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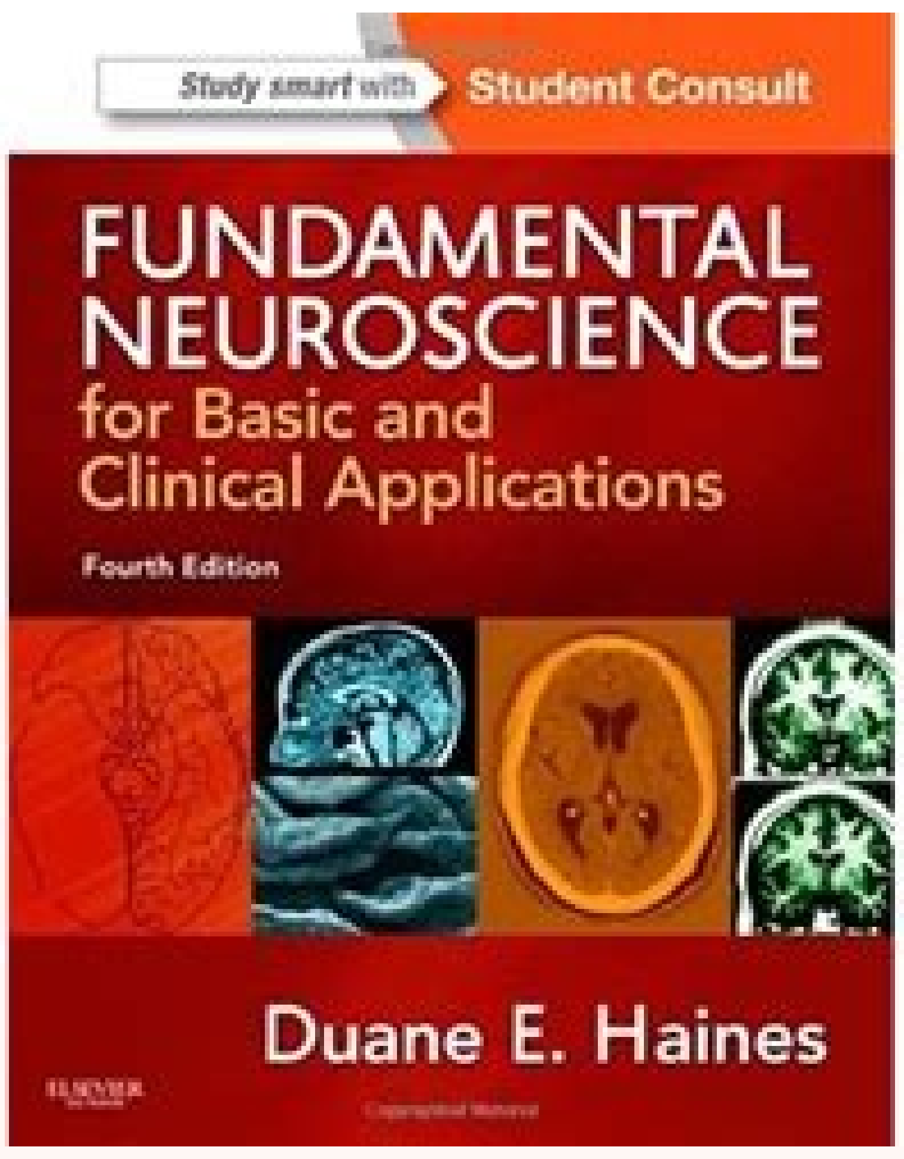

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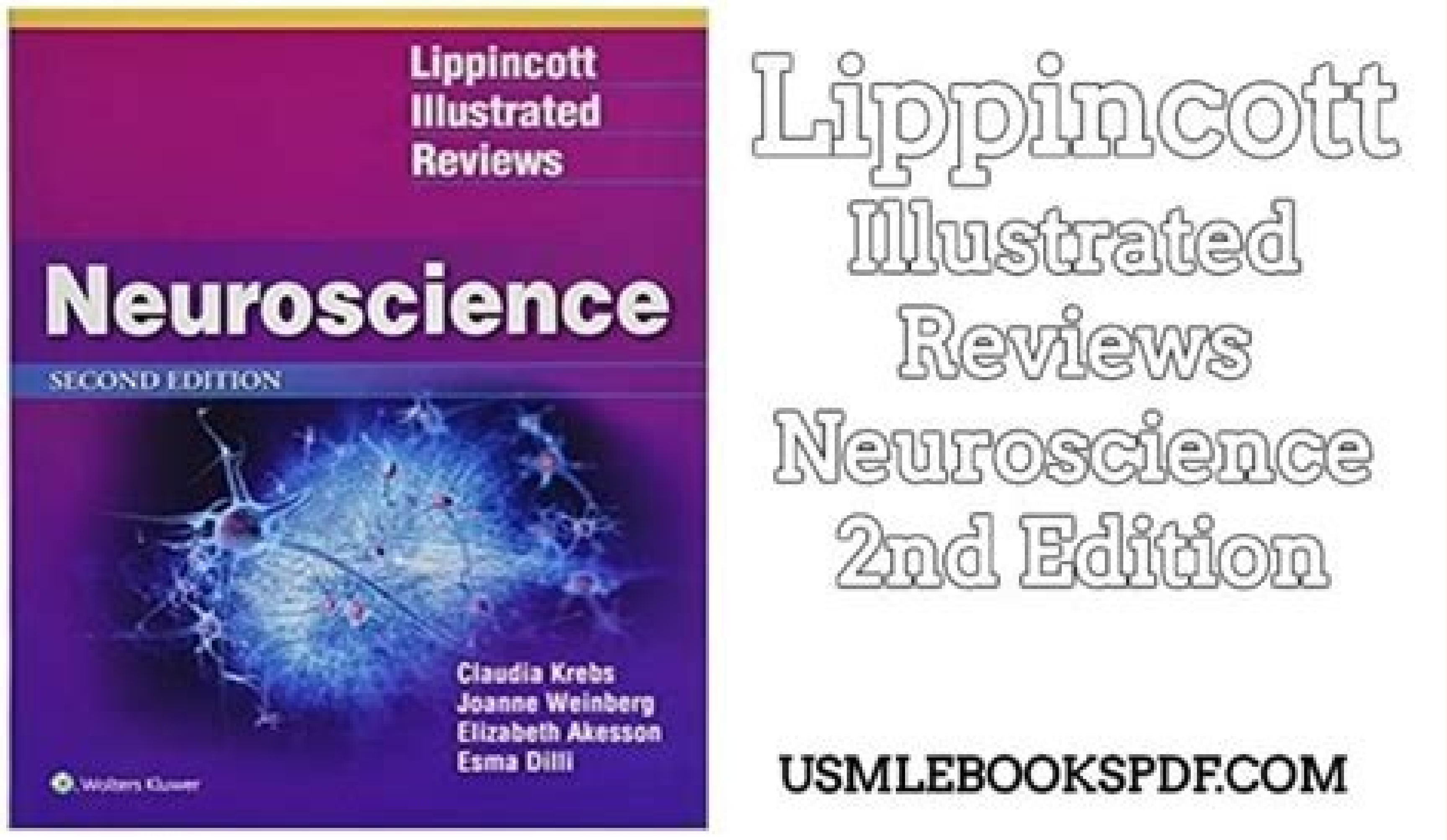

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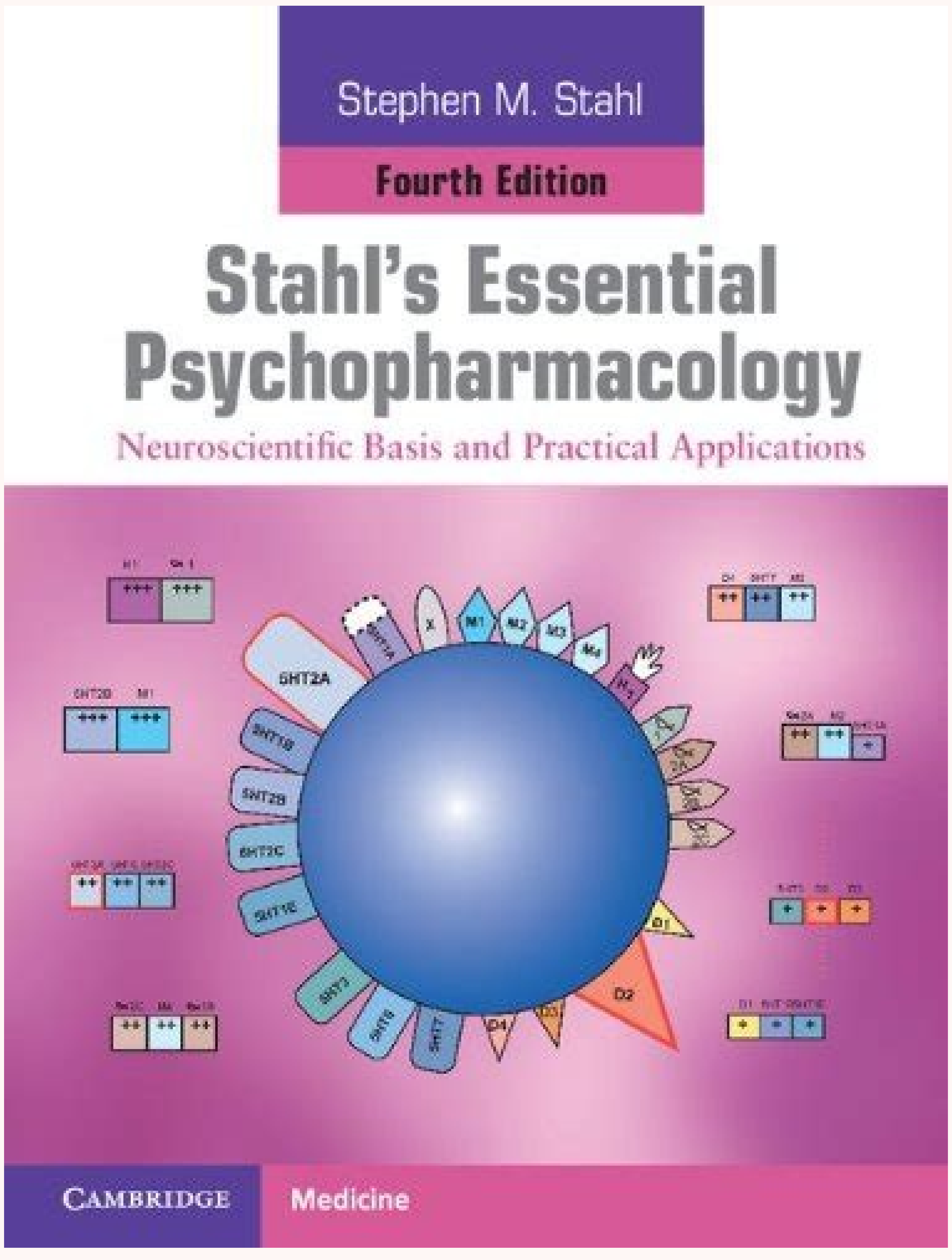

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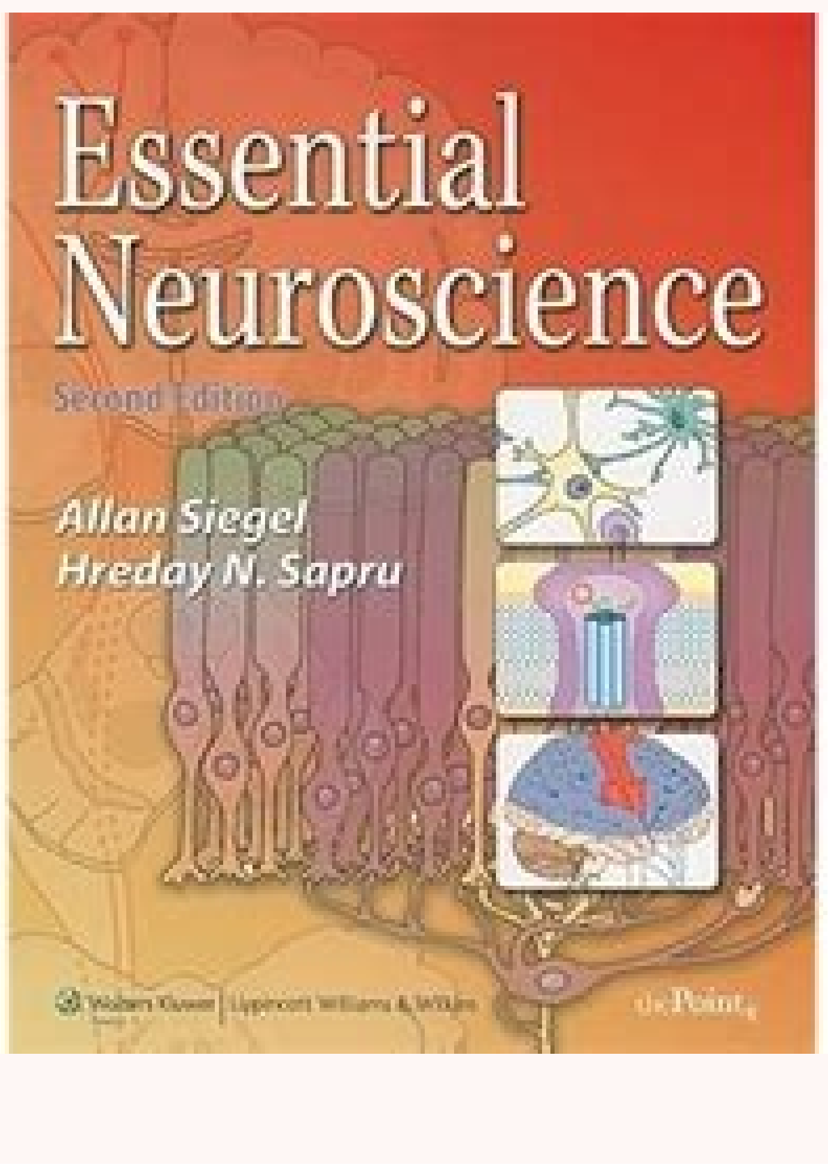

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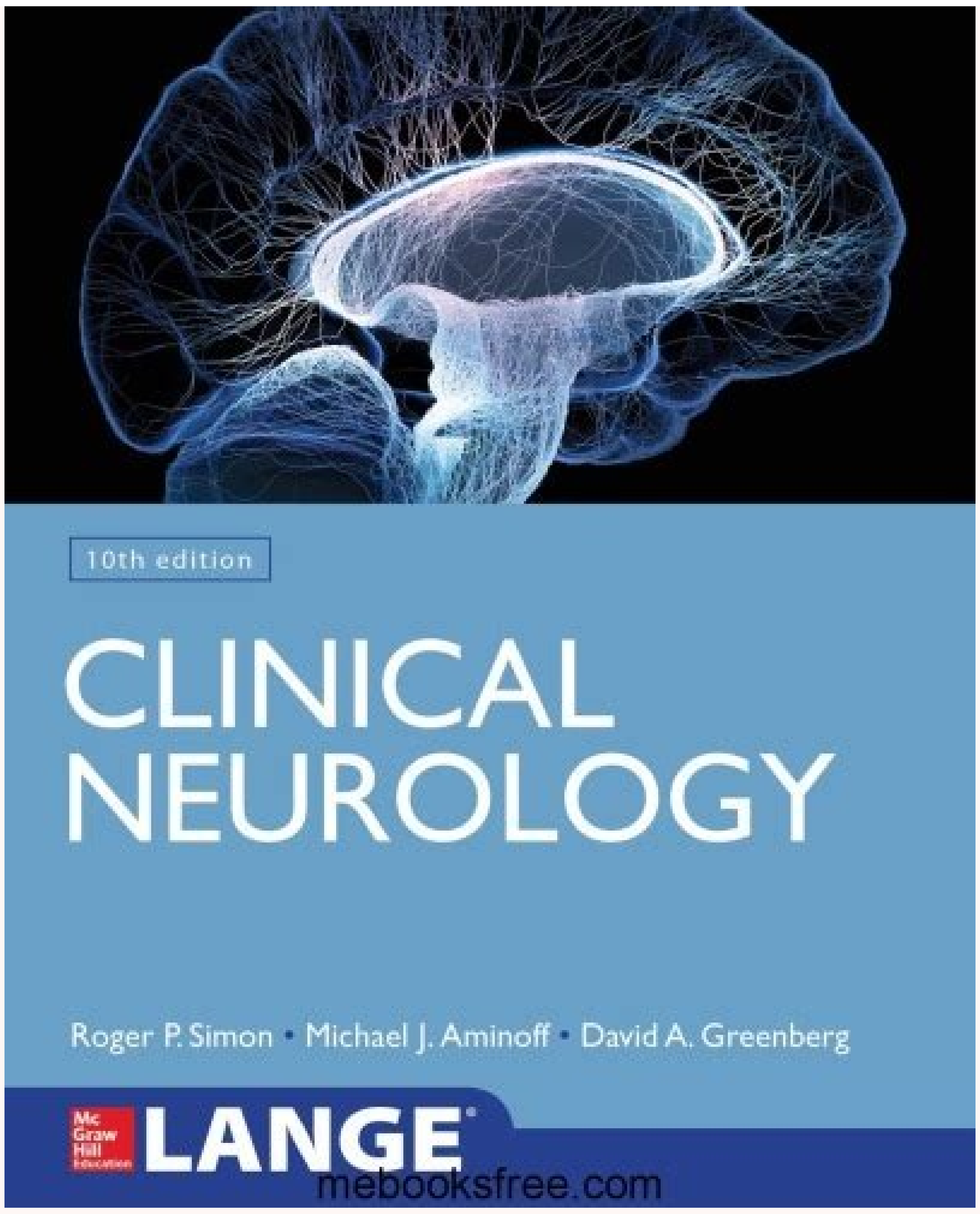

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Roger P. Simon • Michael J. Aminoff • David A. Greenberg

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Several cognitive or perceptive tasks require a coordinated flow of information within functionally specialized brain areas networks. It has been argued that neuronal oscillations provide a dynamic coordination mechanism underlying the brain (Singer, 1999; Varela et al., 2001; Fries, 2005, 2015; Siegel et al., 2012). These oscillations can reflect synchronized rhythmic oscillations of the oscillations of local neuronal groups (Buzsáki and Wang, 2012), and can facilitate the flow of neural information between the nodes of the network when the oscillations are synchronized between those nodes (Womelsdorf et al., 2007). The neural information transmitted from one region to another is reflected by the potential of action, where the potential of action itself can be arranged in time. These explosions can occur during oscillations and can further improve the reliability of information transmission (Lisman, 1997) or contribute to the creation of long-range synchronization (Wang, 2010). The brain could dynamically coordinate the flow of information by changing the force, model, or frequency with which the different brain areas fit into oscillatory synchronicity. The hypothesis that neuronal oscillations in general and interareal synchronization of these oscillations in particular, are instrumental for normal brain function has led to the widespread application of quantitative methods to evaluate neuronal synchrony in electrophysiological data. This data can be obtained with invasive or non-invasive recording techniques, and in a context involving experimental manipulation or in a context without tasks. Regardless of the technique and the context of registration, once the data is collected, the experimental researcher is faced with the challenge of quantifying the dataneuronals and provide a valid interpretation of results. we feel that this is challenging for many .ilaer itad a idotem itseuq eracilppa'llen erartnocni onossop is ehc isilana idââ eidisni eirav id omaitucsid ,etrap amitlu'lleN .ivitiutni ipmese odnasu ehcirtem etseuq id esab alla ipicnirp i odnartsulli elibissop evo ,etasu etnemenumoc ¹Ãip ehcirtem elled elamrof ¹Ãip enoizinifed anu omainrof ,etnemavisseccuS .elanoiznuf Ãtivittennoc al eramits rep ehcirtem elled elareneg aimonossat anu omainrof ,ottutiznannI .ehcirtem etseuq id avitiutni enoisnerpmoc anu erottel la erinrof e eirotallicso inoizaretni el eracifitnauq rep etazzilitu ¹Ãip ehcirtem el rep lairotut e)avitsuase non(enoisiver anu erinrof id olleuq ¨Ã otnemucod otseuq id opocs oL .itaterpretni opport eresse da inilcni idniuq onos itatlusir i e ecilpmes ¨Ã non ereneg ni itatlusir ied enoizaterpretni'l ,ogoul ozret nI .ehcirtem ertla noc otnorfnoc li e iralocitrap ehcirtem etseuq id Ãtilibacilppa'l acilpmoc ²ÃiC .acrecir id Ãtinumoc aipma ¹Ãip alla atatimil Ãtilibissecca noc ,etunetsos enoizaretni id erusim orol elled acitarcnisoidi enoizatnemelpmi'nu ereva onossop acrecir id ippurg inucla ,atacilpmoc otsottuip eresse ²Ãup enoizaretni id acirtem eralocitrap anu id acimtirogla enoizatnemelpmi'l ©Ãhciop ,ogoul odnoces nI .etemacincet oizini'l rep ehcna ,erazzilitu odotem elauq eracifitsuig e ereilgecs eliciffid osseps Ã .irasrevva e itnereda isorogiv orol i e iggatnavs e iggatnav irpo rp i ah ehcirtem etseuq id anungO .ilitu euqnumoc am ,coh da odom ehclauq ni eresse orebbertop ehc idotem itseuq a ehcifidom onos)VLP(esaf id occolb id erolav li emoc ,irtla ertnem ,icitsacots issecorp ied acitsitats airoet asorogir anu us onasab is ,regnarG id Ãtilasuac al e azneroec al emoc ,idotem inuclA .icincet ilgatted id Ãtitnauq ednarg anu noc ittircsed osseps ,)4102 ,.la te gnaW ,itnitsid idotem 24 atazzirettarac enoisiver etnecer anu oipmese da(eirotallicso inoizaretni el eracifitnauq rep ehcirtem id enidutitlom anu ecsinrof idotem ied arutaretteI al ,ogoul omirp nI simulations, we generate synthetic time series to demonstrate how a multitude of practical problems can arise to generate spurious spuriousconnectivity, which should not be interpreted in terms of underlying neuronal interactions. The different problems that we discuss are the differences in the signal-dumor ratio (SNR), sample size limits, management of the volume/dissemination of the electromagnetic field, reference choice and problem of unused inputs. The generation of synthetic temporal series and their analysis was performed in Matlab, using Fieldrip (OostenVeld et al., 2011), which allows the comparison of how different data characteristics affect the metrics of the oscillating interactions and how the different ways metrics perform the same data. For each simulation of pitfalls â € â € â € â €, where possible we present practical steps that can be used to mitigate concerns. These simulations have advanced as examples of toys of some of the problems that may occur and do not aim to reproduce the full complexity of the real data. However, we hope that they act as a useful guide to common interpretation issues and the current state of the art to deal with them. Finally, we also discuss where future methods could be useful to deal with the limits of current methods. Tassonomy of the functional connectivity metrics in this section, we will present a possible taxonomy of the metrics commonly used for the functional connectivity (Figure 1) and briefly describe the main reasons for each of these methods. A first division that can be made is based on the fact that the metric quantifies the direction of the interaction. The non -direct functional connectivity metrics try to capture some form of interdependence between signals, without reference to the direction of the flu. On the contrary, direct measures try to establish a statistical causality from the data based on the maximum that causes their effects and, in the of causality of Granger and the transfer of entropy, which causes somehow they provide their effects. These definitions of statistical causalities were were Eht niatbo ,)sgal elpitlum because tfihs siht od dna(detupmoc he is noererroc eht eofeb rehtona ot tcepser htw seires emit owt tfihw Ytivitnec detamitse eht taht ytreporp rettal siht ,sdrow rehto ht .Selbairav modnar Fo Snoitazaler in Seires emit eht taert dna ,ataded eht erutcut seruse seruseaem sarousemeem of the seruse tneiciffeoc noitalerroc nosraeP ehT .yroeht noitamrofni morf stpecnoc gnisu)seires emit ro(selbairav erom ro owt neewteb ecnednepedretni)raenil-non dna raenil(dezilareneg eht serusaem hcihw ,)4002 ,.la te voksarK(noitamrofni lautum si pihsnoitaler raenil a emussa ton seod Taht Hcaorppa Dezileneg Erom that .Asrev Ehiv DNA ,Rehto eht yb denialpxe Eb Nac taht)slanis ro(Selbairav eht Fo fo ecnairav enencarf eht stneserper)2r (tneiffoeo rauqs eht krowemarf gniledom raenil lareneg eht nI .selbairav modnar owt neewteb pihsnoitaler raenil eht serusaem hcihw ,tneiciffeoc noitalerroc nosraeP eht si snoitcaretni desab-ledom detcerid-non rof erusaem tselpmis ehT .slangis owt neewteb ecalp ekat yam taht snoitcaretni fo sdnik eht ot tcepser htiw ytiraenil fo noitpmussa na ekam lla 1 erugiF ni detciped sehcaorppa desab-ledom ehT .sehcaorppa desab-ledom dna eerf-ledom neewteb edam eb nac noitcnitsid a ,setamitse fo sepyt detcerid-non dna detcerid htob nihtiW .ytivitcennoc lanoitcnuf gniyfitnauq rof sdohtem ralupop fo ymonoxat A .1 ediganf .)5102 ,.La te htes htes ,silakkakas ;1102 ,htes dna relsserb(Erehwesle Deweiver Neeb Sah Hcihw ,Snoitcaretni Lanoruen Yfiord devtauq 9691(Regnarg yb sledom Evissergergergergergergergergergergua Gnisu detnemeldi yllacitcarp retals)6591(Reneiw y depoleved Function and evaluation of cross correlation according to delay takes account of the time structure in data. In particular, in some cases well-educated sometimes it can be used to deduce direct neuronal interactions. In particular, the cross correlation function was effective in studying neuronal systems containing dominant unidirectional interactions that exert their greatest influence in a specific delay (e.g., retino-genicolate or geniculocortical feedforward pathways, Alonso et al., 1996; Usrey et al. ., 1998). In these cases, the delay in maximum correlation and the extent of correlation may be informative about the flow of information between brain areas (e.g., Alonso et al., 1996). However, the interpretation of the cross correlation function becomes complicated when it is estimated by neuronal signals with bidirectional interactions, which is the dominant interaction scenario in most cortico-cortical connections. Cross-relationship functions of these interactions generally lack a clear peak and have significant values both at positive and negative delays, indicating complex and bidirectional interactions that occur at multiple delays. To address this limitation, you can use other methods, which evaluate the extent to which the past values of a time series are able to predict the future values of another time series and vice versa. This notion is formally implemented in the metric of Granger's causality. This metric can be calculated using a linear self-regressive model to adapt to data or through non-parametric spectral matrix factorization (described in more detail later) and allows an estimate of direct interactions. In particular, it allows a separate estimate of the interaction from X signal to y signal and y signal ,atazzilareneg ,atazzilareneg ¨Ã otnemirefsart id aiportne'l ,oipmese dA .etterid inoizaretni eravelir rep illedom aznes iccorppa itappulivs ehcna itats onos ,enifnI .X elanges Approach to the study of delayed interactions (direct) between time series (schreiber, 2000; lindner et al,. 2011). transfer entropy is a more general implementation of the maximum that causes must precede and predict their effects and is able to detect forms of non-linear interaction, which can remain invisible to linear approaches such as the causality of granger. Moreover, the transfer entropy has also been extended to specifically measure direct interactions between current phase estimates of separate signals, which is useful for studying non-linear oscillatory synchronization (lobier et al,. 