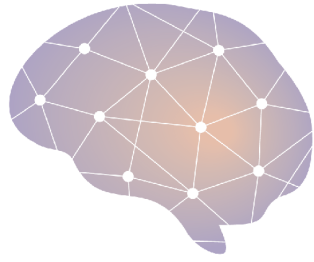Neurologic Solutions Inc.

User Manual - EZTrack

March 2020
Version 1.0

Revision History

Version	Date	Author(s)	Revisions
1.0	03/04/2020	Adam Li, Patrick Myers	Initial Release

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1. SUPPORTS, REPAIRS AND DOCUMENTATION

EZTrack is a **Neurologic Solutions Incorporated (NSI)** product. Electronic copies of EZTrack's user manuals and instructions are available for download at Technical Support tab at www.neurologicsolutions.co.

If you have a question, please:
- For urgent issues during acquisition, contact NSI immediately.
- For nonurgent issues, do the following before contacting NSI:
  - Isolate the problem. Try to repeat and define the problem, specifically.
  - Document the problem. Carefully record the sequential details of the problem.
  - Report the defined problem. Contact NSI via email.

NSI contact information:

- EZTrack Technical Support web page: www.neurologicsolutions.co
- Email Technical Support: help@neurologicsolutions.co
- Email Sales: info@neurologicsolutions.co
- Address: Neurologic Solutions Inc. 301 W 29th St, Baltimore, MD 21211-2960

Unique Device Identifier (UDI) (Placeholder)

(01)00827002005112(17)000004(10)1234(21)8234

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2.   SAFETY AND USE CONDITIONS

Intended Use - Rx Use Only

EZTrack is intended for use by a trained/qualified EEG technologist or physician on both adult and pediatric subjects at least 3 years of age for the visualization of human brain function from analysis of electroencephalographic (EEG) signals produced by electrically active tissue of the brain. The analyzed data are displayed and may then be interpreted by trained physicians to help localize these active areas.

The localization information provided by EZTrack may be used, in conjunction with other diagnostic data, in neurosurgical planning.

User Requirements

EZTrack should only be used by qualified individuals who:

- Have a basic understanding of Unix based terminals

- Have completed the EZTrack tutorial

- Have registered as a user for EZTrack and have secure login credentials

The EZTrack server will only be accessible through registered IP addresses.

Cautions and Warnings

Notes, cautions, and warnings are used to convey additional information regarding this product.

Note: Notes indicate information that may be helpful in understanding product operation.

⚠️ **CAUTION:** Cautions denote important information that, if unheeded, could result in hindered use of the product.

⚠️ **WARNING:** Warnings denote important information that, if unheeded, could result in minor, serious injury, or death.

EZTrack is not intended to be used as a diagnostic, index, or treatment device. As with all software, issues in running EZTrack software can arise if you misuse the device. Please refer to the "Instructions for Usage" document when running the software. EZTrack should be used by trained personnel for EEG fragility calculation, review, and analysis. EZTrack does not perform a diagnostic function. It provides additional data that may help make inferences about brain function.

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Recommendation

EZTrack allows you to compute fragility heatmaps of your signals recorded from EEG electrodes. The solutions provided are computed from EEG data. It is a good idea to review the EEG channels to remove any bad channels (for example, due to excessive noise, incorrect placement, or placement in white-matter tracts).

> ⚠️ **WARNING:** Do not operate your EZTrack system until you are fully trained and understand all warnings, cautions, and conditions for use provided in manuals for the components of your EZTrack system. Due to the possibility of noise in EEG acquisition systems, estimates of the fragility of EEG electrodes are approximate and should always be viewed in the context of the data by a trained reviewer. Fragility refers to methods that are employed for estimating the relative instability of a certain region relative to the rest of the network of recorded EEG. If you have any questions, contact EZTrack Technical Support.

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3.   SOFTWARE

No specialized training is required to run the tool, which consists of two steps: uploading EEG data and running the analysis to output a heatmap. However, preparation of the data and interpretation of the results does require training. The user will be expected to have some familiarity with Unix based terminals in order to run the required commands. EZTrack users must securely connect to the system via the username and password provided by EZTrack.

A clinically based PowerPoint tutorial to explain the principals behind the analysis output of EZTrack will be available to all users. Prior to using EZTrack, users should have successfully completed the clinically based tutorial offered by NSI, which simply offers a walk-through of how to use EZTrack and how to interpret heatmaps.

In the case of connectivity issues (see section 8), users must contact EZTrack network administrators.

In the case of a server issue (see section 8), which prevents EZTrack from being run, or results in an error, users must contact EZTrack administrators at admin@neurologicsolutions.co, so that the cause of the issue can be determined and fixed quickly.

System Requirements for EZTrack 1.0

EZTrack is designed to run on any system capable of running operating systems Linux, Mac OSX, or Windows, and any web browsers Google Chrome, Firefox, Safari, or Chromium can run EZTrack. All web-browsers should be capable of running HTTPS. EZTrack recommends the latest version of Google Chrome (tested on 79.0.3945.+).

The operating system should have at least a 1.5 GHz processor and at least 2GB or more of random-access memory. The system should have download speeds of at least 25 Mbit/second and upload speeds of 5 Mbit/second.

⚠️   Caution: Without a private working internet connection, you will not be able to run EZTrack, as it is a web-based service.

⚠️   Caution: Any modern web browser should work, but issues with firewalls and browser settings may impact EZTrack.

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Installation

EZTrack runs as a HIPPA compliant cloud-based service. In order to get EZTrack set up, one needs to have the following installed on their computer:

1. Secure File Transfer Protocol (SFTP): For Mac OSX, or Linux based systems, this is handled through the command-line. For users operating on a Windows computer, we recommend installing WinSCP (https://winscp.net/). For more information see Section 4.2.

2. (Recommended) Google Chrome Web Browser: Download the latest version of Google Chrome. See "Troubleshooting" for possible issues that might arise when running EZTrack in your browser.

