, bipolar disorder patients have reduced auditory steady-state gamma power.[96,120,121] However, beta and gamma responses during cognitive paradigms could be differentially affected by different pathologies. Several studies have shown reduced beta power and phase locking in schizophrenia patients using visual Gestalt stimuli[122,123] and N-back tasks.[124,125] Conversely bipolar patients are reported to have increased beta responses during the visual oddball paradigm, with these increased responses being normalized after valproate monotherapy.[126] Bipolar patients are also reported to have reduced event-related gamma coherence during a visual oddball paradigm,[127,128] while Alzheimer's disease patients have increased event-related gamma coherence under the same conditions and in auditory steady-state gamma responses. Future research is needed comparing different pathologies with the same paradigm and methodology. In line with this idea, a series of studies explored the event-related brain oscillatory responses in the context of a verbal working memory (WM) paradigm (N-back verbal WM task for letters) in different groups of neuropsychiatric disorders, which all show dysfunctions of this cognitive function. Compared with controls, patients with first-episode psychosis (FEP) exhibit increased frontal theta ERS in all WM conditions,[129] while the theta power was reduced in patients diagnosed with ADHD.[130,131] However, both power and time course of frontal alpha ERD/ERS cycle was modified in ADHD patients, while that was not the case in FEP. In dementia disorders, abnormal theta power[130,132] during WM activation was associated with progressive MCI (PMCI), but not stable MCI (SMCI). Moreover, parietal beta ERS was decreased in PMCI in the N-back task compared with SMCI and controls.[133] These results argue in favor that WM load-related EEG parameters could differentiate each pathology. Supporting this view, the combination of 3 two-back related EEG indices at baseline provided a prediction of MCI deterioration with 90% of correctly classified MCI cases. The fact that the highly accurate distinction between PMCI and SMCI included beta ERS and P200-N200 ERP components demonstrate that the combination of EEG biomarkers may be a reliable tool for characterization of psychiatric disorders.

- qEEG: Resting EEG records the brain's spontaneous electrical activity over a period of time and continues to be a valuable tool for research and diagnosis.[134] Resting state EEG activity can be quantified as different frequency components that are relatively stable over time[135] through mathematical analyses performed on the raw EEG activity using standardized algorithms.[136] The activity of these specific oscillatory bands, including alpha, beta, theta, and delta frequency range, encompass quantitative EEG (qEEG) and have been linked to one's attention and arousal level both at rest[134] and during various tasks.[137] Alpha activity is most commonly associated with relaxed wakefulness, whereas beta activity is associated with active concentration and focused attention.[138] The 2 slower bands, delta and theta, are typically associated with reduced cortical activation of the brain, and can be linked to higher levels of inattentiveness, drifting, and less focus.[138] ADHD is often characterized by increased frontal theta and posterior delta.[139,140] Conversely, increased theta power has previously been found to be associated with enhanced feedback processing and improved error detection,[141] while reduced theta activity has been linked to increased difficulty maintaining attention and concentration.[142] The spectral power and coherent activity of these bands during resting conditions are frequently used as a baseline measure of brain activity in the research of cognitive processes, including those of decision making and risk taking.[135] Although qEEG may suffer from the problem of volume conduction or common sources,[143] specific algorithms for the identification of signal sources can address this issue.[144,145] Therefore, compared with the traditional visual EEG scoring, qEEG measures can provide a useful source of information for both clinicians and scholars in a relatively low-cost and easy to administer way. For example, power spectral density (ie, the distribution of the power of a signal in the frequency domain), can be used in order to determine spatial structures and localize areas with brain activity or abnormalities.[146,147] Furthermore, brain functional connectivity measures, such as EEG coherence, provide an important estimate of functional interactions between neural systems operating in each frequency band, offering potentially valuable information about network dynamics and functional integration across brain areas.[148] However, some limitations prevent the conversion of the vast amount of qEEG results into a diagnostic tool for daily clinical practice. First, one considerable element is the variability of methodologies employed in qEEG studies, which causes discrepancies when testing for robustness of the results. Second, there is substantial variability in EEG recordings both across and within individuals, even in the absence of psychiatric disorders, suggesting that other variables in addition to pathophysiological factors can heavily influence results. Finally, common patterns of qEEG abnormalities emerge when multiple psychiatric disorders are considered, highlighting that some of the measures might be not enough sensitive as a differential diagnostic tool.