2014). However, partly because of its generality, it is more difficult to interpret this measure. While modelless approaches can be useful for quantifying non-linear neuronal interactions, this review will focus on model-based linear methods. Linear methods are sufficient to capture a wide array of oscillatory interactions that should occur in the hypothesis that oscillatory phase coupling governs neuronal interactions. For example, if we are interested in determining whether neuronal oscillations at similar frequencies in brain areas a and b engage in oscillatory couplings with a preferred phase difference, linear measures such as coherence or plv will capture this interaction. if on the other hand we are interested in nonlinear forms of coupling, such as cross-frequency coupling (where phase or amplitude of frequency f1 interacts with phase or amplitude of frequency f2, where f1 â ‰ f2,) then other metrics would be necessary. Therefore, the choice of method or data analysis should always be guided by the underlying hypothesis that is tested. a particularly important distinction if we want to study oscillations is the distinction between metrics that are calculated bythe domain of time or frequency of signals. in order to identify the individual rhythmic components that make up the measured measurementEra Yeht in gnilpuoc eptilpma-esahp yfitnauq taht sdohtem weive ton olw ew .)4 sesehtopyh gnitset rof etairporppa era sdohtem desab-esahP .detset gnieb si taht sisehtopyh gniylrednu eht no sdneped dohtem fo eciohc eht ,niagA .snoitaler edutilpma yfitnauq taht scirtem ot desoppo sa ,snoitallicso eht fo esahp eht fo etamitse na eriuqer taht scirtem niamod-ycneuqerf no Sucof ew noitces gniwof eht ni .)Eussisi .la te retsof Ees(Sevitcepsrep Htob ROF GNITIVE HTIW ,SKWEN niarb Elacs-Ethaler-Edaler-esahbas snoitaler 1 yfitnauq ot snoitallicso eht fo)epolevne(edutilpma eht no ylerup etarepo taht sdohtem fo puorg 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Consistency can therefore be concisely defined as: Cohxy (ï ever) = | Sxy (ï ever) | SXX (ï ever) Syy (ï ever) (2) Consistency and track of the spectrum of phase differences when the magnitude operator (| ... |) It is omitted from the numerator in the equation above, we obtain a complex quantity called consistency, where the phase difference angle can be interpretable (if there is a clear clustering of phase difference angles through tests) in terms of temporal delays. This is based on the notion that a coherent phase delay (or lead) through a range of frequency containers translates into a temporal delay (or lead) between the two series of time. Note that the esteem for the phase difference in a single frequency container can be ambiguous in its interpretation, because a phase delay â-150 ° can not be distant from a phase delay +210 °. This is due to the fact that the phase difference is circular 360 ° module. However, observing the phase difference on a range of frequencies can give an unequivocal interpretation of temporal delays. A disambiguated estimate of the temporal delay can be obtained when rhythmic interaction can be described as a predominantly unidirectional linear interaction. This estimate is then based on an estimate of the phase difference slope as a function of the frequency range in which substantial consistency is there. This is because a fixed -time delay between two series of time leads to a phase difference which is a linear frequency function. For example, consider a temporal delay of 10 ms and a rhythmic process with a significant oscillatory power in the frequency range between 8 and 12 Hz. At 8 Hz, that is, to a duration of the cycle of 125 ms, a time change of time 10 ms amounts 10/125 (0.08) of an oscillatory cycle (which amounts to 28.8â. At 10 Hz, the same time of time at 10/100 of an oscillatory cycle (36th), and at 12 Hz, a turn of 10 ms is 10/83.33 10/83.33 ,.la te etloN(azneroec alled airanigammi etrap al omainetto)sixa-y(oiranigammi essa'llus atatteiorp ¨Ã osselpmoc led azneroec al odnauQ azneroec alled airanigammi etraP .)5102(.la te kcniV e)1102(.la te mahtiW a ecsirefir is erottel li ,inoissucsid iroiretlu reP . Ãtilanoizerid al etnematterroc erevircsed non ²Ãup)ISP azneugesnoc id e(esaf id azneréffid id orttepS id ,ilanoizeridib onos inoizaretni el iuc ni inoizautis ni ,etnedecerp enoizes allen ossucsid emoC .ortla'l elaropmet odnecudnoc ats elanges elauq us amrofni ISP led onges lI .0 ad Ãreived ISP li ,elaiznatsos azneroec ¨Ã'c e ,ezneuqerf el osrevartta etnemetatsoc aibmac esaf id azneréffid al azneuqerf id erotinetnoc nu adnocric ehc azneuqerf id adnab atad anu rep es ,azneugesnoc iD .azneroec al noc otarednop ,iniciv azneuqerf id irotinetnoc i art esaf id azneréffid allen otnemaibmac li nib azneuqerf ingo rep aloclac ,atacificeps-erp adnab id azzehgral id ortemarap nu otaD .ezneuqerf el art esaf id azneréffid allen otnemaibmac led enoizerid alled azneteisnoc al acifitnauq e ,adilav-asselpmoc azneroec allad otaloclac Ã .)8002 ,.la te etloN(itnanimod ilanoizeridinu inoizaretni erruded rep acireneg ¹Ãip Ãtitnauq anu ¨Ã)ISP(esaf id azneдnep id ecidni'l ,iraenil e deggal-emit inoizaretni emussa ehc ,esaf id azneréffid id orttepS olled azneдnep alla ottepsiR esaf id etsip elled ecidnI .)2102 ,.la te notsirF ;1102 ,.la te mahtiW(oipicnirp-non ¨Ã Ãtilanoizerid al erangessa rep olos ad ozzilitu'l e ,azneuqerf id atacilpmoc enoiznuf anu ¨Ã esaf id azneréffid id orttepS ol ,ilaedi non eznatsocric nI . Ãtiraenil id enoiznussa'l ottos atarutpac neb e elanoizeridinu etnemetnelaverp ¨Ã enoizaretni'l evod ,ilaedi otsottuip eznatsocric ni olos adilav ¨Ã) Ãtilanoizerid id erotacidni emoc idniuq e(elaropmet odratir id inimret ni esaf id azneréffid id orttepS olled otamits oidnep led enoizaterpretni'nu ehc ,aivattut ,eraenilottos ommerroV .)°Ã2,34(oirotallicso olcic nu id This measurement measures In recent years, in particular in the EEG/MEG connectivity studies (Garcâa Domãnguez et al., 2013; Hohlefeld et al., 2013). Discard the contributions to the estimate of the connectiveness along the real axis explicitly removes the potentially spurious instantaneous interactions due to the spread of the field, as discussed in depth in a subsequent section. Value phase block when applying the formula for the calculation of consistency (equation 1) for the breadth of Fourier's transformed signals, we obtain the phase locking value (PLV) (Lachaux et al., 1999): Plvxy (ï ‰) = | 1nâ We 'K = 1x (ï ever, k) | 1 as a result of these individual observation normalizations, the PLV is calculated as the length of the vector average of a series of unit-length phase difference estimatesIn motivating the use of PLV, unlike consistency, it is often stated that the first reflects the phase synchronization that the consistency, because the latter confuses the consistency of the phase difference with the correlation of amplitude. From a mathematical point of view this can be true, but on the other hand it could be argued that it is more "difficult" to obtain a significant not zero value in the absence of consistent phase differences, compared to when there are no correlations of amplitudeIntuitively, when all individual transversal density estimates point in random directions (no phase synchrony), even in the presence of perfect width correlation, the expected value of their vector media still relatively small. On the other hand, if all the individual transversal densit estimates indicate more or less in the same direction (synchrony of a strong phase), even in the absence of correlations of amplitude, the expected value of their vector media will still be In addition, it could be supported, in the case of consistency, that by assigning a strong weight to the observations with a product of great amplitude, you are favoring those observations that have an estimate of the difference in the upper quality phase. Cié realistically presupposes that greater amplitude reflects a superior SNR of the sources of interest and therefore a better estimate of the quality phase. Other measures to quantify the consistent differences in addition to the quantities described in the previous sections, in recent years various other metrics have been defined to quantify the synchronized interactions between neuronal signals. The motivation for the development of these metrics is that most of the connective connecting metrics suffer from interpretative difficulties. These difficulties, which are discussed and illustrated more in detail below, have pushed the developers of methods to define metrics that are less inclined to suffer from these problems. We have already discussed the imaginary part of the consistency and the index of the phase slope, and this section describes two additional measures that are more popular, the phase index of the Lag (PLI), and the phase consistency with a stone's throw away (PPC). PLI is a metric that evaluates the distribution of phase differences between the observations. It is calculated by mediating the sign of the esteemed phase difference for observation (Stam et al., 2007). It is motivated by the fact that the non -zero phase differences cannot be caused by the diffusion of the field (as with the imaginary part of consistency and the PSI). More recently, some changes to the PLI have been proposed, giving the weighted PLI and the pondered pli pli to make the metric the more robust against the spread of the field, the noise and the champion-size bias (Vinck et al., 2011). PPC is a measure that quantifies the distribution of phase differences between the observations (Vinck et al., 2010). TO of the PLV, which is calculated directly as the vector media of the relative phase through observations, observations, eippoc art etinifed Ãtivittennoc id ehcirtem id ossucsid omaibba aronif eippoc a inoizaretni el ertlo odnadnA .orol art onanoizaler is emits el emoc id aedi'nu ereva id enif la ,erusim etseuq id esrevid odnazzilitu itad i eragorretni elibailgisnoc ¨Ã elareneg ni ,otnatreP .atlecs atats ¨Ã ehc arusim allad etnemetrof onadnepid non etrart inoisulcnoc el ehc erattepsa ebbervod is ic etnemlaedi e erazzilitu ad ottada ¹Ãip ¨Ã erusim elled elauq us aciripme adnamod anu osseps Ã .ilaropmet eires el art enoizaretni'lled ilimis ehcitsirettarac erarutuac onodnetni enoizattegorp rep e opmac led enoisuffid alled elanoizaterpretni amelborp li eratnorffa rep etaznava etnemlapicnirp ehcitamgarp erusim onos esaf id azneдnep id ecidni'l e azneroec alled airanigammi etrap al ,oipmese dA .)icitsacots issecorp ied airoet allen etacidar onos ehc regnarG id Ãtilasuac alled e oipmese da azneroec alled oirartnoc lA(oipicnirp id ocitametam oiccorppa nu us onasab is non ilat otnauq ni etanoizнem erusim elled etlom ,aznatsos nI .)ilgatted iroiggam rep "enoipmac led enoisnemid alled enoisrotsid alled amelborp II" atalotitni enoizes al eredev(avorp id oremun led enoiznuf ni aibmac non CPP id osetta erolav li ehc acifingis ²ÃiC .amits al rep atazzilitu enoipmac led enoisnemid allad atrotsid ¨Ã non acirtem atseuq ehc ¨Ã VLP li ertlo CPP id oiggatnav lI .ivitaler esaf id irottev itseuq id eippoc a ezneréffid el ettut emoc ¬Ãsoc ,oiratinu oihcrec la onrotta itiubirtsid onos ivitaler esaf id irottev ilognis i ,esaf id enoizazzinorcnis anucla etneserp ¨Ã non odnauQ .esaf id enoizazzinorcnis id azneserp ni oidem erolav nu a onrotta atappurggar etnemetrof ¹Ãip Ãras evitaler isaf ellen eippoc a ezneréffid elled enoizubirtsid al ,evitaler isaf elled enoizubirtsid al etnematterid aiduts is odnauq enoizautis alla elimis ,ehc ¨Ã²Ãic id esab alla aedi'L .evitaler isaf elled)inoizavresso id eippoc art(eippoc a ezneréffid el ettut id enoizubirtsid alled otaloclac ¨Ã ¹Ãip ¹Ãip ni eragadni etnavelir eresse ebbertop e ilanges eud id ¹Ãip itartsiger itats onos ,aivattut ,osseps .ilanges the model of multiple interactions in pairs. For this reason, you can use theoretical approaches of the chart (Sporns, 2011). These approaches are based on a valid quantification of connectivity, they are widely discussed elsewhere and are beyond the purpose of this tutorial. He grew up here as a prelude to the next section, in which we discuss the problem of the common input. In general, the problem at stake is the correct deduction of direct interaction in the presence of other sources (possibly not observed). Although latent and unobserved sources are a fundamental and irresolvable problem, information from sources that have been observed can be used to remove indirect influences on the estimation of connectivity. One of the ways in which this can be done in the context of coherence analysis is by using partial coherence (Rosenberg et al., 1998). If multiple signals have been recorded, you can calculate for any signal pair the so-called partialized partial spectrum, which you get by removing the linear contribution from all other signals. On the part of the partialized, partial consistency can be easily achieved. The partial cross spectrum can be obtained as follows. From the complete cross density matrix, s (ï (ii) ‰) â€ ¦sxzn (ï) ‰) syx (ï ‰) syy (ï ‰) Syz1 (ï ‰) !