A discussion on LORETA software use and licensing.

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by Leslie Sherlin PhD.

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Leslie Sherlin, PhD

There recently has been some discussion regarding the use of low resolution brain electromagnetic tomography or LORETA, sLORETA and eLORETA. I felt compelled to make a few comments regarding this since there may be some confusion of how LORETA works and the usage of LORETA as an inverse solution specifically the licensing agreements of the KEY Institute for Brain-Mind Research at the University Hospital of Psychiatry, Zurich.

My intention is to very briefly explain the license agreement so that the end user can be informed. I’ll do so in an informal way by telling the story of the implementation of these methods from my perspective. For a more formal description of the use of LORETA families and some examples you can see a recently written chapter 4 by myself (Sherlin, 2009) in the latest edition of the book Introduction to Quantitative EEG and Neurofeedback edited Budzynski, Budzynski, Evans & Arbarbanel.

In 2000 I had the great privilege to visit with Roberto Pascual-Marqui PhD, the developer of the LORETA family, with my colleague and fellow student Marco Congedo. At this time the LORETA-Key software (Pascual-Marqui, 1994, 1999), had not been widely distributed and utilized in the United States. Marco had significant interest in using LORETA for visualizing brain activity and for exploring newer methods for neurofeedback and had many questions for Roberto. So upon the invitation of Roberto, Marco found funding to travel to Zurich and learn the details from the creator and I happen to be standing in the right spot at the right time. Roberto Pascual-Marqui trained us extensively on how to use his software, named LORETA-Key, which had been already released as free academic software. The LORETA-Key software is a collection of independent modules that the user must run in sequence in order to get from raw EEG to LORETA images.

Upon our return after learning the mechanics of performing an analysis I wanted us to develop a mini-program that would perform the extensive steps necessary in the LORETA-Key software all at once taking care of all possible options in a clear and understandable manner. The analysis was very labor intensive with many batch steps running many different modules. The room for error was great and the user had to be tedious and detailed and still the process would take significant time. With some already existing programming skills Marco wrote a very clean program that would run the LORETA-Key modules after the user had input the necessary data details. This program we called the Workstation (Congedo, 2000). Upon the recommendation of our primary professor and supervisor Joel Lubar, PhD, we formed a company to distribute this program to the larger clinical field of neurofeedback and QEEG providers. The company was named Nova Tech EEG representing our mission and goal of providing “New Technology for EEG”. This very straightforward program, Workstation (released in 2001), was a hit because it allowed clinically oriented users the ability to perform LORETA analysis with a greater ease and utilize this incredible tool in performing and understanding the current source density localization in their subjects and clients, preventing possible errors operating the research-oriented LORETA-Key program. Later we created several other software tools and interestingly revolutionized the development of applications in the neurofeedback industry. Prior to the Workstation (Congedo, 2000) and later the EEG Editor (Congedo, 2001) and finally EureKa! (Congedo, 2005), many of the analysis software were still compiled in the DOS operating system despite many newer developer environments integrating Windows 32 gadgets being released. This made our applications more convenient, professional and provided higher visual acuity in displaying the EEG and the spectral output. It should be noted that since 2005, Nova Tech EEG has also released all of the in house software as freeware, stating unequivocally that our goal was to make inverse solution tools as accessible as possible in the neurofeedback community.

For some time these software along with the original LORETA-Key package were the only ones available for computing LORETA output “all-
at-once”. Meanwhile, myself and Marco developed the first adult normative database for LORETA current density in the frequency domain using non-parametric statistics (Congedo and Lucar, 2003). Other third party commercial entities developed programs that would perform LORETA analysis seamlessly calling up the LORETA-Key modules, although there were considerable differences in the applications and the output options. It is worth noting that the directions for seamless integration of the LORETA-Key modules into third-party software have always been clearly explained in the help files of the LORETA-Key software. At some point through the development of third party software the Key Institute and Pascual-Marqui felt it necessary to restrict the licensing of the software due to apparent misuse. In the June 2007 release of the LORETA-Key software there was a new screen following the previous End User License Agreement (EULA), screens which required the user to agree not to misuse the LORETA software. This screen reads:

This software computes LORETA from scalp electric potential differences (time domain EEG/ERP) or from EEG cross-spectra (frequency domain). One particular very incorrect usage is to cheat LORETA with the input.

Examples of misuse:
1. Inputting scalp electric potential spectral powers will not output LORETA (current density) spectral powers.
2. Inputting scalp electric potential square roots of spectral powers will not output LORETA (current density) square roots of spectral powers.
3. Inputting scalp z-transformed-maps will not output LORETA (current density) z-transformed-values. The three previous invalid inputs to LORETA violate the mathematics and the physics underlying all computations.

Furthermore, they violate any correct usage of statistical analysis. Some more technical details can be found in:

It wasn’t long after a wider spread distribution of the LORETA software and use in the community of QEEG and neurofeedback that the natural question arose of if the current source density of interior cortical areas could be operant conditioned in the same manner as the scalp neurofeedback was being conducted currently. This was actually our first concern as announced during a workshop at ISNR by Joel Lucar, Marco Congedo, David Joffe and Leslie Sherlin (Lucar, Congedo, Joffe, & Sherlin, 2001). The workshop was the starting point for a 3 year project which would be Marco’s dissertation where he demonstrated and verified that in fact the deeper structures could be trained using “LORETA feedback” (Congedo, 2003). This work was published the following year in IEE Trans. in Rehabilitation Engineering and Neuronal systems (Congedo, Lucar and Joffe, 2004) and is still today a pioneering study in multi-channel neurofeedback. Dr. Lucar’s lab continued to pursue these techniques with additional validation studies (Cannon et al, 2007, 2009). Currently the method is used in several other universities and is becoming available in several neurofeedback systems.