- Microstates and connectivity: A body of research in EEG with the potential of becoming extremely useful for clinical applications involves the development of analytical methods for the assessment of brain dynamics (through microstate analysis) and of information flow occurring across different brain areas during resting states or during the execution of a given task (through functional and effective connectivity, and graph theory). Tasks can be of various types (eg, cognitive, motor), of different difficulty, and involving one or multiple subjects (eg, hyperbrain studies). Microstates analysis is a well-established method for characterizing human brain activity using multichannel EEG.[149] This method is based on the concept that EEG microstates, which are defined as global patterns of scalp potential topographies generated by distributed neural pools synchronously active and semi-stable for short time intervals, dynamically vary over time in an organized manner.[150,151] The brain dynamics described by an EEG time course can be represented by a noncasual sequence of microstates without any type of a priori hypothesis,[152] with the added advantage over classic spectral methods that microstate analysis preserves the time information that is lost with spectral approaches. Taken a step further, this method links patterns of information exchange among brain areas to corresponding patterns of scalp potentials. Functional and effective connectivity are analytical methods that, through the calculation of indices quantifying conjoint properties of EEG signals such as coherence, phase lagged synchronization, or lagged coherence,[153-156] permit the reconstruction of networks of spatially distributed electrodes (sensor level) or brain areas (source level) that are functionally connected during the resting state or the performance of a given task. These networks provide an overview of the functional interactions between neighboring and distant brain regions.[157-160] To elucidate how information is exchanged within the functional networks and to identify their functional properties, graph theory metrics can be used.[161] By defining the brain as a network containing nodes and edges, which respectively represent brain regions and connecting pathways between those regions, graph theory metrics permit to quantify several network features, such as the local and global efficiency in transferring the information between close and distant brain regions.[158,159] The results of these microstates and functional connectivity analyses may have an impact on clinical applications such as schizophrenia,[28,162,163] psychosis,[164] depression,[165] and mood and anxiety.[166] A more recent application of functional connectivity concerns the study of how information is exchanged between individuals during the performance of a common task (hyperbrain studies). The results from hyperbrain scanning have helped elucidate neural mechanisms of social interaction and have identified neural networks and electrophysiological biomarkers associated with cooperative and competitive behaviors (for reviews, see Czeszumski et al[167] and Balconi and Vanuelli[168]). Recently, researchers have also started to investigate group dynamics in ecological settings during full-body motor interactions[169,170] and to explore the effect of being face-to-face on interpersonal relationships and brain-to-brain synchrony.[171,172] This new area of investigation may have an important application in clinical settings for exploring how the relationship between the patient and the clinician affects the brain states and functional connectivity of the patient and of the clinician. However, all the aforementioned analytical methods require that the quality of the raw EEG signals be improved by eliminating interferences of biological or instrumental origin without distorting true electrophysiological information on the brain activity.[173] This is even more important if these methods are meant to be applied in a clinical context. Visual inspection and the manual rejection of artefactual data epochs is the most used method to remove artefacts from EEG recordings. However, this procedure is time consuming and dependent on the experience of the operator, and results in a considerable loss of information on brain function. Therefore, several methods have been proposed to identify and remove artefacts from EEG recordings (see Islam et al[174] for review). Some of these methods recently succeeded to combine all desirable properties: automatic detection of artefacts, good performance, good generalizability, efficiency, and transparency.[175,176] Online versions of these methods are presently under development; they will be extremely beneficial for clinical applications where time is crucial for a quick diagnosis.

*Phase 0: Start date of restrictions and main consequences.* All 25 reports from 13 different countries reported a complete closing of research activity, starting January 23, 2020 (Sichuan Normal University, China) and at the latest during March 2020.