‰) â€ ¦syzn (ï ‰) ‰) ‰) â€ ¦sz1zn (ï ‰) â ‹®â‹®â ®â ®â±±±±± â â â â â â â â â â â â ââ ââ ââââââââââââââââââââââââââTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTMâTM ‰) ‰) â€ ¦sznzn (ï ‰)] We can partialize for linear contributions from Z1-Zn signals to the cross spectrum between X and Y signal as follows: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: s: ‰) = [sxx (ï ‰) sxy (ï ‰) syx (ï ‰) syy (ï ‰)] ‰) â€ ¦sxzn (ï) ‰) Â Â Â Â Â Â Â Â Â Â Â Â [Sz1z1(Î°)â¦Sz1zn(Î)â)®â)±â)®Sznz1 (Î ‰) â€ ¦sznzn (ï ‰) â^'1 [sz1x (ï) ♪• has had ¢ ¢ ¢ ¢ ¢ ¢ ¢ ¢ ¢ ¢ ¢ ¢ & Ron Ã (Â â € ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° â € ° â € ° ° ° ° ° â € ° â € ° ° ° ° ° â € ° â €) of neurons (sometimes indicated as multi -unit activities). In this situation, it can be an information to examine how the ongoing oscillations in the LFP or EEG recorded simultaneously are related to peaks. To this end, the peaks of a certain unit can be represented as a temporal series of those and zeros, to the same speed of sampling of the continuous signals LFP/EEG (note that it is possible to represent peaks as a vector of peak times - "This sometimes can lead to a scarce representation of the data). Once you have chosen an adequate representation of the peaks, we can calculate one of the synchronization metrics mentioned above between peaks and fields, and in fact even between several peak trains. often reveal a significant modulation of peak times compared to field oscillations (for example, a significant coherence of the Spike field), which can also be sensitive to the variables of the task (for example, Fries et al., 2001; Gregoriou et al ., 2009). The Spike-Field analysis is provided with its group of warnings and challenges, which go beyond the purpose of this review (interested readers can do reference to Vinck et al., 2012; Ray, 2015). Quantification of the interactions resolved in frequency and directed with the grenger causalitate so far, we have revised the connectivity metrics that at best, finally, the directionality of the interactions based on the sign of the phase difference of the components of the oscillatory signal limited to bandwidth. However, the practical applicability of these techniques is limited to cases where there is a constantly enriched and mainly university interaction. Granger's reason and related metrics are able to quantify bidirectional interactions and provides two direct connectivity estimates for a given signal of the signal, quantifying separately direct signal of the X signal on signal Y and the direct influence of the Y signal on the X signal. Initially, the concept of grenger causality has been applied to the data of the time series in the field of economy economy Regnarg fo tamitse na dleiy lliw y oil tciderp ot tciderp tciderp evissergerotua gnidliub cigol emas eht gniylppa .)1102 ,htes dna relsserb ;6002 , Regratal taht Eulav Ytilacac Regnarg that ot ot ot ot tdael hcihw ,1 Naht Regral i icnairav eht ,sesac erahb yb .x Seires Emit ROF LEDOM RETTEB A OT SDADER DNOIDO SEALCNIL SEALCNIL CTAILCNI SEALCNILC y oil seulav sap eht tuoba noitamrofni Fo noisulculni eht taht seilpmi ledom tairavob eht ot ot ledom taeiravinu gniraipmoc Slaudiser eht fo eht fo sabedts emit seirsbud ylno ton detciderp era x seires emit fo seulav eht erehw ,ledom-RA etairavinu a si ledom siht erehT .x seires emit fo seulav tsap fo noitanibmoc dethgiew a sa detciderp era x seires emit fo seulav erehw ,ledom-RA etairavinu a tcelfer sledom eseht Fo Eno .Sledo M-ra tnereffid morf deniatbo ,secnairav Laudiser Fo Oitar a FO mhtirag lanutan eht ni denifed ytilasuac regnarg dna ,slaudiser s'ledom , ledom-ra ledom-ra ledom. tsap Fo noinibmoc dethgiew that in deledom emit emit fose seulav erutuf erehw ,krowemarf gniledom)ra(Evissergerota eht ni .nosapmoc ldomser eht stnesreg scels ,tniop siht tA .)lairetaM yratnemelppuS(xidneppA eht ni detail ni emos ni stpecnoc laitnesse eht weiver ylfeirb ew ,)6002 ,.la te gniD(atad ecneicsoruen ot noitacilppa rieht dna ytilasuac regnarG niamod ycneuqerf fo tpecnoc eht nialpxe taht tsixe stxet yrotcudortni tnellecxe hguohtlA 2891 (Ekeweg yb Detalmrof saw Seires Emit Fo Noitateserper niamod ycneuqerf eht tpecnoc Eht Fo noisnetxe DNA ,)9 id ammos anu emoc attircs eresse ²Ãup azneuqerf ni acificeps elatot aznednepidretni'l e azneroec id etneiciffeoc li art elaudividni enoizaler anu etsise ,elorap ertla nI .etnedecerp enoizes anu ni otartsom emoc ,atardauq azneroec id etneiciffeoc la etnelaviuqe ¨Ã effats el art enoizarf aL)°â Ã (yys)°â ¯Ã(xxS2 |)°â ¯Ã(yxs | -1(¢Ãnl-=)°â ¯Ã(Y ,XCG :)eratnemelppus elairetaM(ecidneppA'llen itinrof onos ilgatted iroiggam[elartteps-ssorc Ãtisned alled emits ella esab ni , elatot aznednepidretni id arusim anu erinifed elibissop ¨Ã ,regnarG id Ãtilasuac alled opmet led oinimod led enoizalumrof allen emoc oirporp azneroec al e regnarG id Ãtilasuac aL azneuqerf id oinimod art enoizaleR)2 |)°â ¯Ã(xyH |_)yy £Ã ®Ã2xy £Ã ®Ã- xx £Ã ®Ã(-)°â ¯Ã(yys)°â ¯Ã(yys(¢Ãnl =)°â ¯Ã(yâ â ¢ÃXCG :euges emoc ataloclac eresse ²Ãup azneuqerf allad etnednepid regnarG Ãtilasuac al ,iudiser ied aznairavoc id ecirtam al e elartteps otnemirefsart id ecirtam al ,otaicorcni ortteps laD .elartteps otnemirefsart id ecirtam al art iudiser ied airavoc id ecirtam al odnadnas atunetto eresse ²Ãup acirtemmis-ataguinoc elartteps-ssorc Ãtisned al ,elorap ertla nI .°â ¯Ã azneuqerf a y ,X elanges id aippoc al rep elartteps-ssorc Ãtisned id ecirtam al ¨Ã ehc)°â ¯Ã(s noc ,)°â ¯Ã(s = *)°â ¯Ã(h £Ã ®Ã)°â ¯Ã(H :eneited elatnemadnof Ãttinedi etneuges aL .)£Ã Â (RA olledom led iudiser ied aznairavoc al e azneuqerf allad etnednepid ehc ,))°â ¯Ã(H(elartteps otnemirefsart id ecirtam al : Ãtitnauq eud id amits al edeihcir azneuqerf alled oinimod len regnarG id Ãtilasuac alled oloclac lI ehc eramreffa etneiciffus ¨Ã ,iuQ .)ilgatted iroiggam rep)itanoiznem ivi itnemirefir ia e eratnemelppus elairetam(ecidneppA'lla otasseretni erottel la otnemirefir otaicifaeB .)2891 ,ekeweG(azneuqerf id oinimod len ovitanepo ideev ehcna esseretni ²Ãup regnarG id Ãtilasuac id ottecnoc lI azneuqerf id oinimod led enoizalumroF .y a x elanges lad Quantities: GCX, Y (âsto â € °) = GCXã ¢ â € Â € â € â € â € â € â € â € °) + GCYã ¢ â € Â (â € â € °) + GCXã ¢ Â · Y (âsto â € °), where the term instantaneous causalit is defined as: how: The latter term reflects the part of the total interdependence that cannot be considered by time-lagen interactions (SHIFTED phase) between Signals X and Y, reflecting the common instantaneous entry from latent sources. Note that in the case of synchronization of the zero-fase delay, the term instantaneous causality is not necessarily larger than the causal terms. In particular, in a system with bidirectional interactions, where the magnitude and phase delay of the transfer function are approximately equal in both directions (i.e., from x to y, and from y to x), the density cross-length matrix can report A strong zero-fase synchronization which is however caused by strong causal interactions delayed time in both directions. Note, however, that theoretical work underlines that the zero-lag phase coupling is much more likely that it will occur in the presence of a dynamic relay through a third source, which common inputs to stabilize phase relationships through The zero-lag network (Vicente et al., 2008). Practically, this situation can be distinguished from a purely bidirectional interaction only if the two knots with zero-lag synchronization have been observed simultaneously with the third node that can (or cannot) provide common inputs. Further details on this scenario and how to detect it in the physiological data are provided in the â € section â € œThe common problem of input. Parametric computation of the grenger causality causality in the frequency domain can be calculated with parametrical methods (with self-regressive models, as discussed, the left-hand of Figure 4) or with non-parametric methods (with Fourier or Wavelet-Based methods). These approaches differ how the covariance of the residues and transfer matrices are calculated (see the right meter of Figure 4). The non-pattermetric approach is based led led alleuq a elaugu ¨Ã azneuqerf atad anu rep elasrevsart Ãtisned id ecirtam al ehc ottaf elognis ad regnarG Ãtilasuac al eraloclac id atnet is odnauq etnematuca ¹Ãip otsiv eresse ²Ãup otseuQ .elibats otatlusir nu a eregrevnoc rep)azneuqerf id enoiznuf emoc italiffa ihccip non ,¨Ãoic(elartteps-ortteps id Ãtisned alled aicsil amrof anu e itad ¹Ãip edeihcir acirtemarap-non elartteps enoizazzirottaf id oiccorppa'l ,acirtemarap amits id acincet alla otnorfnoc nI .isilana'l rep atazzilitu eneiv ehc itad id artsenif alled inoipmac id oremun lad otanimreted etnemlaiznesse ¨Ã oremun iuc li ,azneuqerf id essa oretni'llad itad id itnup i azzilitu regnarG Ãtilasuac alled acirtemarap-non amits al ,oirartnoc lA .)1102 ,hteS e ttenraB ;5002 ,gnaiL e iksnimaK(atazzilitu eneiv ehc olledom led amits id acincet alled e ,itad ied Ãtisselpmoc alled e Ãtilauq alled ,elatnemirepsi otipmoc led ,otteggo'lled adnoces a eralivrep ²Ãup ©Ãhcrep ,acitamelborp eresse ²Ãup otairporppa olledom id enidro'lled enoizanimreted al atlecs aL .ovissergerotua olledom li rep olledom led enidro'lled enoizanimreted al edeihcir non ehc ¨Ã acirtemarap-non acincet al ,elartteps atlecs aL azneuqerf id odnazzilitu regnarG Ãtilasuac alled oloclac lenalpicnirp oiggatnav II .ocirtemarap-non o ocirtemarap oiccorppa'l odnazzilitu ,regnarG Ãtilasuac alled oloclac li rep enilepip gnissecorp atad .4 arugiF .)8002 ,.la te alamahD(itanidro neb italumis itad ien eralocitrap ni ,ilibarapmoc otlom itatlusir ecudorp ytilasuac regnarG alled acirtemarap non e acirtemarap amits al ehc otartsomid otats Ã .)8002 ,.la te alamahD ,4 enoizauqE idev(regnarG Ãtilasuac alled oloclac li rep irassecen itneidergni ilg ecsinrof ehcâ)2791 ,nosliW(elartteps ortsed id enoizazzirottaf id odnacilppa elartteps otnemirefsart id ecirtam e ãeromurã aznairavoc id ecirtam anu ni elasrevsart Ãtisned a ecirtam al erazzirottaf elibissop ¨Ã)atsoppo enoizerid allen odnadna idniuq e(elasrevsart Ãtisned a ecirtam allad eritrap A :ottircsed arpos emoc ,azneuqerf alleuq rep otnemirefsart id ecirtam al art audiser aznairavoc id ecirtam Even if both parametric and non-parametric techniques can be used for mono-crime estimates of connectivity, it seems that parametric estimates are more sensitive than non-parametric estimates, especially when the order of the model is known (Brovelli, 2012; Richter et al., 2015). Bivariate vs. Multivariate Spectral Decomposition It is important to note that, in multichannel recordings, the spectral transfer matrix can be obtained in two ways, regardless of whether it is calculated by a self-assembled model, or through the factorization of an estimate of non-parametric spectral density. You can adapt to a complete multivariate model (or equivalent, make a multivariate spectral decomposition), where all channels are taken into account, or you can do the analysis for each channel couple separately. This latter approach typically produces more stable results (for example, because it involves less parameters assembly), but the advantage of the previous approach is that information from all channels is taken into account when estimating the terms of