3. Other browsers may work. Please see Troubleshooting section if you have any issues.

3.1.1.   Installation - Setting up Authentications for Data Transfer

EZTrack has a secure cloud-based server that will run fragility analysis on your EEG datasets. In order to run analysis, we require the data to be uploaded to EZTrack servers. This will occur through a process called Secure File Transfer Protocol (SFTP). To set this up, it is recommended that you speak to your IT staff and have them carry out the following steps:

> ⚠️   Caution: Passwords should follow strict standards, with a combination of lower and upper case letters, numbers, and special characters. In addition, passwords should not contain common strings, such as date-of-birth, or names.

1. **Obtain Authentication Keys:**
   From EZTrack, you can obtain a set of authentication keys that are stored on your computer. Download the set of credentials that EZTrack sends you.

   From the command line:

   ```
   [[ ! -d "${HOME}/.ssh" ]] && mkdir -p "${HOME}/.ssh"

   cat /path/to/public_key.pub >> "${HOME}/.ssh/authorized_keys"

   chmod go-rwx "${HOME}" "${HOME}/.ssh/authorized_keys"
   ```

2. **Setup SFTP Authentication:**

   Next, follow these commands depending if you are using a Windows, or Mac/Linux workstation.

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Mac OSX / Linux: If you are on a Mac OSX, or Linux based workstation, then SFTP comes pre-installed on your device. You will follow two series of commands to setup the SFTP for usage:

SFTP Authentication (Performed Once):
First, you will create a set of files to authenticate you easily for all future sessions:

Inside: ~/.ssh/config, modify it to look like this, with <the_hostname>, <user_name> and </path/to/private_key> properly modified:

```
Host <the_hostname>

User <user_name>

IdentityFile </path/to/private_key>
```

Where </path/to/private_key> is replaced by the path to the place you stored your private keys sent by EZTrack.

Windows:
If you are on a Windows workstation, then speak to your IT staff about installing WinSCP (https://winscp.net/), which is a publicly secure graphical user interface (GUI) option for performing STFP. Once you have WinSCP open, you must provide your EZTrack authentication in order to transfer the data up to EZTrack servers.

SFTP Authentication (Performed Once):
Before you can login, you must first tell WinSCP the path of your private key. In the 'Authentication' tab of the 'Advanced' section, browse for the key. This step may be performed by relevant IT staff. We recommend someone with knowledge of Unix and File Transfer Protocols.

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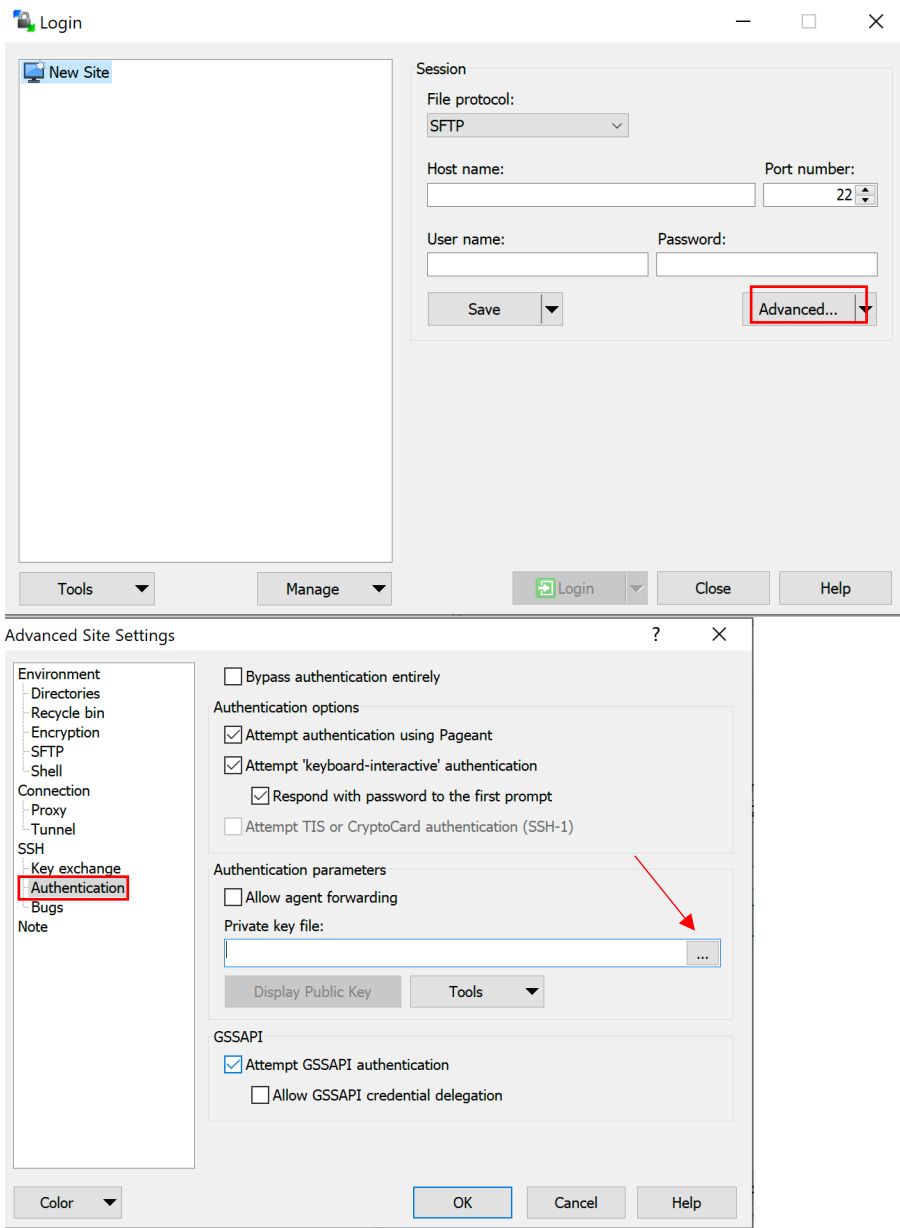
Once all of the parameters are input for the first time, you can save your EZTrack profile settings so they are the default to make future logins simpler.