*Phase 1: Activities implemented in response to the pandemic and planned date of restarting.* Based on our survey, all institutions stopped all research activities and the enrollment of new subjects. It is possible that for some studies, new participants will need to be enrolled to compensate for these losses (eg, in follow-up studies), which was not budgeted in grants.

Respondents to the survey reported teleconferencing/working from home is a central component of the overall response to the COVID-19 pandemic. Some follow-up on clinical data can be collected by phone. However, the situation is still not very clear concerning a restart of electrophysiological research activity. Indeed, since April-May 2020, only 7 labs (of 24) reported a smooth reopening of the lab, mainly for material consultation and use of software, but also for a slow restart of participants' recordings, while all others only envisaged re-opening from June to October 2020.

*Phase 2: Precautions planned or implemented during reopening.* Similar to those implemented in clinical care units, the main precautions included strict hygienic rules, safe distancing, and testing for infection symptoms before participants' enrollment. However, it is striking to note that several labs are still waiting for department dispositions to be able to reopen. Initial guidelines suggest separate setup and recording rooms, limited contact between technicians and participants, complete disinfecting of all equipment and surfaces after each session, no face-to-face positioning during EEG setup (all electrode application performed from the participant's side or back), masks and gloves for technicians and participants. Some laboratories are advocating face shields and disposable gowns during EEG set up, and gloves for participants that must make a manual response (keyboard, response pad, etc), or thorough cleaning of response hardware with antiviral solutions.

*New opportunities brought by the pandemic situation.* While a challenge to the "normal" way of working, virtual work could represent an unexpected opportunity for researchers to reanalyze previous and/or new collected data, acquire new analysis and methods skills, design new experiments, write reports or papers, and brainstorm new ideas and projects. However, it has to be taken into account that working from home during a pandemic is neither an extended sabbatical nor "business as usual" and that researchers, due to their frequently precarious employment positions, might even be more affected than other people in consequence of the pandemic. On the other hand, the current situation might also help develop new research programs (eg, the effect of COVID-19 on cognition). Indeed, data collected from Wuhan indicates that more than 35% patients with COVID 19 manifest certain neurological symptoms.[177] Also, a systematic review paper compiled results from short- and long-term studies of people hospitalized by the 3 most recent coronaviruses, namely SARS in 2002-2004, MERS in 2012, as well as the current COVID-19.[5] The analysis found that almost 1 in 3 people hospitalized went on to develop posttraumatic stress disorder (PTSD). The prevalence of depression and anxiety were roughly 15%, and more than 15% also experienced chronic fatigue, mood swings, sleep disorder, or impaired concentration and memory.

This pandemic can also help promote new methods of EEG recording, through the use of disposable EEG caps (which are already being promoted/distributed by some biomedical device companies) or through the development of remote EEG tools. During the past decade, efforts have been made by researchers and manufacturers to develop novel sensors and electronics to produce EEG systems mounting dry electrode caps that satisfy the requirements of hardware portability, reduced preparation times, high spatial resolution, long-term use, good comfort levels, and the wireless transmission of EEG signals.[178,179] These systems meet the requirements of neuroscience investigations in ecologically valid (ie, "real world") conditions and, so far, they have been mainly employed in unconventional neuroscience applications, such as in sports sciences studies.[180] However, these systems have the potential to make a real breakthrough in the way the EEG monitoring of patients is done during a pandemic like COVID-19: the ease of cap mounting and the wireless transmission of the EEG data permit the envisaging of a new solution for the remote EEG monitoring of patients. Specifically, with these new methods participants can prepare and perform an EEG session by themselves at home: they can apply the dry electrode cap, connect it to the miniaturized amplifier, record and store the EEG signals, and then transmit the resulting data to the clinician for expert supervision and analysis (undeniably, quality and comparability of EEG signals recorded without a technician guided procedure remains to be assessed). In the latter case, there is an opportunity for informed consent processes and collection of some questionnaire data (including demographic data) to be conducted by phone or video conference, or other online methods ahead of testing sessions to minimize in-person contact.