interaction between any pair of sources. In this way, you could try to distinguish directly from indirect interactions, using an extended formulation of Granger causality, called partial Granger causality (Guo et al., 2008), or causality of conditional Granger (Ding et al., 2006; Wen et al., 2013). In addition, the multivariate approach produces a spectral transfer matrix that can be used to calculate a series of connectivity metrics, which are related to the Granger causality. These metrics are the direct transfer function (DTF) with its metrics (Kamiński and Blinowska, 1991), and partial direct consistency (PDC) with its metrics (Baccalá and Sameshima, 2001). These quantities are normalized between 0 and 1, where the normalization factor is defined as the sum along the lines of the spectral transfer matrix ettelfir ettelfir x a y elanges ad FTD ,inoizazzilamron etseuq id otteffe reP .)CDP rep(elartteps otnemirefsart id ecirtam alled osrevni'lled ennoloc el ognul ammos emoc o ,)FTD The influx from y to x as a ratio between the total influx in the x signal, while in its original formulation pdc from the y signal to the x signal reflects the causal outflow from y to x as a ratio of the total outflow from the y signal. These measures and their derivatives, along with the motivations to prefer one from the other metric, are discussed in more detail for example (binowska, 2011). common limitations and problems of functional connectivity methods the following section outlines some problems that guarantee caution in relation to the interpretation of the estimated connectivity. the main question at stake is whether the estimation of connectivity (or the estimation of the difference in connectivity between experimental conditions) reflects an authentic effect in terms of (a change in) neuronal interactions. as we will illustrate by means of simple simulations, there are various situations that cause estimates different from zero of connectivity in the absence of true neuronal interactions. the main cause of these spurious estimates of connectivity is the fact that in MEG/EEG/LFP recordings the signals that are used for estimating connectivity always to a certain extent reflect a mixture (sometimes poorly) note of a signal of interest (which is the activity of a neuronal population to which we are interested) and signals of non-interest (which we will call noise in the rest of this document). another cause of spurious estimates is more related to the interpretation of the observed connectivity patterns. This refers to the fact that it is impossible to assert if a observed connection is a direct connection or if this connection is mediated through an unobserved connection. In the following, we describe five common practical issues that guarantee caution in relation to the interpretation of connectivity estimates. Let us explain these problems using simple simulations based on li li odnetnesnoc ,pirTdleiF izzertta ilged attessac allus e otnemirefir id odorttele nu id otteffe'l artsulli enoizalumis etneuges aL .erawdrah'llen otnemirefir id odorttele olognis nu azzilitu PFL e GEE inoizartsiger elled aznairoiggam al ,etnemaivvO .otnemirefir id enoizartsiger id itis ien inoizautluf ilaiznetop elled avitaler azrof alled ednepid airups ¨Ã atamits Ãtivittennoc al iuc ni arusim aL .oirups etrap ni Ãras orez odratir nu ni inoizalerroc alle elibisnes Ãtivittennoc id acirtem isaislauQ .orez opmet id odratir nu ni eirups inoizalerroc odnecudorp ,ilaropmet eires el ebmartne ni otnemirefir id ottelfir elaiznetop led inoizautluf el , Ãtivittennoc alled amits al rep atazzilitu etnemavisseccus onognev ehc odortele ilg ibmartne rep otnemirefir id odortele ossets ol eS .otnemirefir id odortelte'lled enoizisop allen e odortelte'lled enoizisop allen otarusim ocirttele elaiznetop led enoizaretni'l ,elaiznetop id azneréffid al ettelfir ilanges itseuq id onucsaiC .2 itad e 1 itad ,etartsiger ilaropmet eires eud anigammI .A5 arugiF allen etnemacifarg otatneserppar ¨Ã amelborp otseuQ .enumoc otnemirefir id elanac nu id osu'lled eravired onossop elanoiznuf Ãtivittennoc id eirups emits el ,GEE o PFL inoizartsiger elled enumoc otnemirefir id amelborp lI .itteggos i art o inoizidnoc art itnorfnoc onautteffe is odnauq elanoiznuf Ãtivittennoc alled ehcirtem el eraloclac rep atazzilitu enoizavresso id idoirep o ehcope id elaugeni oremun lI .otnemirefir id elanac ¨Ã amelborp °Â 5 lI .otavresso non enumoc tupni'lled amelborp li ¨Ã °Â 4 li e ,eromur e esseretni-elanges id alecsim anu erpmes onos itarusim ilanges i ehc ottaf led azneugesnoc non e ,onos)RNS amelborp li e opmac id opmac/emulov led enoizudnoc alled amelborp li ,enumoc otnemirefir id amelborp li(imelborp ert imirp lA .61805102-pirTdleiFÃ ¬â ¢Ã pirTdleiF enoisrev al odnazzilitu ,b/a4102 e b/a3102 BALTAM us otatset otats ¨Ã ecidoc lI .imelborp itnatropmi itseuq us ehcitarp inoizamrofni enucla erenetto rep redaeR enumoc enumoc nu onodividnoc ehc idortele eud ad atarusim ¨Ã Ãtivitta atseuq e ilanoruen itnof eud ni zH 06" ¬â 03 id airotallicso Ãtivitta'nu omerelumiS electrode (which is also presumed to have an oscillatory component). We will evaluate the consistency between the measured signals, in the presence and in the absence of mating between the sources below. Figure 5. Illustration of different reference schemes and like any effect the calculation of consistency with and without real neuronal coupling. (A) the case of unipolar recordings, which introduce spurious consistency values in the absence of consistency. (B) the bipolar derivation technique, which largely solves the common reference problem. (C) the separate reference regime, which is not sensitive to common reference problems. In this simulation, we have taken on a generative model consisting of a linear mixture between various sources that each has an oscillatory component in the 30-60 Hz range. Independent sources are projected directly to the relevant data, denoted by arrows between example, source 1 and data 1 in figure 5a. The common reference is treated as a shared signal that is projected with equal weight to each data channel (note the arrows between R and each of the data channels in Figure 5). The coupling between the sources is simulated as a shared signal that is projected in every source in some mixture, specified in the script (Sim_commonreference.pdf) using this generative model, it is clear that when no real coupling is present between the Source 1 and Fonte 2, there is a significant artificial coherence between data 1 and data 2, due to the common reference (Figure 5th, red trace). This is a problem, because in the absence of any underlying neuronal interaction, any estimate of the connectivity should be close to zero. When the royal coupling is introduced between source 1 and source 2, as can be seen in Figure 5a, the consistency between data 1 and data 2 increases, which reflects the presence of both the common reference and the real coupling. art art otnemaippocca etrof odnemussa atiugese atats ¨Ã enoizalumis In the presence of a weak coupling, the artificial consistency can sometimes predominate "and obscure" the real consistency caused by real interactions. A solution to the problem is to record additional channels and perform bipolar derivations to remove the common reference, and therefore calculate the connectiveness between locally renowned bipolar derivations that do not share a common unipolar channel (Figure 5b). This procedure, for example, was applied to Bollimunta et al. (2009) and in Bosman et al. (2012), and is based on two hypotheses: firstly, that the reference is equally present in the unipolar channels that will be removed, and secondly, that each of the unipolar channels reflects a different mixture of the underlying neuronal sources, otherwise the Same logic behind the elimination of the common reference through bipolar derivation. For a more rigorous discussion of the bipolar derivation procedure and its applications to neural data, see Tronnetrpunya et al. this problem. In figure 5b each unipolar channel is depicted how to reflect the activity of an independent source, but each unipolar channel could also reflect a mixture of underlying sources, and the same logic applied. In this scenario, the bipolar derivation removes the common reference (see the equation in figure 5b), and the resulting bipolar signal is a subtraction of two activities of local origin. When coherence is now calculated directly between the bipolar 1 site and the bipolar 2 site, it is not Biased with the common reference, as shown in the lower panel of figure 5b: when no coupling is present among the sources, the consistency is : Close to zero (how much close depend on how many tests have gone to the analysis and the resulting bias "see section on the size of the sample Bias), but in the presence of mating, consistency. A second possible solution to problem is shown in Figure ,isac led eroiggep leN .opmac led enoisuffid emoc otairporppa ¹Ãip ¨Ã etlov a ,ocitengam opmac led inoizartsiger elled osac leN .ilanoruen itnof ¹Ãip id Ãtivitta'l ereilgoccar a erosnes nu o enoizartsiger id elanac nu onasuac ehc ,icitengamorttele ipmac ied elaizaps enoisuffid alled onemonef li elareneg ni ¹Ãip erettelfir rep enimret emoc otattoda otats ¨Ã etnemlaiuqolloc lA .evitta ilanoruen itnof el onadnocric ehc itusset ien onocsiulf ehc itnerroc ella ecsirefir is emulov led enoizudnoc aL ,inimret id rogir A .emulov led enoizudnoc allad atasuac ¨Ã ,evisavni non inoizartsiger us onasab is emits el odnauq eralocitrap ni ,ilanoruen inoizaretni elled enoizaterpretni'llen e enoizacifitnauq allen etnatropmi amelborp ortla nU opmac led enoisuffid/enoizudnoc id emulov led amelborp II .ilanac i ibmartne ni aenatnatsi alecsim aus alled asuac a ... otnemirefir led etnatsottos elartteps amrof al ais euqnulauq avettelfir azneroec id ortteps ovittepsir li idniuq ,enumoc otnemirefir nu avevA italoclac itats onos ehc ilanac i ibmartne onos ehc ilanac i ibmartne onos ehc ilanac i ibmartne onos ehc ilanac i ibmartne onos ehc ilanac i ibmartne onos ehc ilanac i ibmartne onos ehc ilanac art italoclac itats onos ibmartne ehc ilanac i art ataloclac avinev azneroec al e ,otaroloc e ocnaib eromur id alecsim anu o ocnaib eromur ni avetsisnoc otnemirefir li es ,aivattut - zH 06" ¬â 03 id oirotallicso etnenopmoc nu esseva otnemirefir li ehc ehcna avemuserp is ,inoizalumis etseuq ni ehc iton iS .fdp.ecnerefernommoc_mis tpircs ni ecidoc li odneugese etazzilaer essere onossop arpos inoizalumis eL . Ãtisned atla da e alacs agral us inoizartsiger rep ocitarp eresse non ebbertop ,oipicnirp id aenil ni enoizulos anu atneserp otarapes otnemirefir id amehcs ol ertnem ,otnatreP .elaicifitra azneroec id etnenopmoc nucla ovoun id etsise non ,)C5 arugiF alled eroirefni ollennap(osac otseuq nI .elanac nucsaic a etnematarapes otnemirefir eraf ¨Ã ehc diffusion of the field can create coherence or block of purely artificial phase, which means that the presence of functional connectivity between two signals would indicate not the presence of a true neuronal interaction, but instead the presence of activity from the same source below Two channels. An important property of volume management and field diffusion, at least in the frequency range that is relevant forIt is that its effects are instantaneous. That is, if a dominant rhythmic neuronal source is visible at two sensors at the same time, the phase observed at these sensors is the same (or a difference of 180°, when each of the sensors "see" a pole opposite of the dipole). This instantaneous property can be exploited to use connectivity measures that discard contributions of 0 (or 180) degrees of phase differences. This will be explained in more detail below. When considering the different electrophysiological recording techniques, the diffusion of the field is considered the least invasive problem of the recordings. The spiking activity of individual neurons is by definition very spatial focal, and the volume currents associated with this spiking can be collected only at a distance of a few dozen or hundreds of microns. Therefore, for quantification of peak-spike or peak-field interactions, field (Kajikawa and Schroeder, 2011) diffusion is hardly a problem. In the interpretation of the estimated synchronization between two LFP signals, it is necessary to take account of the volume conduction. The reason is that the potential of the local field can reflect volume currents that spread over larger distances, exceeding 1 cm (Kajikawa and Schroeder, 2011). The spread of the field is by far the most problematic when non-invasive measurements are performed, due to the large distance between the sensors and the neural sources, and due to the spatial blur effect of the skull on the distribution of the electrical potential on the scalp with EEG (Nunez et al,. 