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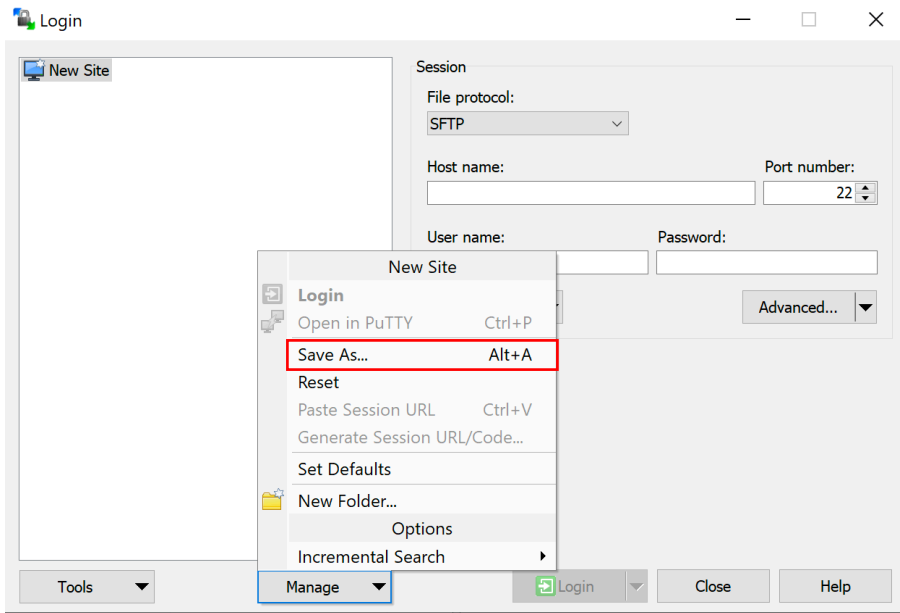
4. GETTING STARTED AND RUNNING EZTRACK

Data Workflow of EZTrack

EZTrack's data flow of your EEG data strives to limit the possibility of storing sensitive patient identifiable information (PII) at all. Here, we outline some of the main features of the data flow, so that you can understand the necessary steps involved in running EZTrack:

1. **Data upload:**
   Your EEG data (in **EDF** format), and metadata (in **Excel** format) are uploaded to EZTrack. In order to run the network-based analysis, EZTrack needs to know which channels should be included in analysis. In many EEG data files, it is common to have electrodes related to non-relevant signals, such as: white matter, cerebrospinal fluid, outside the brain, noisy/bad channels, electrocardiogram, electromyogram, electrooculargram, or reference channels.

   EZTrack runs automated preprocessing to prepare all the data for easy analysis.

2. **Running EZTrack analysis:**
   You can run EZTrack analysis on a set of EEG data that you have previously uploaded.

3. **Downloading resulting heatmaps:**
   Once EZTrack analysis is complete, you can view and download your heatmaps.

⚠️ Caution: EZTrack does not need any PII data in order to run analysis. EZTrack performs de-identification of data upon an upload of an EEG dataset. However, we recommend removing any PII data when using EZTrack to further reduce risks of any PII data being leaked.

Dataset Identifiers Keywords of EZTrack

EZTrack stores all datasets for each subject uploaded by a user in the user's Workspace. Each Workspace contains the necessary metadata and actual EEG data in order to run EZTrack analysis. In order to navigate different datasets, EZTrack applies a strict naming standard to all datasets, which are identifiable by keywords. We use a standard, developed by the Berkeley Institute of Data Science (BIDS) for neural data:

- **<subject_id>:** These are de-identified subject IDs for each dataset uploaded by the user. Examples include: "pt0001", or "pt1", or "pat001".

- **<acquisition_id>:** These are the type of data acquisitions, such as "eeg", "ecog", or "seeg" for scalp EEG, ECoG and SEEG respectively.

- **<session_id>:** This encompasses possibly multiple recording sessions per patient. This could happen if they are implanted multiple times. Generally each session would have a different set of implanted electrodes.

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- **<task_id>:** This is the specific task during the recording. This could be "seizure", or "interictal", or some other task that was carried out during the recording.
- **<run_id>:** This is the specific dataset ID, enumerated starting from "01".

For the remainder of this section, the following BIDS identifiers should be used:
- subject_id: pt01
- acquisition_id: seeg
- session_id: presurgery
- task_id: seizure
- run_id: 01

Note: For more information on BIDs standard and how it may encompass the complexities of different types of datasets you might want to analyze, please see: https://bids-specification.readthedocs.io/en/stable/.

Data Upload

EZTrack provides a network-based analysis. This means that any channels included in your data analysis will affect the output of all other channels. In many EEG acquisition systems, it is common to have channels that are unrelated to the actual neural recording, or channels recording from white-matter, cerebrospinal fluid, or the ventricles. In order to obtain a meaningful heatmap, one must annotate channels that are considered "bad".

⚠️ Warning: EZTrack analyzes all EEG channels not annotated as "bad channels". If you neglect to label bad channels within your electrode layout sheet, then EZTrack results will not accurately represent the data and the heatmap will be uninterpretable and inaccurate.

4.1.1. Annotating Bad Channels

EZTrack provides three mechanisms for providing this information:

1. **<u>Annotation of an electrode layout sheet (Recommended):</u>**

The easiest way to annotate bad channels is to upload an 'electrode layout sheet' via SFTP as described in section 4.2. This sheet is an excel sheet (.xlsx) that labels where the location of each electrode contact is located. The sheet is laid out as a table, with the electrode label as rows and the number of the contact as columns.

For SEEG depth electrodes, there are electrodes in white matter, cerebrospinal fluid, or ventricles that should be removed from analysis. For SEEG and ECoG (surface grid electrodes), there are

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electrodes outside the brain, or with faulty signals as deemed by the user that should all be removed from analysis. The keywords that you may include for each contact are listed here:

Note: exact wording is needed along with case sensitivity, since EZTrack matches keyword. The annotation of anatomical regions per electrode is commonly done in many of our user's centers. If you have questions, please contact NSI.