## Discussion

The current COVID-19 pandemic has profoundly affected the use of electrophysiological measures in psychiatric clinical practice, and in research. Based on our survey, most clinical centers (11 of 15) cancelled all EEG measures: all activities were stopped, and contact with patients was kept through phone or tele-conference. Interestingly, 4 other centers (University Hospital of Munich, Germany; University Hospital of Tübingen, Germany; the University Hospital Zurich, Switzerland; and the University Hospital of Rome Tor Vergata, Italy) did not suspend EEG activity, only decreasing the number of exams in order to respect strict safety rules. It is important to highlight that the continuation of EEG activity under strict conditions did not result in any increase in the number of reported COVID-19 infections among patients and technicians. This underlines a major concern still existing among clinicians in psychiatric units: are EEG measures considered to be of great importance in the management of psychiatric disorders? Many centers only consider electrophysiological measures as an add-on dispensable tool that is not necessarily required, but rather as "nonpriority exams." However, electrophysiology is a unique, widely applicable tool, providing information on brain function that is helpful and even required in a wide range of (neuro)psychiatric conditions. At least the conventional EEG testing (resting states with eyes closed and eyes closed; activation states with hyperventilation and photic stimulation) is a very important clinical investigation, as it is used as a monitoring tool in many clinical centers for psychiatric inpatients (and indicated outpatients) to exclude epilepsy, organic (structural) disorder, drug side effects or drug intoxication, and disorders of consciousness. Indeed, in the clinical workup, EEG is required (*a*) to detect delirium, which is the most common psychiatric syndrome found in the general hospital setting with a prevalence that surpasses of most commonly known and determined psychiatric disorders. The risk of developing delirium is higher among the elderly, as well as in patients with dementia, patients with a history of brain dysfunction or in patients taking medications with high psychoactive activity, particularly those with high anticholinergic potential which are associated with the highest incidences of delirium when taking more than 3 medications.[181] The EEG can be helpful tool in the differentiation of delirium from a primary mood, anxiety or psychotic disorder.[8] (*b*) Several studies have found that a sizeable proportion of borderline personality disorder (BPD) patients show an EEG with presence of a static (nonprogressive) and nonmetabolic diffuse EEG slowing and paroxysmal activity. They either found evidence of brain dysfunction or current epilepsy in 27% of related cases, as well as a history of head trauma, encephalitis, or past seizures in 11%. It suggests that electrophysiological investigations may be useful in investigating BPD.[8] (*c*) Approximately 25% to 30% of patients with panic disorder have demonstrable EEG abnormalities indicative of a process other than an idiopathic panic disorder. It follows that the presentation with panic symptoms is a definite indication for obtaining EEG work up.[182] (*d*) In clinical presentations where diagnostic blurring occurs (ie, differential diagnosis of dementia or focal temporal epilepsy, differential diagnosis of the agitated and disorganized psychotic patient, and psychiatric manifestations of nonconvulsive status epilepticus). (*e*) EEG is the gold standard to examine clozapine and lithium toxicity monitoring, as well as to diagnose nonconvulsive epileptic status. Despite decades of research, qEEG is still under discussion as clinical tool to assess neuropsychiatric patients, with evidence suggesting some utility for clinicians. At the end of the 20th century, a review concluded that qEEG can be an aid to distinguishing between delirium or dementia and depression, between schizophrenia and mood disorders, between environmentally induced and endogenously mediated behavioral disorders; and serve in evaluating alcohol or substance abuse.[183] A later review found justification for the clinical use of qEEG for attention deficit disorders, ADHD, and learning disabilities. It is envisaged as an aid in the detection of organicity as the cause of brain dysfunction in children who present with learning and attention problems, and in differential diagnosis, and may be useful in optimizing pharmacologic, remediation, or psychological intervention.[184] A recent review concluded that qEEG represents a critical tool not necessarily to pinpoint an immediate diagnosis but to provide additional insight in conjunction with other diagnostic evaluations in order to objective information necessary for improving clinical diagnosis and treatment response evaluation.[185]