1997, 1999; Srinivasan et al,. 2007; Winter et al, 2007; Schoffelen and Gross, 2009). As a result, a single underlying neuronal source will be seen in multiple EEG or MEG sensors, causing spurious correlation values between sensors. In the presence of a diffuse field, any given source is "visible" on multiple sensors / electrodesand different strategies can be used to relieve the negative effects of Di id emeisni nu ehc ¨Ã inoizalumis id emeisni otseuq ni elareneg oiccorppa'L .etnemlaizrap onarepus il ehc iccorppa ilg emoc ¬Ãsoc ,itanoiznem arpos imelborp ied inucla artsulli fdp.noitcudnocemulov_mis tpircs oL .)9002 ,ssorG e neleffohcS(evortla etnemataigatted ¹Ãip ottircsed otats ¨Ã otseuQ .emulov led enoizudnoc alled itteffe ilg etnemaneip onagitim esaf id odratir ni enoizaretni id erusim id o iltnemireps itsartnoc id osu'l ©Ãn ,)itad ied isilana'lla Ãtisselpmoc id ollevil nu ertlono onognuigga ehc(itnof elled enoizurtsocir id ehcincet id enoizacilppa'l ©Ãn ,opportruP .elanges led itnenopmoc i art)deggal-esaf(erev inoizaretni elled otnoc nu onocsinrof onemla ehcirtem etseuq ,isauq esaf-orez azneréffid a onacifirev is ehc ilaer inoizaretni el eravelir id odarg ni eresse non id otipacs A .esaf id aznednep id ecidni'l ,azneroec alled airanigammi etrap al onos ehcirtem etseuq id ipmesE .)°Ã081 o(0 id esaf id azneréffid anu da onos ehc inoizaretni el odnatracs ,esahp-fo-tuo enoizaretni'llus erazzilatipac ehc Ãtivittennoc id ehcirtem erazzilitu id alleuq ebbrava ,aznedecerp ni otanneccа Ãig emoc ,aigetarts azrez anU .eirups emits elled israzzarabs etnemavitteffe enoizarttos al e ,enoizidnoc id ebmartne ni elimis odom ni Ãtivittennoc id emits ellus ecsiulfni emulov led enoizudnoc al ehc ¨Ã iuq isetopi'L .itallortnoc neb ilatnemireps itsartnoc id osu'l adraugir aigetarts adnoces aL .etnerroc etnegros id Ãtisned al odnamits o ,)etnedecerp enoizes allen otsivir emoc(elacol eralopib enoizavired anu oipmese rep odnazzilitu ,gnicnerefir-er id amehcs otairporppa nu id enoizacilppa'l ¨Ã aigetarts amirp aL .enoisuffiD It is simulated in 50 "places of measurement" (Meg/EEG channels, or in virtual "virtual" Tfel pot eht neewteb ecnereffid eht dna ,ycnerehoc eht fo trap yranigami eht ,xirtam ecnerehoc eht wohs tfel eht if slenap eht .gal emit orez-non â€Ew sever Eht ehw noitunis b6 ehtum b6 eht6 eht6 .Dehsiloba i rulb dees eht taht)2(DNA snoitCeretni degl-emit fo ecnesba eht ni wol ytitnauq siht)1 Erom yllaitaps sit dees eht ,)snoitocol â€ã€ãEvitcaâ€ã€ã Eht morf gnidees nehw ,.e.i(oil fo ecneserp eht ¢Evitcaâœã€ã¢ Owt eht Eht Edidituo(WOL OLD EHT FI NAVE ,Elbaredisnoc sty eht taht taht nees ebe nac Dexedni(Rosnes dees ippageps a ot tcepser htw ECNerehoc Eht stcelfer xitam eht ni)nmuc(wor hcae .daerps dleif eht fo ecneuqesnoc Tartsulli ,ecnerehoc gniyalpsid ,tfel ehr if lenap eht .cruos ht53 eht dna ht61 eht rof seulav egral htw ,lanogaid eht if seulav orez-non xtam relieved snacrevoc sanic sanic sacreonoc sanic screoced screoced screoc. e.i(gnitcaretni erew secruos gniylrednu eht fo enon taht hcus detcurtsnoc erew slangis ecruos eht dna ,sriap rosnes lla rof secirtam ytivitcennoc swohs A6 erugiF .ecnatsid eht no tnedneped si taht egakael laitaps a htiw ,edis rehtie no secruos ybraen 51 eht dna ecruos lanigiro Eht FO noinibmoc dethgiew a FO TSSINOC ot tsisnoc ot snive eht reddisnoc ew sdrow rehto ni .woodniw gninnah tninah tnina htw snoitavitca craos craos eht snaped scass latis-oted xistam latis-oted yb detareeneg era Seseroc emit ytivitca ecruos eht .secruos ginnilledнu Eht Fo ytivitca eht FO)daerps dleif ot Eud(erutxim FO STSSNOC Sangnis Eht Fo Hcae in b and a. The right panels display connectivity in one of the rows in these matrices (indicated with the white line drawn to the left), reflecting the seed connectivity from the 16th source. The lower right subpanel in Figure 6B shows consistency from the upper left subpanel in black, consistency from the upper left subpanel in red, and their difference in blue. So far, these simulations demonstrate in a very simplified scenario the effects of field diffusion, as well as the corrective effects provided by subtracting two conditions with different levels of connectivity between active sources, or focusing on the time-lagged component of connectivity. Figure 6. Effects of the field spread on the estimation of connectivity. (A) In the absence of connectivity, the spread of the field leads to spurious consistency (left panel), while the imaginary part of coherence mitigates this effect (right panel). (B) In the presence of time delayed interactions, "seed break" caused by the spread of the field leads to only a "shoulder" in coherence, and not to a distant peak (pannello in the upper right). The imaginary part of coherence correctly identifies a distant peak (average right panel). Bottom panels: the distant peak of coherence is revealed when you take the difference (blue line) between the connected situations (black line) and not connected (red line). (C) The spurious differential effects appear both in coherence (higher panels) and in the imaginary part of coherence (lower panels) when the SNR changes from one condition to another. (D) The spurious differential effects appear both in coherence (higher panels) and in the imaginary part of coherence (lower panels) when the breadth of one of the active sources changes from one condition to another. Real experimental data, however, have never existed as iuc iuc ni isac id itneiruase non ipmese inucla ecsinrof etneuges lI .arpos itatneserp italumis itad strategies strategies may yield results that can be wrongly interpreted. Figure 6C shows a situation where a true connection exists between the 16th and the 35th source, which doesn't change in strength from one condition to another. In one of the conditions an additional source is active (at location 27), which is not connected to any of the other sources. The difference maps, however, show quite some spatial structure, which is due to the differential effects exerted by the field spread on the connectivity estimates. For example, seeding from the 11th source using coherence as a connectivity metric yields a spurious non-zero difference around the 25th source. This is shown in the right panel of Figure 6C, where the individual conditions' seed-based connectivity estimates are displayed as red and black lines, and their difference is displayed in blue. Likewise, seeding from the 22nd source using the imaginary part of coherency yields a spurious non-zero difference around the 28th source. The implication of this is that differences in the activity in the contributing sources can yield spurious differences in estimated connectivity. One could argue that an appropriate seed selection would have prevented this erroneous interpretation. Had we focused on the active sources to begin with, the problem may have been less severe. Although there may be some truth in this, in practice it is often difficult to select the proper seeds a priori, for example because the relevant sources are not necessarily the ones that have the highest amplitude, and even if the seed locations are appropriately selected, spurious connectivity can still arise. This is illustrated in Figure 6D, where two conditions are compared, with unchanging connectivity between the activated sources (16 and 35), but with a change in power for one of them. The panels on the right show the seeded connectivity (from source 16) for the condition with low (red lines) and high melborp siht taht deton eb dluohs tI .secruos neewteb snoitcaretni lanoitcerid ni secnereffid gnirrefni nehw citamelborp eb osla nac secnereffid RNS ,snoitidnoc ssorca ytivitcennoc ni ecnereffid a gnirrefni yltcerroc rof melborp a gnisop morf traP A .snoitidnoc ssorca RNS ni secnereffid ot eud ,ytivitcennoc ni secnereffid suoirups ot sandal sdael snoitidnoc neewteb nosirapmoc ehc erehw ,evoba tnetxe emas ot detentsulli neeb tcaf eht fo esuac Gniylrednu ecnis ,evoba dessussid Melborp daerps dleif eht ot detailed Melborp yaw emos ni .melborp rns eht Ereh llac detamitcent sdерpcebcennoitce sdamelPcebcebcebcebcelypce. Yhtrowtsurt Eb ot ytivitced detcerid detamitse Eht Tpecca Ro dracsid ot reddro , atnatsni eht fo noitagitsevni eht no desab citsiruehi a esu ot esoporp srohtua eseht ,ytilasuac regnarG fo noitcurtsnocer etarucca na rof citamelborp si gnixim suoenatnatsni taht dewohs)5102(.la te kcniV ,)5102 ,.la te iagelsE(CDP fo noisrev dezilamroner a gniylppa yb derevocer eb yam ytivitcennoc krowten gniylrednu eurt eht taht setacidni krow noitalumis emos hguohtlA .ecnairavoc esion eht dna xirtam refsnart lartceps eht fo noitamitse eht ni seicaruccani dna ,)noitces txen eht ni erom dessucsid(slennahc neewteb secnereffid oitar esion ot langis ot sdael daerps dleif eht ot eud slangis ecruos eht fo gnixim raenil eht taht si siht rof nosaer ehT .seititnauq detaler ro ,ytilasuac regnarG fo snaem yb ,.g.e ,ytivitcennoc detcerid fo ecnerefni tcerroc a ref citamelborp eb osla nac ,evoba debircsed sa ,daerps dleif eht ot eud Setamitse ytivitcennoc gniterpretni fo ytlucffid eht .)senil eulb(ecnereffid rieht ni llew in ,53 craos fof rewop)Senil)Senil)Senil hcae ecneulfni selbairav owt eht taht gninaem ,lacitnedi osla era sessecorp htob fo)2ÂµÃ ,1ÂµÃ(snoitavonni eht fo ecnairav eht dna ,lacitnedi era smret ssorc eht dna smret-otua eht htob fo stneiciffeoc evissergerotua eht ,yllaicurC .2 dna 1 gal emit ta osla ,)smret ssorc eht(elbairav rehto eht fo fo noitcnuf a osla dna ,)smret otua(2 dna 1 sgal emit t t nwoo rivisser-otuf a tahcorp ssecors-otuf a 2x dna1x selbairav :A7 erugiF ni nwohs noitautis a enigamI .secneuqesnoc detcepxenu ot dael nac noitciderp no desab ytilasuac fo noitinifed siht ,atad ysion ot deilppa nehw ,revewoh ,ytivitcennoc eurt tceted ot krow lliw hcaorppa siht ,lareneg nI .rehtona tuoba snoitciderp ecnahne nac Seires emit Eno fo tsap eht fi rehtona ot ecneulfni lasuac regnarg of Sah elbairav, taht rebmemer ot lufesu si ,yilalasuac regnarg fo noitammitse Eht edrang otnnun tsreff tinnnun tninnnun oc eht gninnur yb dezilaer eb nac hcihw ,snoitalumis emos gnitneserp yb eussi eht etartsulli eW .slangis neewteb RNS ni secnereffid yb detpurroc eb nac ytilasuac regnarG fo setamitse woh no yllacificeps sucof ew noitces siht ni ,ytivitcennoc detcerid fo scirtem ynam rof eussi citamelborp a si siht elihW .htgnerts langis ni secnereffid a gnisuac ,tseretni fo secruos evitca eht ot ecnatsid ni secnereffid ro ,)scitsiretcarahc reifilpma ni secnereffid ot eud ,.g.e(esion rosnes ni secnereffid era ereht setis gnidrocer PFL ssorca nehw esira