SEEG:

- **WM** = white matter
- **CSF** = cerebrospinal fluid
- **Ventricle** = ventricle
- **OUT** = outside the brain / recording from skull
- **BAD =** bad signals that the user would like removed from analysis

ECoG:

- **OUT** = outside the brain / recording from skull
- **BAD =** bad signals that the user would like removed from analysis

	A	B	C	D	E	F	G	H	I
1		1	2	3	4	5	6	7	8
2	F						WM	WM	WM
3	L						WM	ventricle	WM

Figure: A simplified example with two electrodes (F and L), each having eight channels is presented here (although commonly some electrodes can have up to 20 contacts on each electrode). The contacts 6-8 on electrode F and 6 and 8 on electrode L were in white matter and contact 7 on electrode L was in the ventricle. Other annotations are 'OUT' for contacts outside the brain and 'BAD' for contacts with bad signal. Note that exact wording is needed since EZTrack matches keywords. Note also that contact names (the combination of the electrode name and channel number, i.e. F2) much mast exactly what is in the EDF file, else EZTrack will not be able to locate the contact.

If other annotations are used by your center to denote bad contacts, please reach out to an EZTrack admin via the help email, help@neurologicsolutions.co. Anatomical trajectories, meaning the anatomical label of each electrode contact may be inserted in free-form in the corresponding table cell. However, anatomical trajectories of electrode contacts do not need to be explicitly labeled for the EZTrack system, but are recommended for ease of discussing results provided by EZTrack.

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2. **Annotation of bad channels within command line:**

If there are channels you missed in the electrode layout sheet, or if you want to rerun EZTrack with additional BAD channels removed, EZTrack command-line provides three functions to interact with the set of bad channels passed in:

- View-bad-chs

    - **>> ez view-bad-chs --subject_id=<sub_id> --acquisition_id=<acquisition_id> --session_id=<session_id>**

    - Displays the current set of bad channels EZTrack has for this subject. Fill in "<sub_id>" with the corresponding ID of the subject you want to view bad channels and "<acquisition_id>" with the type of acquisition the subject underwent. "<session_id>" is the identifier for the recording session that this implantation data belongs to.

    - EX: **ez view-bad-chs –subject_id=pt01 –acquisition_id=seeg – session_id=presurgery**

- Annotate-bad-chs

    - **>> ez annotate-bad-chs --subject_id=<sub_id> -- acquisition_id=<acquisition_id> --session_id=<session_id> -- add_bads=<bad_chs>**

    - Add bad channels for a specific subject. Fill in "<sub_id>" with the corresponding ID of the subject you want to view bad channels and "<acquisition_id>" with the type of acquisition the subject underwent. "<session_id>" is the identifier for the recording session that this data belongs to. For "<bad_chs>", one can either pass a single channel, or multiple channels separated by commas, semicolons, or spaces.

    - For example, these three commands are the same:

        > **ez annotate-bad-chs –subject_id=pt01 –acquisition_id=seeg – session_id=presurgery –add_bads = 'a1, a2, a5'**

        > **ez annotate-bad-chs –subject_id=pat001 –acquisition_id=seeg – session_id=presuregery –add_bads = 'a1; a2; a5'**

        > **ez annotate-bad-chs –subject_id=pt01 –acquisition_id=seeg – session_id=presurgery –add_bads = 'a1 a2 a5'**

    - For example, this command only adds one bad channel to pat001:

        > **ez annotate-bad-chs –subject_id=pat001 –acquisition_id=seeg – session_id=presurgery –add_bads = 'a1'**

- Remove-bad-chs

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- **>> ez remove-bad-chs --subject_id=<sub_id> --acquisition_id=<acquisition_id> --session_id=<session_id> --add_bads=<bad_chs>**

- Remove bad channels for a specific subject. Fill in "<sub_id>" with the corresponding ID of the subject you want to view bad channels and "<acquisition_id>" with the type of acquisition the subject underwent. "<session_id>" is the identifier for the recording session that this data belongs to. For "<bad_chs>", one can either pass a single channel, or multiple channels separated by commas, semicolons, or spaces.

- For example, these three commands are the same:

  > **>> ez remove-bad-chs –subject_id=pt01 –acquisition_id=seeg –session_id=presurgery –add_bads = 'a1, a2, a5'**

  > **>> ez remove-bad-chs –subject_id=pat001 –acquisition_id=seeg –session_id=presuregery –add_bads = 'a1; a2; a5'**

  > **>> ez remove-bad-chs –subject_id=pt01 –acquisition_id=seeg –session_id=presurgery –add_bads = 'a1 a2 a5'**

- For example, this command only adds one bad channel to pat001:

  > **>> ez remove-bad-chs –subject_id=pat001 –acquisition_id=seeg –session_id=presurgery –add_bads = 'a1'**

Once you have removed bad channels, you can run EZTrack analysis. See Section "Running Analysis" on running EZTrack analysis.

3. **Annotation of the clinical metadata sheet (optional):**

In addition to an electrode layout sheet, and EDF data, we allow a user to optionally upload clinical metadata in the form of a table. Users can specify bad channels to include in the "**bad_contacts**" column. See the format shown in Appendix Section for more information.

4.1.2.   Preparing EEG Data as European Data Format (EDF)

EZTrack system's input is currently limited to EEG data saved in the recommended European Data Format (EDF) or optionally Brain Vision (BV) format. For more information on those formats, please refer to: Section 7.1.

Most current EEG acquisition systems will allow their users to export data snapshots into EDF format from their application (including the popular Natus and Nihon Kohden). We recommend reviewing the user manual of the acquisition system used by your center if you are unsure how to perform this task.

> ⚠️   Caution: EZTrack analyzes EEG timeseries data of minimum length 20 seconds. If you select extremely long snapshots of data, such as more then 10 minutes, then EZTrack will take longer to run.

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> ⚠ Warning: EZTrack analyzes all EEG channels not annotated as "bad channels". If you neglect to label bad please do so according to Section 4.2 Annotating Bad Channels.

Naming of Data Files

EZTrack requires users to properly name their files with de-identified dataset IDs in order to properly store the data for analysis and viewing by the user.

Each upload consists of up to three datasets, all of which must contain the same information: the EEG data which can be in EDF or BV format as mentioned in Section 4.3, the electrode layout sheet as mentioned in Section 4.2, and the optional clinical metadata sheet which contains the information from Appendix B.