Besides reassessing the utility and the clinical relevance of electrophysiological measures in psychiatric care management, the main objective of the present article was to collect data throughout the world allowing us to enumerate some guidelines in order to restart smoothly and safely these electrophysiological measures in psychiatric clinic as soon as possible, and be prepared to continue safely these activities in case of COVID-19 second vague or to face with a future new pandemic. Recommendations could be summarized as follows:

- Patients or participants should be checked for COVID-19 symptoms before EEG testing. If a negative test result cannot be assessed through testing, at least body temperature, presence of symptoms (cough, runny nose, sore throat, loss of taste or olfactory sense) and possible contacts with infected persons should be tracked; recording sessions should be delayed for at least 14 days where possible and after symptoms have vanished for at least 48 hours.
- Social distance should be respected by employing one-to-one contact (the technician and the patient); of course, cap installation should be performed by the technician; if possible, use of two separated rooms should be the first choice. If the EEG recording equipment must be in the same room as the participant, the technician and participant must be a minimum of 2 m apart; obviously, safety measures including masks, gloves and frequent hand washing should be utilized; technicians are required to wear face masks and gloves and to restrict direct contact with the participant to a minimum. Participants should wear a face mask when in proximity to technicians. Participants may remove the face mask during recording to avoid any contamination of the EEG through hypercapnia (via rebreathing exhaled $CO_2$). Participants and technicians should use hand sanitizer before and after the recording session. Technicians should apply the EEG set up only from the side and back of the participant. Nose electrodes should not be used, although infraocular electrodes not underneath the mask are acceptable. Participants making a manual response should wear gloves, or the response instrument (keyboard, mouse, response pad) should be enclosed in a plastic bag that is disposed of after each session, or the response instrument covered with a plastic shield that can be disinfected after each use.
- Between each recording, the recording room and the various recording materials should be disinfected (using disinfection solutions such as 70% ethanol or 70% isopropyl alcohol as appropriate) and the room must be ventilated at least 10 minutes. Indeed, a study of aerodynamic analysis in patient areas with high air exchange at 2 Wuhan hospitals has measured very low or nondetectable concentrations of airborne SARS-CoV-2 (Liu et al, 2020)[186]. An unpublished study by Kazahiro Tateda, described in a broadcast video in collaboration with NHK world, has demonstrated that opening a window

will create a breeze that quickly will blow away micro-droplets; this should be done at least once an hour.

- The utility of these measures has proven to be efficient in 4 centers of our survey, which did not report any confirmed COVID-19 infection impact due to the continuation of electrophysiological recordings. Therefore, such measures allowed the continuation of electrophysiological activity in these clinics, while all other centers have to completely stop their recordings. These closures had a drastic impact on clinical patient management, as the quality of the diagnostic procedure and of the therapeutic orientation of inpatients presenting unclear or atypical clinical symptomatology or showing unresponsiveness to therapeutic interventions was reduced. Furthermore, unclear clinical syndromes possibly related to drug intake or intoxication (eg, lithium or clozapine) could not be clarified within a short EEG recording. The discrimination between a catatonic state of schizophrenia and an epileptic seizure by an EEG was also excluded, a situation requiring an accurate differential diagnosis before initiating a treatment that is regularly seen in emergency services.
    - If EEG and qEEG are first-line electrophysiological tools in psychiatric clinic, other tools such as ERPs, EROs or microstates are still waiting for a “true” implementation in clinical care units, even despite encouraging research data. Indeed, cognitive ERPs appear to be a promising clinical tool through longitudinal follow-ups of individual psychiatric patients to monitor the progression of the disease (spontaneous and/or due to a treatment) or to predict the future trajectory of the disease at the end of a treatment.[23-25] EROs appear to be used frequently to assess circuit function in schizophrenia,[95] FEP,[96] and the prepsychosis prodromal stage.[97] Reduced delta and theta responses during different WM paradigms have also been found in schizophrenia, bipolar disorders and dementia.[107,113,115] Differentiation between clinical populations (specificity) is of course of the greatest importance in a clinical context. Accordingly, compared with controls, patients with FEP increased frontal theta ERS in all WM conditions,[129] while the theta power was reduced in patients diagnosed with ADHD.[130,131] These results argue in favor that WM load-related EEG parameters could differentiate each pathology. Supporting this view, the combination of N-back related EEG indices at baseline provided a prediction of MCI deterioration, with allowing for the correct classification of 90% MCI cases. The fact that the highly accurate distinction between PMCI and SMCI included beta ERS and P200-N200 ERP components provides evidence that the combination of EEG-related methodologies may be a reliable tool to characterize psychiatric disorders. Microstates appear to be useful to identify novel diagnostic and treatment options for schizophrenia patients,[28] for the diagnosis of psychotic disorders[164] and bipolar disorder,[187] to reveal depressive symptomatology during depressive episodes[165] and to identify aberrant neural dynamics in patients affected by mood and anxiety disorders.[166] Resting state measures such as frontal alpha asymmetry, prefrontal theta cordance or EEG-vigilance regulation seem to have the potential to serve as predictive biomarkers to inform the choice of treatment, for example, in affective disorders.[38,39,188] In this view, the COVID-19 impact on psychiatric electrophysiological research was tremendously negative. All experimental protocols in the research institutions included in this survey were cancelled, suggesting that such actions were widespread globally; this has led to an enormous loss of time, of data and of money. Moreover, even if it seems that the end date of some grants will be postponed for 1 year, this is certainly not universal. Furthermore, the halting and delayed restart of EEG data collection poses significant challenges for students who have to finalize required works such as master’s theses, doctoral dissertations, or internship reports. Research departments and universities will have to address these problematic situations so as to avoid unintentionally punishing those affected students.