Newer methods were developed by Pascual-Maqui in 2002 and it was named standardized LORETA or sLORETA (Pascual Marqui, 2002). This new implementation had to its advantage the ability to localize test point sources with zero localization error in the absence of noise, which had not previously been accomplished. Since my goal here is not to distinguish the difference in the methods I will skip over these technical issues. It will suffice to say that despite the name, from a mathematical point of view sLORETA is very different from the old LORETA method, and much more accurate. The sLORETA-KEY software was released by Dr. Pascual-Marqui once again as free academic software, but now there were new licensing agreements. As compare to the previous package there was an additional clause that, “This free academic software package is intended for use in research… If you install and use this software, you have then accepted the “license agreement”, and from then on, by law, clinical use and commercial use are strictly forbidden (Pascual Marqui, n.d. b)” This means that any use of the sLORETA package as published and distributed by the KEY Institute cannot be utilized outside the scope of research only. The use of this package cannot be used for creating clinical reports. Not less important, the sLORETA-Key software modules computing sLORETA images cannot be called upon anymore by third party software. The days of utilizing third party software for automatic processing of LORETA data were over to protect the software against misuse and profiteering.

It wasn’t long after the original publications of Pascual Marqui (Pascual Marqui, 2002) on the new sLORETA method that others began to independently replicate the sLORETA work (Congedo, 2006; Congedo et al. 2006; Wagner et al, 2006). This, or any other, independent replication does not fall under the same licensing restrictions because the independently replicated sLORETA algorithms are generated independently, that is, they do not use the implementation in the sLORETA software package distributed as freeware from the KEY Institute. One implementation of this sLORETA transformation was in the EureKa! Software. It made use of the same head model of the old LORETA-Key software, making the sLORETA computation as straightforward as LORETA computations! Due to the fact that the head model implemented in the new sLORETA-Key package is not open, the older LORETA-Key viewer had to be utilized rather than the newer sLORETA viewer but the computations using sLORETA in this way are completely legal and ethical. The end user must comply with the EULA of the software and use in the community of QEEG and neurofeedback that the natural question arose of if the current source density of interior cortical areas could be operant conditioned in the same manner as the scalp neurofeedback was being conducted currently. This was actually our first concern as announced during a workshop at ISNR by Joel Lucar, Marco Congedo, David Joffe and Leslie Sherlin (Lucar, Congedo, Joffe, & Sherlin, 2001). The workshop was the starting point for a 3 year project which would be Marco’s dissertation where he demonstrated and verified that in fact the deeper structures could be trained using “LORETA feedback” (Congedo, 2003). This work was published the following year in IEE Trans. in Rehabilitation Engineering and Neuronal systems (Congedo, Lucar and Joffe, 2004) and is still today a pioneering study in multi-channel neurofeedback. Dr. Lucar’s lab continued to pursue these techniques with additional validation studies (Cannon et al, 2007, 2009). Currently the method is used in several other universities and is becoming available in several neurofeedback systems.

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References


Congedo M. (2006), Subspace Projection Filters for Real-Time Brain Electromagnetic Imaging, IEEE Transactions on Biomedical Engineering, 53(8), 1624-34.


4 Comments

1. **Jay Gunkelman** says:
   *May 2, 2009 at 1:46 pm*

   Leslie,

   When it comes to the use of LORETA, the easiest thing to do is listen to the opinion of the author of the technique regarding how and when it is appropriate to use the technique.

   When Roberto Pascal-Marqui tells us that an execution of his software violates the underlying mathematical assumptions and invalidates the result, like the use of Z-score LORETA does, then to persist with the use of the invalid technique in the face of the author’s dismissal of the approach seems to be motivated by something other than science.

   I appreciate the approach that doesn’t provide all the pre-set band sources, and which can give statistically insignificant sources as well as valid sources. I prefer to identify a significant finding and then find that source alone, which avoids the false positive source identifications.

   I understand that the execution you and marco provided gave a table which shows the multiple statistical comparison evaluation of significance, though often people close out that window and go straight to the “sources”, regardless their significance (or lack thereof). This is why I like to find a source of a specific finding which is identified, and not a big “batch” of sources…

   Thanks for the well done clear summary of these sometimes “hard-to-comprehend” issues where people’s vested interests so often confound rather than clarify.

2. **hagedorn** says:
   *May 7, 2009 at 10:03 am*

   Leslie,

   I’ve been to a few other military bases over the last couple of months and there is an increasing interest in my talks about neurotherapy applications for active duty, dependents and vets. I’m finding out that my increasingly well funded and eager colleagues are somewhat naïve about the technology, equipment quality, research support, and their ethical applications. It is for this reason that your clarification on the correct use of LORETA comes at a good time. I think we have a responsibility to police and educate our peers and I want to thank you for your contribution to this end.

   Regards,
   Dave

3. **J. Schaller** says:
   *June 17, 2009 at 12:02 pm*

   Hello

   I just found this site and the interesting article about loretta.

   I tried to find out how I can post a question on my own but I did not find the answer. So I reply to this posting.

   Can anybody tell me how I can ask questions to this forum? Do I have to install WordPress? Is it possible to install it without a website?

   Thank you for your help.

   Jörg
4. **Brian Milstead** says:  
*June 24, 2009 at 1:02 am*

Ask a question and get an answer related to your post. We have a couple of authors here to answer questions.

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