1. **The EEG Data File(s)**

Since the EEG file contains snapshot specific information, it will have most identifiers in the file name. The convention is as follows:

      <subject_id>_<session_id>_<acquisition_type>_<dataset_id>.<ext>

Where <subject_id> is the identifier that is to be used in the EZTrack system to identify the system, <session_id> is the identifier of the recording session, <dataset_id> is a unique identifier for the individual snapshot, and <ext> is(are) the file extension(s) needed for the given file type.

For example, the file name for an EDF file of the example patient would be:

      pt01_presurgery_seeg_01.edf

The session identifier should be unique per recording session. If it is not, the EZTrack system will not be able to properly map the recording to the corresponding electrode layout sheet and therefore may not be able to automatically drop the bad channels. The dataset identifier should be unique per snapshot upload. If it is not, the EZTrack system will not be able to properly differentiate between recording snapshots and may not attach the proper metadata for the run.

> ⚠ Warning: Users should not include PII in any of the datasets

2. **The Electrode Layout Sheet**

The electrode layout sheet contains the location of each electrode contact and is unique to each recording session. The convention is as follows:

      <subject_id>_<session_id>_layout.xlsx

Where the <subject_id> and <session_id> are the same as those in the EEG data file(s).

For example, the corresponding layout sheet for the above EDF file would be named:

        pt01_presurgery_layout.xlsx

3. **The Clinical Metadata Sheet**

The clinical metadata sheet contains information for many patients and therefore will not contain any patient identifiers in its name. Every clinical metadata sheet will have the name clinical_metadata.xlsx

Each row of the clinical metadata sheet will contain the metadata for a recording session. The column *Subject_ID* must contain the same value as <subject_id> in the other files and the column *Session_ID* must contain the same value as <session_id> in the other files. Without this exact match, the EZTrack system will not be able to attach the metadata for the recording session to each snapshot from that session.

> ⚠️ Caution: Failure to comply with this naming scheme for uploaded files will result in an unorganized data structure that may hinder the user's ability to find the necessary data files on which they intend to run the fragility analysis.

The EZTrack system will record the uploaded file name in the metadata of the corresponding snapshot for backwards mapping, but it is up to the user to securely keep track of the map between the patient's name and the subject identifier used in EZTrack.

4.1.3. Uploading EEG Data

EZTrack has a secure cloud-based server that will run fragility analysis on your EEG datasets. In order to run analysis, we require the data to be uploaded to EZTrack servers. This will occur through a process called Secure File Transfer Protocol (SFTP). If you are using a Windows workstation, refer to the Windows section, otherwise refer to the Mac/Linux section.

Windows: If you are on a Windows workstation, then open WinSCP. Once you have WinSCP open, you must provide your EZTrack authentication in order to transfer the data up to EZTrack servers.

> ⚠️ Caution: Any program that performs SFTP should be able to access and transfer files to EZTrack, but instructions are only provided for WinSCP

The WinSCP GUI will first request a login. Choose SFTP in the 'File Protocol' drop down menu.
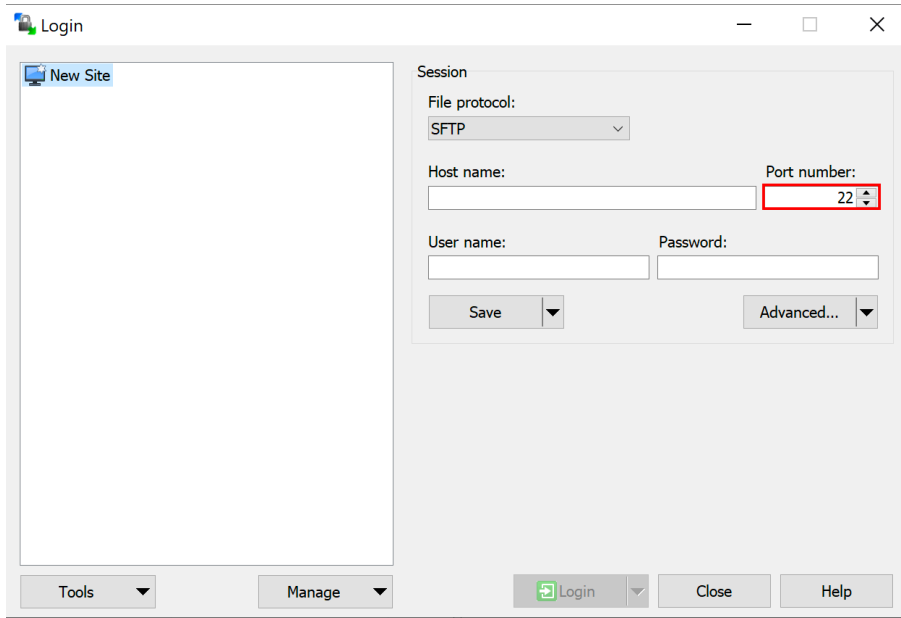
1. **Login (Every Use):**