Finally, at the research level, the only positive point of the lockdown situation was that working from home and tele-conferencing may have helped some researchers to analyze previous data, to read and write papers or grants proposals, to acquire new skills (new analysis tool, for instance), and to strengthen some (inter)national collaborations (leading, for instance, to the writing of this article). Indeed, tightening the collaboration with other laboratories in the same and close countries, or even worldwide, and emphasizing the use of common protocols for EEG recording across laboratories, as well as fostering standardization initiatives like EEG-BIDS (started in February 2019),[189] may ease data sharing, and multicenter studies. Ultimately, boosting such joint ventures will maximize the efficiency of data recording and speed data collection once on site work is allowed and not restricted by social distancing and lockdown measures in case of a second wave of COVID-19 pandemic or other future pandemics. Furthermore, it could help researchers to take advantage of regional differences in the evolution and timing of such lockdown measures; avoiding abrupt discontinuities on project execution and potentiating smoother timelines for research projects and boosting replicability and reproducibility of electrophysiological research. It is worth noting that the ability to partake in these benefits differs from case to case, depending on competing demands such as childcare, care for elderly or infirm relatives, or other variables pertaining to home life.[190,191] Also, the COVID-19 situation could stimulate new areas of research (eg, the cognitive and brain impact of lockdowns), as well as the development of new research strategies, such as the outsourcing of these electrophysiological activities from hospital or the development of remote EEG tools.

## Conclusions

The COVID-19 pandemic, just like all crises, has yielded challenges for clinicians, researchers, patients and participants, and also lessons to learn from and new opportunities to pursue. Even if the outbreak of the pandemic will eventually be suppressed, the psychosocial consequences of forced social distancing, changes in established norms of individual and collective behavior, economic difficulties and ubiquitous fear and anxiety from any respiratory symptoms will likely negatively affect the mental well-being and physician/technician-patient relationship in an unprecedented way in the modern era.[4] By collecting the experiences of experts from all over the world, this consensus article furnishes practical recommendations to follow in operationalizing electrophysiological *monitoring* measures during COVID-19 pandemic, mitigating the risk of infections, and in preparing the community for any future pandemic (for therapeutic NIBS tools, see Bikson et al[36]). The main objective was to furnish recommendations to ensure the safety of patients, participants, clinicians, researchers, and staff members during the reestablishment of access to clinical EEG services and research operations. Indeed, we are convinced that electrophysiological measures are of the greatest importance/relevance in the clinical management of mental diseases. Indeed, the present expert panel emphasizes that even if electrophysiological measures may not allow a differential diagnosis of psychiatric syndrome without clinical assessment, they can be considered as important complementary biomarkers of brain (dys)functions and contribute to stratification of subjects to predict prognosis or response to treatment. Indeed, even in patients with the same clinical diagnosis EEG/ERP measures may contribute to triage, as the patient with more severe abnormalities in EEG/ERP measures should be considered at greater risk in the present moment, as well as having a greater risk of worse psychiatric manifestations and prognosis. Such recommendations could therefore not only promote the continuation of such exams in future pandemics but also reassess the idea of why and how they should also be considered as "priority exams." Articles dealing with the methodological concerns of such an approach[82] as well as with the necessary development of multisites recordings guidelines[192] or application of existing guidelines[193,194] are of the greatest relevance in this regard. Indeed, this would allow recording electrophysiological measures that may be compared and used across studies in order to avoid functional misinterpretations of the data as well as to prevent from the emergence of controversial results from different laboratories.[195]