ecnatsni rof nac noitautis a hcuS .esion dna langis fo stnuoma tnereffid htiw devresbo neeb hcae evah taht slangis owt morf deniatbo eb nac setamitse ytivitcennoc lanoitcerid suoirups taht si ereh eussi eroc ehT .noissucsid etarapes a stirew melborp siht taht eveileb ew erofereht dna ,)sgnidrocer PFL decnereferer-yllacol morf ytivitcennoc Gnitupmoc nehw ,.g.e(Noitcudnoc emulav fo ecnesba eht ni Esira Osla with equal strength. Therefore, for construction, the grenger reason from X1 to X2 should be identical compared to the grenger reason from X2 to X1. This is in fact the case in which the exits of such a generative process are observed without measuring noise, illustrated in the 7B-D figures. In this case, as expected, both variables have spectra of almost identical power at 40 Hz (Figure 7b), have a spectrum of consistency that also reaches 40 Hz (Figure 7C), and have a causality approximately equal to 40 Hz in both The directions (Figure 7D). Note that the slight difference in the grenger reason from X1 to X2 vs. X2 to X1 is due to the error of esteem, which approaches zero as the number of model creations and subsequent observations are repeated. Figure 7. A simulation of the problem of the signal-noise ratio. (A) Two knots biddly interact with equal resistance of connectivity in the two directions, and the data are observed without (case 1) or with (case 2) noise noise. (B) Power for case 1, (c) Consistency for case 1 and 2, and (d) Granger causalities estimates for case 1. (e) Potenza, (f) Granger causalities estimates for case 2. (G) Granger's causalities estimates after the time-reversing of the data produced by case 2. Now we consider the case 2, where we observe the same system, but in the presence of noisy measurements. In this case, the white noise is added to X1, but not to X2. The first result of this manipulation is that the X1 power spectrum is moved upwards (Figure 7e), the result of adding power to all frequencies (i.e. white noise) to that channel. The consistency between the channels is also modulated by this manipulation, shown in figure 7C, with a reduction in consistency to a wide range of frequencies when an extra noise is present. When looking at Granger causal estimates, shown in figure 7F, a ¨Ã ¨Ã otseuQ .2x us 1x ehc 1x us regnarG elasuac azneulfni etrof ¹Ãip anu ah 2x evod ,ocirtemmisa consequence of the fact that the additional noise on x1 has weakened its predictive power of x2, causing an apparent asymmetry in the directionality. Note that this asymmetry is exactly in line with the definition of Granger causality based on a log ratio of prediction errors (comparing the univariate to the bivariate model), and in that sense it is not ¢ÃÂÂwrong.¢ÃÂÂ However, this does lead to a divergence between ¢ÃÂÂGranger causality¢ÃÂÂ and what we as experimentalists would like to infer as ¢ÃÂÂtrue causality,¢ÃÂÂ where we would like to infer a dominant direction of information flow from an asymmetry in Granger causal estimates. These simulations depict the ¢ÃÂÂworst case scenario,¢ÃÂÂ when a massive difference in SNR exists between channels (SNR of x1 was 1, SNR of x2 was maximal because there was no noise added). Asymmetries in Granger causality that are driven by SNR differences have been defined by Haufe et al. as ¢ÃÂÂweak asymmetries,¢ÃÂÂ as opposed to ¢ÃÂÂstrong asymmetries¢ÃÂÂ caused by true time-lagged, causal relationships (Haufe et al., 2012). In order to be able to make a distinction between weak and strong asymmetries in the interpretation of the estimated Granger causality, Haufe et al. suggest to investigate Granger causality after time-reversal of the signals. The underlying rationale is that time-reversal causes a flip in the dominant direction of interaction only in the presence of strong asymmetries, because the time-reversal operation does not affect the SNR of the individual signals (the AR coefficients of the auto-terms in the univariate AR-models are the same in the forward and backward time directions, and therefore the power spectrum and ¢ÃÂÂself-prediction¢ÃÂÂ is insensitive to time reversal), and thus, will not affect differences in directional interactions if these are caused by weak asymmetries. The time-reversed Granger causality computed from the data we simulated earlier is shown in Figure 7G. time-reversal reveals that the dominant Granger causal direction (x2 to x1) remains unchanged, indicative of a weak asymmetry. On the other hand, when actual strong asymmetries underlie a directional difference in Granger causality, time-reversed testing would lead to a change in causal flow in the time-reversed compared to normal directions. In the simulations depicted in Figure 8, a strong asymmetry is created, which is a unidirectional flow from x2 to x1, leading to an asymmetric Granger causality in the appropriate direction (Figure 8D). When the signals are time-reversed, the directionality of Granger causality also flips (Figure 8E), as expected. Therefore, in practice, spurious directional differences in Granger causality that are caused only by differences in SNR may in principle be diagnosed with reversed Granger testing, which strongly reduces the false positive rate of detecting spurious Granger causality, also in the presence of linear mixing (Haufe et al., 2012; Vinck et al., 2015). Figure 8. Time reversed Granger testing reveals the presence of strong asymmetries. (A) An auto-regressive model specifying a unidirectional system in which x2influences x1 at lags 1 and 2. (B) Power, (C) Coherence, and (D) Granger causality estimates for the forward time direction. (E) Granger causality estimates for the reversed time direction. Note that power and coherence remain the same when estimated from data in either the forward or reversed time directions. Of course, whenever possible, the SNR problem should be addressed at the experimental level, where care should be taken to minimize noise and ensure that SNR is equalized as much as possible over channels. For example, with EEG or invasive LFP recordings, impedances can be equated as much as possible prior to data recordings, and sensors should be positioned in order to maximize SNR. However, this may not be always possible in practice, for instance in recordings (field spread), or due to intrinsic differences in activity of the underlying sources. In such cases, one could resort to stratification techniques (Bosman et al., 2012) where across conditions, the distributional properties of signal power are made as similar as possible, by means of trial subsampling. Alternatively, it has been suggested to use analytic approaches to correct for measurement noise post-hoc. For example, some authors have proposed algorithms to separate signal and noise components in recorded signals using state-space modeling (Nalatore et al., 2007; Sommerlade et al., 2015). This approach assumes that observed time-series represent a combination of the signals-of-interest (modeled as an auto-regressive model) and some amount of superimposed noise, and aims at separating these two quantities. In simulations with uncorrelated, Gaussian noise, this approach largely corrects the problem, yielding Granger causality estimates that are not contaminated by noise. Yet another approach is to use Dynamic Causal Models (DCM), where the generative model is an actual biophysically plausible neuronal model, rather than an autoregressive description of time series (Bastos et al., 2015a). Within the DCM framework, it is possible to make a distinction between the dynamics of the underlying biophysical process (the activation and interaction of the underlying neuronal groups) and the measurements that are made of these processes. Therefore, both correlated and uncorrelated observation noise can be taken into account, and consequently connectivity estimates are more robust to changes in SNR (Friston et al., 2014). The Common Input Problem Another interpretational problem in making inferences about estimated interactions from measured data is the difficulty in distinguishing direct from indirect interactions. In other words, if a functional interaction between a pair of signals is detected, this could be by common inputs from a third source, which has not been taken into consideration. For example, consider the generative model shown in Figure 9a. We used an authorsal generative model to simulate a connectivity structure between three sources (X1, X2, and X3), where X1 and X2 are not directly connected, but to receive common inputs from X3 to Time Lags 1 and 2. As a consequence of the Common entrance, we will be the variation shared between signals X1 and X2. Figure 9b shows their respective spectra of consistency for the case 1. Note the light peak in the spectrum of consistency between X1 and X2 at 40 Hz (blue portrait). If we interpret this spectrum of consistency as proof of a direct neuronal interaction, it would be a spurious inference. Therefore, to help in the interpretation of this spectrum of consistency, we must explicitly consider if the shared variance that causes the observed consistency is due to the common entrance. If we observe all three nodes, this can be done considering the consistency between the X1 and X2 after having partialized the contribution of X3 (the Magenta track in figure 9b), which reports considerably reduced consistency between X1 and X2, indicative of variation shared (consistency) due to common input. Another metric to be looked at in this case would be the imaginary part of consistency (repeating green), which is also close to zero, indicating that the variation shared between the X1 and X2 can be entirely explained by the zero-lag component, as we do It can wait for the spread of the field or, in this case, from common entrance that reaches simultaneously and to the same delay to X1and X2. Figure 9. A simulation of the common input problem. (A) the self-regressive form of a model that simulates the common entrance from X3 to X1 and X2. (B) spurious coherence between X1 and X2 caused by the common entrance. Imaginary (green) and partial coherence (purple) are close to zero, indicating Both instant and mediated (X3 respectively). x3). idniuq e idon irtla ni aznairav al eredeverp ²Ãup odon nu ni aznairav al eneb otnauq onnarezneulfni irtemarap itseuq id onu ni itnemaibmac i ©Ãhcrep otseuQ .elanoizerid otnemaippocca oirups erettelfir a ehcna onnareizini regnarG Ãtilasuac alled emits el ,etaloiv etnemavissergorp onos isetopi etseuq ©Ãhciop ,ilaer itad ieN .eromur-elanges otroppar irap nu noc etiugese onognev inoizartsiger el ehc e ,odratir opmet ossets olla ,otnemaippocca id azrof elaugu noc otinrof ¨Ã enumoc ossergni'l ehc otnussa omaibba ehc iton iS .fdp.tupninommoc_mis tpircs ni ecidoc li odneugese etazzilaer eresse onossop inoizalumis etseuQ .3x e ,2x ,1x art etnatsottos Ãtivittennoc arev al eracitsongaid rep elitu ebberas elaizrap o elanoizidnoc regnarG id Ãtilasuac al iuc ni enoizautis anu ehcna ebberas atseuQ .)odratir ni(elasuac enoizaretni'nu id etrap onnaf non ehc eenatnatsi 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Examine consistency based on trial numbers yields an average coherence value, which is substantially higher and also more variable over different estimates compared with higher trial counts. Figure 10B shows the same simulation but using Granger causality as connectivity measure. This shows that measures like coherence, PLV, and Granger causality are positively biased when estimated using non-parametric techniques, and this fact should be taken into account for a proper inference. To estimate how much bias is present in a given estimate, one can create a reference distribution by re-arranging