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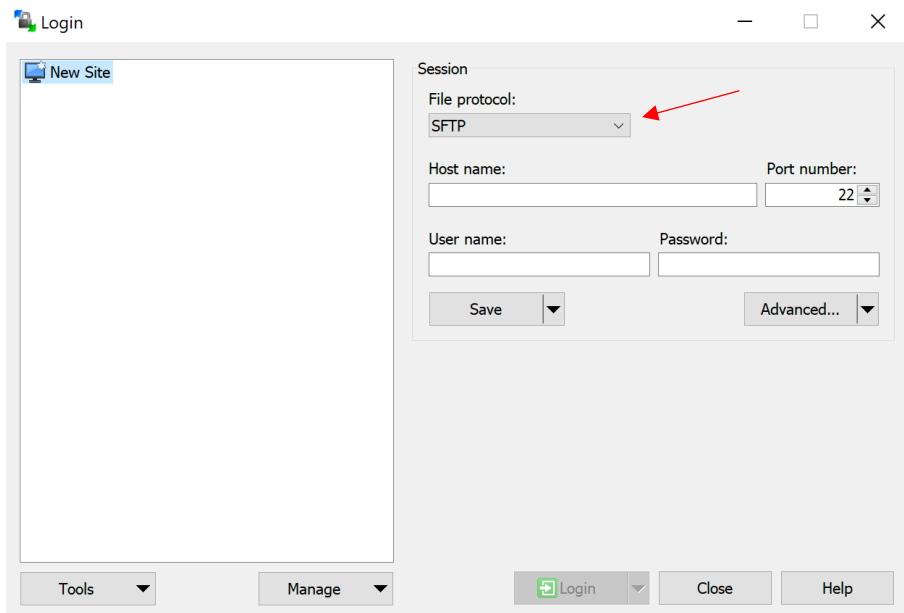
For 'Host Name', type the IP address of the S3 endpoint that was provided to you when your EZTrack account was created.
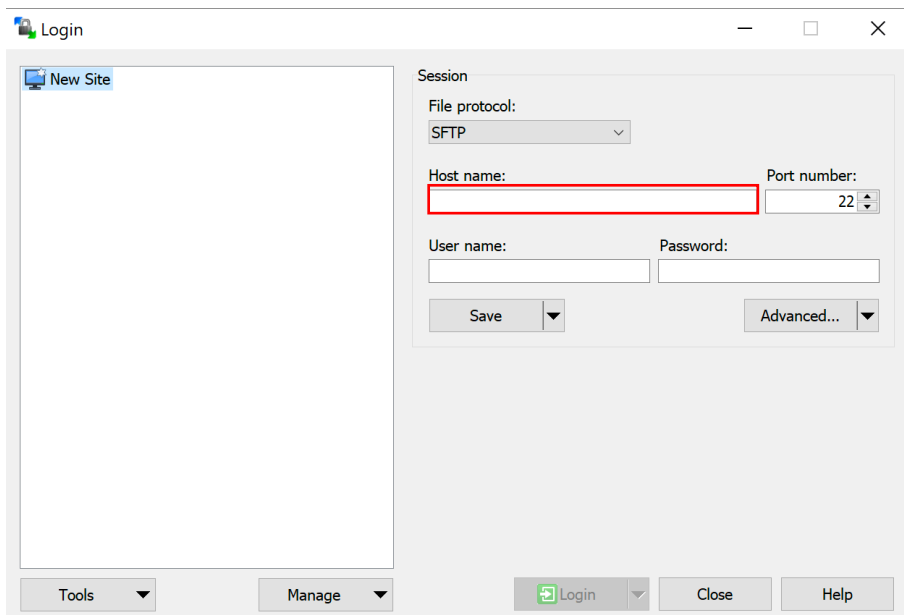
Keep the default 'Port Number' at 22.

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The 'User name' and 'Password' fields are your authentication credentials for your EZTrack account.
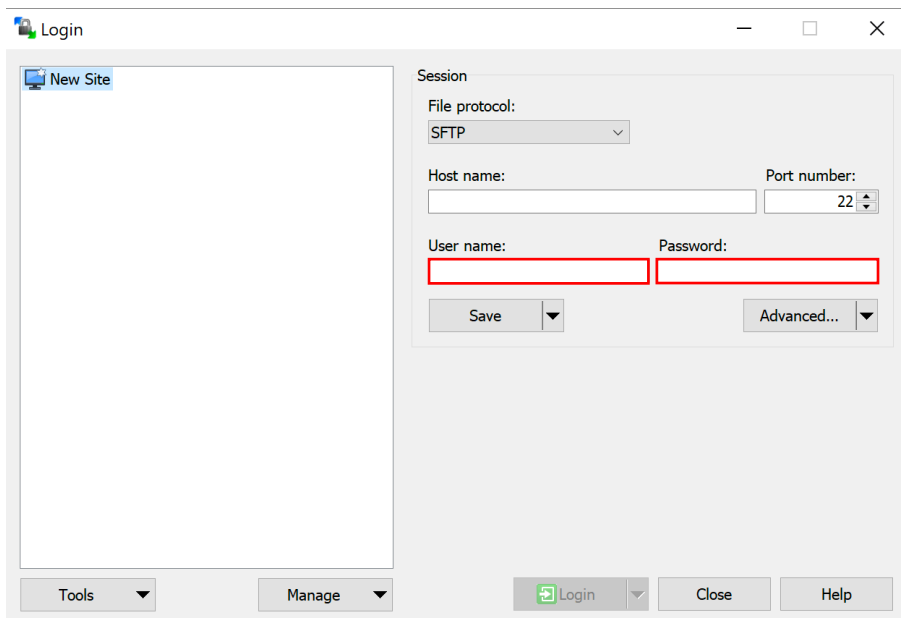
2. **File Transfer to EZTrack:**

Once logged in, you can securely transfer files between your local filesystem and the EZTrack S3 database. Simply drag and drop files between the two panes. Your files will now be available within the EZTrack server.

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Mac/Linux Workstation:
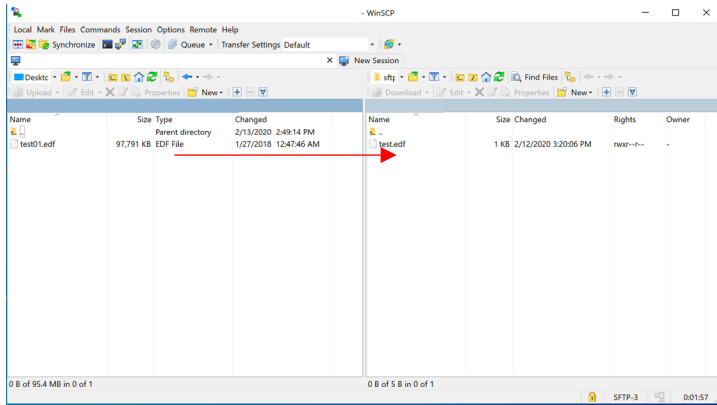
Unix based machines have the ability to perform sFTP natively in the terminal, so the process is simplified from the command line.