### Editorial Note

The recommendations in this Invited Editorial were published as part of the journal's response to the impact of COVID-19 on clinical and research programs and, accordingly, were not peer-reviewed. The recommendations for recording of electroencephalography expressed in this article reflect the consensus agreement of the authors and are not presented or intended as guidelines for clinical or research best practice. These recommendations do not reflect official guidelines of the Electroencephalography and Clinical Neuroscience Society (ECNS) or SAGE Publishing, and do not guarantee protection from infection during an epidemic or pandemic.

### Author Contributions

Oliver Pogarell and Salvatore Campanella had the idea to write the paper and furnished a first draft. All other authors contributed in writing new parts and/or in amending/revising all parts of the manuscript.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.


### Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: S. Campanella was funded by the Belgian Fund for Scientific Research (F.N.R.S., Belgium) and the Brugmann Foundation (CHU Brugmann, Brussels, Belgium). C. Babiloni is supported by the European Committee for the development of the H2020-EU.1.3.1.H2020-MSCA-ITN-ETN-2017-2020 (ID 721281) project with the short title "Blood Biomarker-based Diagnostic Tools for Early Stage Alzheimer's Disease (BBDiag). M Balconi was founded by Catholic University of Milan (Italy), Grant for Research, D1.1. 2019. V. Betti was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program—Grant Agreement No. 759651. L. Bianchi and G. Di Lorenzo were partially funded by a Grant from the Ministry of Defence. M. Brunovsky was supported by the project LO1611, with a financial support from the Ministry of Education, Youth and Sports of the Czech Republic under the NPU I program and by the project PROGRES Q35 of the 3rd Faculty of Medicine, Charles University in Prague. C. Escera was supported by the Generalitat de Catalunya (SGR2017-974), the ICREA Acadèmia Distinguished Professorship Award, and the María de Maeztu Unit of Excellence (MDM-2017-0729). D. Fisher was funded by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada, and Research Nova Scotia. B. Güntekin was funded by The Scientific and Technological Research Council of Turkey TÜBİTAK (grant number 214S111). R. Ishii was funded by a Grant-in-Aid for Scientific Research (C) 19K08017 from the Ministry of Education, Culture, Sports, Science and Technology in Japan. M. Kiang was supported by the Miner's Lamp Innovation Fund in the Prevention and Early Detection of Severe Mental Illness, and an Academic Scholar Award, at the University of Toronto (Department of Psychiatry); and a grant from the Canadian Institutes of Health Research (PJT-168989). E. López-Caneda was supported by the Portuguese Foundation for Science and Technology (FCT) and the project POCI-01-0145-FEDER-028672. S. Olbrich was funded by the Hans und Marianne Schwyn Stiftung and the "Stiftung zur Förderung von Psychiatrie und Psychotherapie. D. Salisbury is funded by US National Institutes of Health R01 MH108568, R01 MH113533, and RF1 MH114223. I. Winkler was supported by the National Research Development and Innovation Office of Hungary (grant number: NKFI K115385). J. Yuan is supported by National Natural Science Foundation of China (NSFC31971018, 31671164).

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