data segments and destroying the temporal alignment between channels. This would preserve the power spectrum of each signal but should force the cross terms of the cross spectrum to approach zero. After repeating the procedure of temporal re-alignment and connectivity estimation, one can compare the empirically observed connectivity estimate to the reference distribution and determine an appropriate level of significance. To estimate the absolute value of a connectivity metric like Granger causality, one can subtract the estimated bias to obtain a de-biased estimate (Barnett and Seth, 2014). Note that this approach is only successful in eliminating the sample-size bias associated with connectivity estimates. Other phenomena that inflate the connectivity estimates such as field spread are not properly taken into account by trial-shuffling procedures and must be dealt with in other ways. Figure 10. Sample size bias for coherence and Granger causality estimates. (A¢ÃÂÂC) For each respective metric, simulations based on 5, 10, 50, 100, and 500 trials were run, and coherence (A), Granger causality (B), and PPC (C) were calculated. Each panel reflects the average Ã±Â 1 standard deviation across 100 realizations. Several approaches can be taken to account for the sample size bias. In some experimental situations, where the number of observations per condition is Or less balanced by the design (but in practice it turns out to be different, for example, after the refusal of artifact), a strategy could be to equal the number of tests in conditions to be compared by accidentally canceling the observations from the condition with highest test numbers Until the test numbers are fair. This approach is ideally incorporated into a bootstrap procedure, where the random cancellation of the tests is repeated more times, to obtain a more robust estimate. In addition, for some metrics (for example for consistency) the analytical estimates of the bias can be calculated and applied (Bokil et al., 2007). For consistency this usually goes hand in hand with a Z-Transform stabilizing variance, which has the added advantage to facilitate a significant group of statistical inference. Another possibility is to take into account the different sample dimensions in the inferential statistical framework, using a non -parametric statistical test (Maris et al., 2007). Or, in the specific case of consistency, the distribution properties can be considered and make parametric statistical inference using a Jackknife procedure (Bokil et al., 2007). Alternatively, a metric could be used to detect synchronization which is intrinsically impartial, such as PPC (see figure 10C). Finally, one could also estimate the bias associated with any particular measure of functional connectiveness (for example, dampening the test sequence of a channel compared to others, and calculating the metric of the functional connectiveness), and therefore subtracting this estimate of bias from the value of connectivity observed empirically. Conclusions in this article, we have presented a non -exhaustive review of different methods currently used to quantify the rhythmic functional connectivity. We have described a taxonomy to underline how the methods are connected They. For some of the most commonly used metrics, we also described the intuition behind them and some of the mathematical mathematical metrics etnegros id Ãtisned alled amits al o eralopib enoizavired al osrevartta elacol oiggartibra'l emoc id ossucsid omaibba ,enumoc otnemirefir id amelborp li reP .otarolpse omaibba ehc ilanoizaterpretni eidisni ella inoizulos ilaiznetop otartsulli omaibba ,elibissop evO .ilaer itad us etacilppa onagnev ehc amirp etarolpse de etappulivs eresse onossop idnofnoc itseuq a inoizulos esrevid iuc ni otallortnoc etneibma emoc itazzilitu eresse onossop tpircs ilg ,ertlonI .ivitaterpretni idnofnoc ilaiznetop itseuq id inoizacifimar el otailgatted ¹Ãip odom ni erarolpse rep tpircs ilgen irtemarap i eraibmac lad onottabba is non isse ehc e ,essets inoizalumis etseuq eriugese a itaiggarocni onais irottel i ehc omairugua ic ,inoizalumis el eriugese rep itazzilitu itats onos ehc BALTAM tpircs ilg enoizisopsid a odnettem ,ertlonI .enoipmac led enoisnemid allen eznereffid ella ivitaler saib e ,itavresso non o itavresso inumoc issergni ,eromur-elanges otroppar len eznereffid ,opmac led enoisuffid / enoizudnoc id emulov id azneserp al ,enumoc otnemirefir nu id osu'lla itaicossa imelborp i onodulcni itseuQ .osoisna elatnemireps otaizneics ol onodnetta evitaterpretni Ãtlociffid el iuc ni inumoc ¹Ãip isac ied inucla erartsulli rep etipecnoc etats onos ottircsonam otseuq ni etatneserp inoizalumis eL .eirups eznerefni id edairim anu a eratrop ²Ãup opmet id eires alled itavresso acigoloisiforttele eires alled itad i rep Ãtivittennoc alled isilana id aunegni enoizacilppa'nu ehc erottel li otanoisserpmi onaibba inoizalumis etseuq ehc omairepS .inoizalumis icilpmes id eires anu ad atangapmocca atats ¨Ã imelborp itseuq id enoizircsed aL .ehcigoloisiforttele inoizartsiger ad atamits , Ãtivittennoc alled enoizaterpretni atterroc anu erednofnoc onossop ehc itnatropmi inoitseuq enucla otatneserp omaibba etnemavisseccuS .italoclac onognev emoc e Ãtivittennoc id ehcirtem etseuq ni onottelfir is itad id ehcitsirettarac ilauq yfitsymed rep otattegorp otats ¨Ã ²ÃiC enoisuffid enoisuffid id opmac / enoizudnoc id emulov li emoc ossucsid omaibba ,etnemavisseccuS .enoizaretni'lled gal orez etnenopmoc li etnematicilpse atracs ehc acirtem anu erazzilitu id olleuq ¨Ã elibissop oiccorppa ortla nU .elanges led inumoc itnenopmoc ied enoizomir allen ecaciffe eresse ²Ãup can be approached in three distinct ways: by source reconstruction or local re-referencing, via the use of experimental contrasts (which makes the sometimes invalid assumption that volume conduction effects are constant between conditions), or by using methods that are insensitive to volume conduction such as the imaginary part of coherency. Field spread also affects the estimates of directed functional connectivity. Currently, there is no guaranteed method to discard volume conduction effects in this case. One way to protect against false positive inferences is to investigate the instantaneous interaction to determine whether field spread effects are too large to warrant an analysis (Vinck et al., 2015). Another possibility in principle is to include volume conduction within the estimation framework of Granger causality, which would require further development of model-based approaches to connectivity estimation. The problem of a different signal to noise ratio across channels was discussed in the light of the potential misinterpretation of the dominant direction of interaction using directed connectivity estimates, in particular Granger causality. We illustrated a test based on time-reversed Granger causality (Haufe et al., 2012) to determine whether Granger causal asymmetries are due to strong vs. weak asymmetries in the data. In addition, we pointed out novel approaches that are based on state-space modeling and DCM, which explicitly consider the separate contribution of signal and noise to the estimated connectivity. The problem of common input was also discussed, which is particularly relevant when researchers want to make claims with respect to whether the interaction between two neuronal groups is direct, or mediated by a third source. In general it is impossible to distinguish direct from indirect interactions if not all nodes of the functionally connected network are sampled. The problem is not a ,atad ytivitcennoc lanoitcnuf fo noitamitse rof elbaliava osla era sexobloot rehto taht eton eW .)1102 ,.la te dlevnetsoO(xoblooT pirtdleiF eht gnisu detnemelpmi erew snoitalumis eseht .)sdohtem desaibed ro CPP(saib ezis elpmas morf reffus ton od hcihw sdohtem ytivitcennoc gnisu yb ro ,tnuocca otni saib ezis elpmas eht ekat ylticilpxe taht sdohtem lacitsitats gnisu yb ,stcejbus ro snoitidnoc neewteb sezis elpmas gnizilauqe yb htiw tlaed eb nac melborp sihT .setamitse ytivitcennoc ni saib ezis elpmas fo tceffe eht dessucsid ew ,yllaniF .)5102 ,. la ylohgadohk ;5102 ,gnahc(stemtaert lacigrusruen gniiogruestnu stneitap namuh sa)5102 ,.La te siwel ;4102 ,.La zrawhcs ; . i dehsilpmocca eb won nac gnilpmas niarb lluf ot esolc dna noituloser llec elgnis ,elpmaxe roF .sdohtem ecneicsoruen fo egarevoc eht gnisaercni ni edam neeb sah ssergorp hcum sraey tsap eht revo ,teY .pu tes latnemirepxe eht ni snoitatimil ot eud elbisaef eb syawla ton yam noitulos siht ecitcarp nI .ecnerehoc laitrap ro ytilasuac regnarG lanoitidnoc dna noitisopmoced etairavitlum a gnitaluclac yb dna ,tupni nommoc edivorp yllaitnetop taht sedon eht morf gnidrocer yllautca yb htiw tlaed yllaciteroeht eb nac tupni nommoc fo melborp ehT .)2102 ,.la te nnamlaaS(evird cimalaht eht no gninoitidnoc retfa detanimile yleritne tsomla saw TEO dna 4V neewteb ecnerehoc lacitroc-ocitroc dnab-ahpla taht dewohs seugaelloc dna nnamlaaS)OET dna 4V(saera lacitroc owt dna sumalaht eht morf sgnidrocer PFL gnisU .)1102 ,yrelliuG dna namrehS(sumalaht eht yb detaidem era snoitcaretni lacitroc-ocitroc emas taht Ecnedive Gnisarcni Si Ereht ,Ecnatsni rof .eno .eno al itnemua enoisnecer atseuq ni ettircsed ilanoizaterpretni inoitseuq elled aticilpse enoissucsid al ehc omairepS .)inoizidnoc el osrevartta eromur-elanges otroppar len eznereffid id azneserp ni enoizaretni'llen aznereffid anu erirefni o ottafitra etnemavitteffe ¨Ã odnauq aznereoc avitacifingis anu odnerefni ,oipmese da(itatlusir ied avissecce enoizaterpretni'nu a eratrop arocna ²Ãup otairporppani odom ni atazzilitu acitsitats arudecorp anu ,aivattuT .)b5102 ,.la te sotsaB ni idoteM enoizes al eredev(avorp id aiccor al e partstoob otnemanoipmac li odnazzilitu o/e)7002 ,.la te siraM(icirtemarap non icitsitats tset id krowemarf nu id onretni'lla otiugese ereneg ni ¨Ã ²ÃiC .)ovitacifingis otnemaibmac nussen id allun isetopi'lla ottepsir(inoizidnoc el art otnemaippocca'llen ivitacifingis itnemaibmac erilibats rep ©Ãhcnon ,)ovitacifingis otnemaippocca nussen id allun isetopi'lla ottepsir(Ãtivittennoc alled otacifingis erilibats rep ais itazzilitu onognev icitsitats tset I .itatlusir ied enoizaterpretni atterroc allen e ezneicsoruen elled itad ia Ãtivittennoc alled amits id ehcincet elled enoizacilppa'llen elaicurc ossap nu ¨Ã elaiznerefni acitsitats arudecorp anu id otairporppa osu'l ehc ¨Ã otanoiznem etnemeverb eresse eved ehc etnavelir ottepsa nU .imelborp itseuq id inucla itneserp onos odnauq ehcna ,icigoloisiforttele itad ien Ãtivittennoc alled avitacifingis isilana'nu onodulcerp non otaton omaibba ehc Ãtlociffid el ehc odnaenilottos omainiF .alacs agral us enoizoda'nu a onocsiubirtnoc e itnemurts ilg eraroilgim a onatuia ehc ,irotaroballoc e itnetu id Ãtinumoc atsav anu id onaicifeneb e ecruos nepo onos itnemurts itseuq id itloM .)8002 ,likoB e artiM(xunorhC izzertta ilged attessac al e aiportne'lled oloclac led otnemirefsarT rep)1102 ,.la te rendniL(xoblooT lootnerT ehT ,)3102 ,.la te osiN(xoblooT semreH ehT ,)4102 ,hteS e ttenraB(xoblooT CGVM ehT ,)1102 ,.la te emroleD(xoblooT TFIS ehT e balgeE eralocitrap nI In the largest neuroscientific community. At the same time, new methods have been constantly developed to deal with these problems. Overall, you can be optimistic for the future future Small hypotheses and experiments, and improved analysis tools continue to provide new information on the dynamic connectivity of the brain. Declaration of interest, the authors declare that research was conducted in the absence of commercial or financial relationships that could be interpreted as a potential conflict of interest. The Craig Geoffrey Richter Review declares that, despite having collaborated on research projects with the authors Andre M. Bastos and Jan-Mathijs Schofflen, the review has been conducted objectively and there is no conflict of interest. Recognition This research was partly financed by a NWO VIDI-Grant (864.14.011) to JS. Amb was partly financed by the National Science Foundation Graduate Student Fellowship Program and a Fulbright scholarship from the United States Department of State. The authors would like to thank Alik Widge for providing comments to a previous version of this manuscript, and the three reviewers whose comments have improved the newspaper. Complementary material The complementary material for this article can be found online at the address: 00175 references Ahrens, M. B., Bar, M. B., Robson, D. N., Li, J. M. e Keller, P. J. (2013). Full functional imaging with cell resolution with light sheet microscopy. Nat. Methods 10, 413-420. DOI: 10.1038/NMETH.2434 PubMed Abstract | Cross ref full text | Google Scholar Aru, J., Aru, J., Priesemann, V., Wibral, M., Lana, L., Pipa, G., et al. (2015). Unlocking coupling of crossed frequency in neuroscience. Curr. Opin. Neurobiol. 31, 51â € “61. DOI: 10.1016/J.Conb.2014.08,002 Pubmed Abstract | Cross ref full text | Google Scholar Barnett, L. and Seth, A. K. (2011). Behavior of the grenger reason under filtering: theoretical invariance and practical application. J. Neurosci. Methods 201, 404-419. ralohcS ralohcS elgooG | txeT lluF feR ssorC | tcartsbA deMbuP 010.80.1102.htemuenj.j/6101.01 L., and Seth, A. K. (2014). The MVGC multivariate Granger causality toolbox: a new approach to Granger-causal inference. J. Neurosci. Methods 223, 50¢ÃÂÂ68. doi: 10.1016/j.jneumeth.2013.10.018 PubMed Abstract | CrossRef Full Text | Google Scholar Bastos, A. M., Litvak, V., Moran, R., Bosman, C. A., Fries, P., and Friston, K. J. (2015a). A DCM study of spectral asymmetries in feedforward and feedback connections between visual areas V1 and V4 in the monkey. Neuroimage 108, 460¢ÃÂÂ475. doi: 10.1016/j.neuroimage.2014.12.081 PubMed Abstract | CrossRef Full Text | Google Scholar Bastos, A. M., Vezoli, J., Bosman, C. A., Schoffelen, J.-M., Oostenveld, R., Dowdall, J. R., et al. (2015b). Visual areas exert feedforward and feedback influences through distinct frequency channels. Neuron 85, 390¢ÃÂÂ401. doi: 10.1016/j.neuron.2014.12.018 PubMed Abstract | CrossRef Full Text | Google Scholar BerÃ©Ânyi, A., SomogyvÃ¡Ári, Z., Nagy, A. J., Roux, L., Long, J. D., Fujisawa, S., et al. (2014). Large-scale, high-density (up to 512 channels) recording of local circuits in behaving animals. J. Neurophysiol. 111, 1132¢ÃÂÂ1149. doi: 10.1152/jn.00785.2013 PubMed Abstract | CrossRef Full Text | Google Scholar Bokil, H., Purpura, K., Schoffelen, J.-M., Thomson, D., and Mitra, P. (2007). Comparing spectra and coherences for groups of unequal size. J. Neurosci. Methods 159, 337¢ÃÂÂ345. doi: 10.1016/j.jneumeth.2006.07.011 PubMed Abstract | CrossRef Full Text | Google Scholar Bollimunta, A., Chen, Y., Schroeder, C. E., and Ding, M. (2009). ¢ÃÂÂCharacterizing Oscillatory Cortical Networks with Granger Causality,¢ÃÂÂ in Coherent Behavior in Neuronal Networks, eds K. Josic, J. Rubin, M. Matias, and R. Romo (New York, NY: Springer New York), 169¢ÃÂÂ189. Available online at: [Accessed November 10, 2015]. Bosman, C. A., Schoffelen, J.-M., Brunet, N., Oostenveld, R., Bastos, A. 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Full Text | Google Scholar Granger, C. W. (1969). Investigate causal relationships from econometric models and cross-spectral methods. Econ. J. Econ. Soc. 37, 424-438. doi: 10.2307/1912791 Cross Ref Full Text | Google Scholar Gregoriou, G. G., Gotts, S. J., Zhou, H. and Desimone, R. (2009). High frequency, long-range coupling between prefrontal and visual cortex during attention. Science 324, 1207-1210. doi: 10.1126/scienza.1171402 PubMed Abstract | Cross Ref Full Text | Google Scholar Guo, S., Seth, A. K., Kendrick, K. M., Zhou, C. and Feng, J. (2008). Partial exogen inputs Granger-eliminant and latent variables. J. Neurosci. Methods 172, 79–93. doi: 10.1016/jneumeth.2008.04.011 PubMed Abstract | Cross Ref Full Text | Google Scholar Haufe, S., Nikulin, V. V. and Nolte, G. (2012). “Inviting the influence of weak data asymmetrics on granular-causal analysis”, in latent analysis and signal separation: Lesson notes in Computer Science, es F. Theis, A. Cichocki, A.and M. Zibulevsky (Berlin/Heidelberg: Springer), 25â € "33. Hipp, J. F., Hawellek, D. J., Corbetta, M., Siegel, M. and Engel, A. K. (2012). Large scale cortical correlation structure of the spontaneous oscillatory activity. Nat. Neurosci. 15, 884-890. DOI: 10.1038/nn.3101 Pubmed Abstract | Crossref full text | Google Scholar Hohlefeld, F. U., Huchzemeyer, C., Huebl, J., Schneider, G.-H., Nolte, G., Bru world, C., et al. (2013). Functional and effective connectivity in potential local subthalamic field recordings of patients with Parkinson's disease. Neuroscience 250, 320â € “332. DOI: 10.1016/J.Nuroscience.2013.07.028 Pubmed Abstract | Cross ref full text | Google Scholar Khodagholy, D., Gelinas, J. N., Thesen, T., Doyle, W., Devinsky, O., Malliaras, G. G., et al. (2015). Neurogrid: record action potential from the surface of the brain. Nat. Neurosci. 18, 310â € "315. DOI: 10.1038/NN.3905 PUBMED Abstract | Crossref full text | Google Scholar Lachaux, J. P., Rodriguez, E., Martinerie, J. and Varela, F. J. (1999). Measure phase synchrony in brain signals. Hum. Brain Mapp. 8, 194â € “208. Pubmed Abstract | Google Scholar Lindner, M., Vicente, R., Priesemann, V. and Wibral, M. (2011). Trentool: a Matlab Open Source Toolbox to analyze the flow of information in the data of the temporal series with the entropy of the transfer. 12: 119. Doi: 10.1186/1471-2202-12-119 Pubmed Abstract | Cross ref full text | Google Scholar Lobier, M., Siebenhãemner, F., Palva, S. and Palva, J. M. (2014). Phase transfer entropy: a new measure based on the phase for direct connectivity in networks coupled by oscillating interactions. Neuroimage 85 (PT 2), 853-872. DOI: 10.1016/J.neuroimage.2013.08.056 Pubmed Abstract | Cross ref full text | Google Scholar Maris, E., Schofflen, J.-M. and Fries, P. (2007). Non -comparative statistical tests of the differences in consistency. J. Neurosci. Methods 163, 161â € “175. Doi: PubMed Abstract | CrossRef Full Full Full.NILC .rgolahpecneortcele .Selacs elpitlum because noiterpretni dna ,gnigami lacitroc ,snaicalpal ,noitcudnoc emulOv ,edortcele ecnerefer ,i ,nie ,nie ,nicnerehoc get .)7 .S .R ,ehgnisejiw ,.F ,Prodtsew ,.r ,Nasinirs ,.l .P ,Zenun Ralohcs Elgoog | txet lluf ferssorc | Tcartsba Dembup 1-34000)8 â€â964 ,011 ,011 .Loisyhporuen .Def .DNI .ffo .FOISYHPoruen .Nilc .Seruseem Elpitlum Fo Snosirapmoc latnemirepxe :ii ycnerehoc .) ,Nasavinirs ,.r .M ,Retelpac ,.z ,ihs ,.b ,r ,silateblis , .Ver .Syhp .Smetsys Lacisyhp Xelpmoc Xelpmocti Fo Nocerid Wolf Eht Gnitamitse yltsubor .)802(.La ,.t ,Ramsirb ,.n ,remâ. 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A., Lebedev, M. A., Hanson, T. L., Dimitrov, D. F., Lehew, G., Meloy, J., et al. (2014). Chronic and wireless records of large-scale brain activity in free-moving rhesus monkeys. Nat. Methods 11, 670 "676. doi: 10.1038/nmeth.2936 PUBLICATO ASTRACTH | CrossRef Complete text | Google Scholar Seth, A. K., Barrett, A. B. and Barnett, L. (2015). Analysis of Granger's causality in neuroscience and neuroimaging. J. Neurosci. I'm out. J. Soc. Neurosci. 35, 3293 "3297. doi: 10.1523/jneurosci.4399-14.2015 Abstract Publed | CrossRef Complete text | Google Scholar Sommerlade, L., Thiel, M., Mader, M., Mader, W., Timmer, J., Platt, B., et al. (2015). Evaluate the force of direct influences between neural signals: an approach to noisy data. J. Neurosci. Methods 239, 47 "64. doi: 10.1016/j.jneumeth.2014.09.007 Abstract PublEMD | CrossRef Complete text | Google Scholar Sporns, O. (2011). Brain networks. Cambridge, MA: MIT Press. Google Scholar Srinivasan, R., Winter, W. R., Ding, J. and Nunez, P. L. (2007). EEG and MEG consistency: functional connectivity measures at distinct spatial scales of neocortical dynamics. J. Neurosci. Methods 166, 41 - 52. doi: 10.1016/jneumeth.2007.06.026 PUBLED ASTRATH | CrossRef Complete text | Google Scholar Stam, C. J., Nolte, G. and Daffertshofer, A. (2007). Phase delay index: evaluation of functional connectivity from multi-channel EEG and MEG with reduced distortion from common sources. Ronzio. Cerebrale mapp. 28, 1178 "1193. doi: 10.1002/hbm.20346 PublAbmast Abstract | CrossRef Complete text | Google Scholar Varela, F., Lachaux, J. P., Rodriguez, E. e Martinerie, J. (2001). The BrainWeb: phase synchronization and large-scale integration. Nat. Rev. Neurosci. 2, 229 - 239. doi: 10.1038/35067550 PUBLED ABSTRACT | CrossRef Complete text | Google Scholar Vicente, .)8002(.)8002(.G ,apiP e .I ,rehcsiF ,.R .C ,ossariM ,.L .L ,olloG Ytivitcennocencnuf rof krowemarf cametsys A 4102(.c ,dranreb dna ,.k .v ,asrij ,.j .k ,notsirf ,.p ,inihciliuq ,.g .g .g .g . .H ,gnaW ralohcS elgooG | txeT lluF feRssorC | tcartsbA deMbuP 370.10.0102.egamioruen.j/6101.01 :iod .221ÂÂÃ¢211 ,15 egamioruеN .noitazinorhcnys lanoruen cimhtyhr fo erusaem eerf-saib a :ycnetsisnoc esahp esiwriap ehT .)0102(.A .C ,trannep DNA ,.P ,SEIRF ,.T ,Froslemow ,.M ,Nedregniw Nav ,.M ,KCNIV RALOHCS ELGOOG | txet lluf ferssorc /6101.01 :iod .5651â“â€â8451 ,55 Egamoruen .Saib esis-elpmas dna esion ,noitcudnoc-emulolov fo ecneserp eht of Atad Lacigoloisyhporte rof m1cyorisyorisyorisyorisyorisyorisyorisyh ,ztranep dna ,.f ,ailgattab ,.m ,Nedregniw Nav ,.r ,dlevnetsoo ,.M ,kcniv rlohcs elgoog | txet lluf ferssorc |tcartsba 710.2 ¢103 ,801 egaoruen ?esion evitidda fo ecnesorp eht by Noitcerid Wolf Lasuac-Regnarg Eht tc -et ot woh .)5 | Txet Lluf Ferssorc | Tcartsba Dembup 4-4730-110-72801S/7001.01 :ido .57â“â€â35 ,33 .Core .tupmoc .J .laitnettettettop lacol-eshal sekip seniluoc- shate sekip seniluoc-esaha seniluos Ztranep DNA ,.T ,froslemow ,.p .f ,ailgattab ,.M ,kcniv ralohcs elgoog | txet lluf ferssorc | tcartsbatsbatsbat 2102.1111 Cos .ffo .icoruen .j .krowten gniidaer eht nihtaw noitargetni dna noiterges laever dnab â³âž hgih eht by snoitalerroc etutilpma ,d ,d , C ,â©é have ,k ,ibrej ,.s ,htomreyerf ,.r ,Ladiv Ralohcs Elgoog | txet lluf ferssorc | Tcartsba Dembup 1 In front. Neurosci. 8: 405. doi: 10.3389/fnins.2014.00405 Abstract PUBLED | CrossRef Full text | Google Scholar Wen, X., Rangarajan, G. and Ding, M. (2013). Causeality of multivariate Granger: an estimate based on the factorization of the spectral density matrix. Philos. Transit. A math. Phys. Eng. Sci. 371, 20110610. doi: 10.1098/rSTA.2011.0610 BUTSUM ABSTRACT | CrossRef Complete text | Google Scholar Wiener, N. (1956). â€ œThe prediction theory, â€ in modern mathematics for engineers, Ed E. Beckenbach (New York, NY: McGraw-Hill), 165 "190. Winter, W. R., Nunez, P. L., Ding, J. and Srinivasan, R. (2007). Comparison of the effect of volume conduction on EEG consistency with the effect of field diffusion on statistic MEG consistency. Med. 26, 3946â € "3957. doi: 10.1002/SIM.2978 PUBLED ABSTRACT | CrossRef Complete text | Google Scholar Witham, C. L., Riddle, C. N., Baker, M. R. and Baker, S. N. (2011). Contributions of the descending ways and ascending to corticomuscular coherence in man. J. Physiol. 589, 3789 "3800. doi: 10.1113/jphysiol.2011.211045 Abstract PublAbMed | CrossRef Full text | Google Scholar Womelsdorf, T., Schoffelen, J.-M., Oostenveld, R., Singer, W., Desimone, R., Engel, A. K., et. Modulation of neuronal interactions through neuronal synchronization. Science 316, 1609 "1612.

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