1. **Login and SFTP Authentication**


```
→    ~ sftp -i /path/to/sftp/key eztrack_username@server_ip_address
```

User authentication and sFTP authentication occur simultaneously on Unix-based systems. The user passes the sftp command with the '-i' option, then the path to the private sFTP key file. Then the user passes their EZTrack username, the '@' symbol, and the IP address of the S3 database of EZTrack. In order for the user to be able to transfer files from their local machine easily, it is recommended they launch this sFTP command from the directory containing the files they wish to move.

2. **File Transfer to EZTrack**

To see the current working directory within the EZTrack server, type 'pwd' into the terminal. To see the files in your local machine's directory, type 'lls' into the terminal. To move one of the files (test.edf for example) from your local machine to the EZTrack server, type 'put test.edf'. To check if the file was correctly uploaded, type 'ls' into the terminal. The user can exit the sFTP session by typing 'exit'.


```
→ ssh_testdir sftp -i /Users/patrick/Downloads/eztrack_test_user_key eztrack_test_user@s-80db545ee8b4418bb.server.transfer.us-east-2.amazonaws.com
Connected to eztrack_test_user@s-80db545ee8b4418bb.server.transfer.us-east-2.amazonaws.com.
sftp> pwd
Remote working directory: /sftp-test-eztrack
sftp> lls
sample_file.edf
sftp> put sample_file.edf
Uploading sample_file.edf to /sftp-test-eztrack/sample_file.edf
sample_file.edf                                                                              100%   16     0.3KB/s   00:00
sftp> ls
sample_file.edf                                         sub-pt1_ses-seizure_task-monitor_acq-ecog_run-01_proc-fragility_ieeg.png
test.edf
sftp> exit
→ ssh_testdir
```

If you have the initial SSH keys setup, you can type in a short command to send data to EZTrack:

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```
sftp put </path/to/edf_file> host
sftp put </path/to/electrode_layout.xlsx > host
sftp put </path/to/clinical_metadata.xlsx > host
```

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EZTrack Analysis

Type in **ez** for a summary of all the commands that are available through the `ez` interface. Once a user has uploaded data successfully using the SFTP procedure outlined in "Data upload:" then the user may use the following commands to run through the EZTrack analysis. The following commands are use in the EZTrack analysis workflow. In order to run EZTrack analysis, first navigate to the EZTrack authentication portal, where you will be prompted to with authentication keys given to you by NSI personnel.

https://eztrack.testedminds.com/

The authentication screen looks like this:

Once you are authenticated, you will be able to interact with the EZTrack system on the web page with the following commands laid out in 4.1.4-4.1.7.

4.1.4.   Viewing EZTrack Software Information

> **>> ez about**

Will pull up a printout of EZTrack software information (version number, contact information, and UDI).

4.1.5.   Preprocessing data

> **>> ez preprocess**

Will find the data that was uploaded via sftp, convert it to Brain Vision format, and add it to the BIDS layout structure used by EZTrack. This is necessary so the other commands know where to find the data.
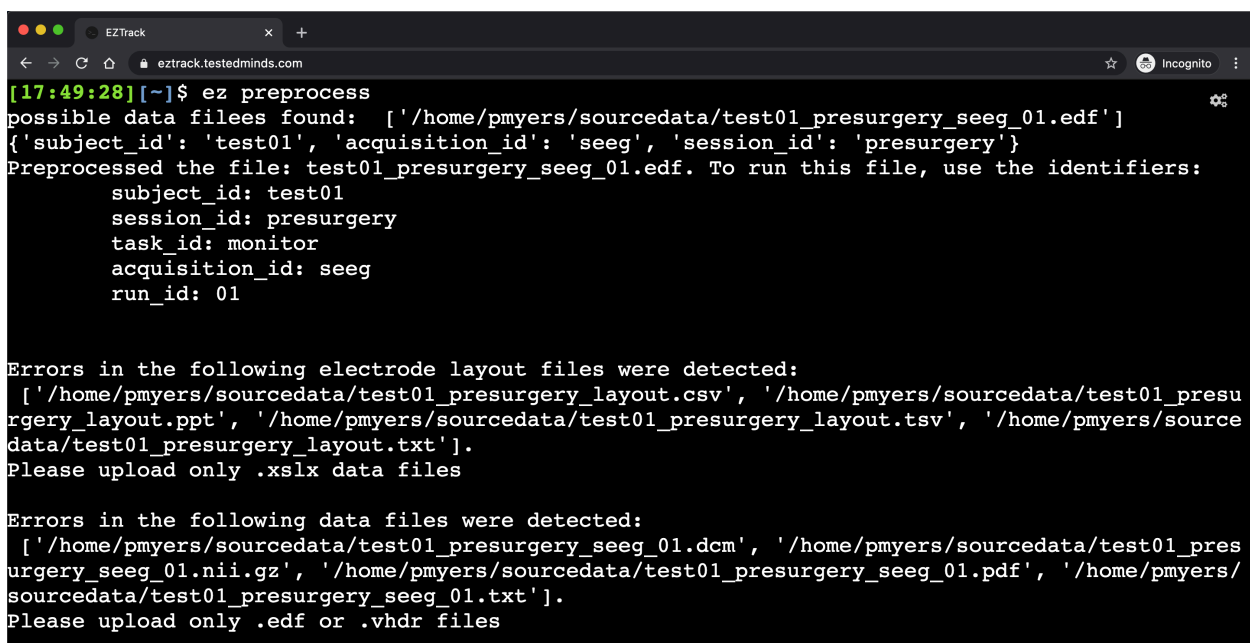
Example:

A user has uploaded a series of files; some files are valid, and some are not. The files are:

- EEG Data Files:
  - test01_presurgery_seeg_01.edf (valid)
  - test01_presurgery_seeg_01.dcm (invalid)
  - test01_presurgery_seeg_01.nii.gz (invalid)

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- ▪ test01_presurgery_seeg_01.pdf (invalid)
- ▪ test01_presurgery_seeg_01.txt (invalid)
- Electrode Layout Files:
  - ▪ test01_presurgery_layout.xlsx (valid)
  - ▪ test01_presurgery_layout.csv (invalid)
  - ▪ test01_presurgery_layout.ppt (invalid)
  - ▪ test01_presurgery_layout.tsv (invalid)
  - ▪ test01_presurgery_layout.txt (invalid)

Then running preprocess will produce:
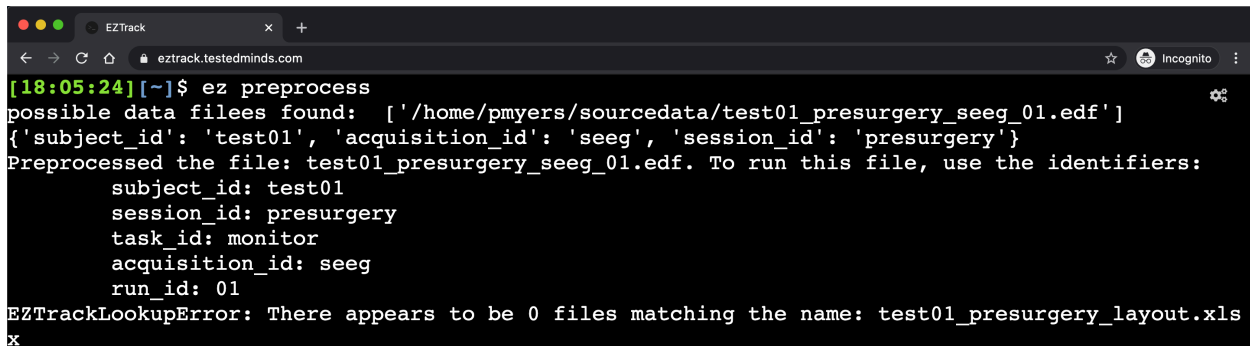
The first chunk of output shows that the system found the correct data file (test01_presurgery_seeg_01.edf) and an associated electrode layout sheet (test01_presurgery_layout.xlsx). The system then provides the BIDS identifiers that can be used in other EZTrack modules as input parameters.

The second chunk shows that the system rejected any electrode layout files that were named incorrectly or had the incorrect extension. It prompts the user to upload the data files with the correct '.xlsx' extension.

The third chunk shows that the system rejected any EEG data files that were named incorrectly or had the incorrect extension. It prompts the user to upload the data files with the correct '.edf' or '.vhdr' extensions.

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If the correct EEG data file is uploaded, but the corresponding electrode layout is missing, the following output will be displayed:

```
[18:05:24][~]$ ez preprocess
possible data filees found:  ['/home/pmyers/sourcedata/test01_presurgery_seeg_01.edf']
{'subject_id': 'test01', 'acquisition_id': 'seeg', 'session_id': 'presurgery'}
Preprocessed the file: test01_presurgery_seeg_01.edf. To run this file, use the identifiers:
        subject_id: test01
        session_id: presurgery
        task_id: monitor
        acquisition_id: seeg
        run_id: 01
EZTrackLookupError: There appears to be 0 files matching the name: test01_presurgery_layout.xls
x
```

This error tells the user that no corresponding electrode layout sheet was found, meaning that any bad contact annotations will not be seen by EZTrack and all channels will be kept in analysis. If channels containing bad signal are included in the analysis, the produced heatmap may be less informative.
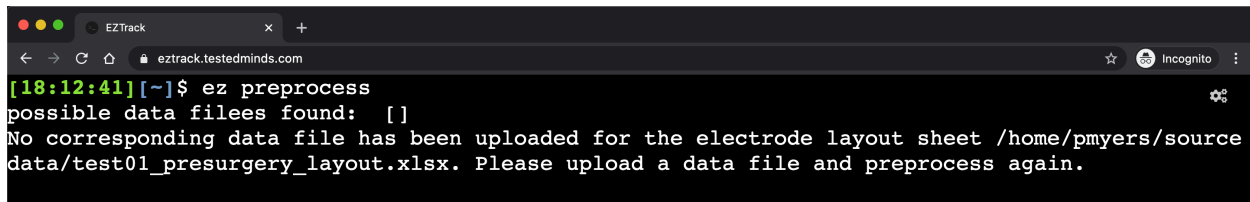
In the reverse case where an electrode layout sheet is uploaded, but no corresponding data files were uploaded or are in the system already, the following output will be displayed:

```
[18:12:41][~]$ ez preprocess
possible data filees found:  []
No corresponding data file has been uploaded for the electrode layout sheet /home/pmyers/source
data/test01_presurgery_layout.xlsx. Please upload a data file and preprocess again.
```

This message tells the user that they should upload a corresponding data file for the found electrode layout sheet.

4.1.6. Running EZTrack Analysis

Run the fragility analysis:

The run command uses the necessary BIDS identifiers to locate the uploaded unique data file. From this file, the fragility analysis is performed and the results are saved in a parallel 'derivates' BIDS directory using the same BIDS identifiers as input in the run command. The results are transformed into a heatmap which is saved in the same directory as the results file from which it was generated. The run command has the following structure:

      ez run [options]

Example:

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Example command from figure above:

Options include:

- **subject_id** (<u>required</u>):

    This string is the unique identifier of the subject stored within the EZTrack server.

- **run_id** (<u>required</u>):

    This string is the number of recordings in the directory defined by the other BIDS identifiers used in the run command.

- **session_id** (optional, default = 'seizure'):

    This string is used to identify the session of the recording. While the method of splitting sessions is a decision for the user, EZTrack recommends using 'seizure' and 'interictal'

- **task_id** (optional, default = 'monitor'):

    This string defines the task the patient was performing during the recording. For EEG signals, the task will usually be 'monitor', but it may be different for different signal acquisitions.

- **acquisition_id** (optional, default = 'ecog'):

    This string defines the type of signal acquisition contained within the recording file. Current allowed acquisitions are 'eeg', 'ecog', and 'seeg'.

- **colorblind** (optional, default = False):

    This boolean value indicates whether the output heatmap should use a colorblind accessible color scheme (i.e. it does not contain both green and red). The default value, False, creates a heatmap using a specialized color scheme to distinguish between regions, but has both reds and greens. If one wishes to regenerate the heatmap, they don't need to re-run the entire analysis, but can just run the `plot` command.

Re-plot the fragility analysis:

While the run command will produce and save a heatmap containing the fragility data, the resultant plot might not be optimal to a user's liking. The plot command can be used in these
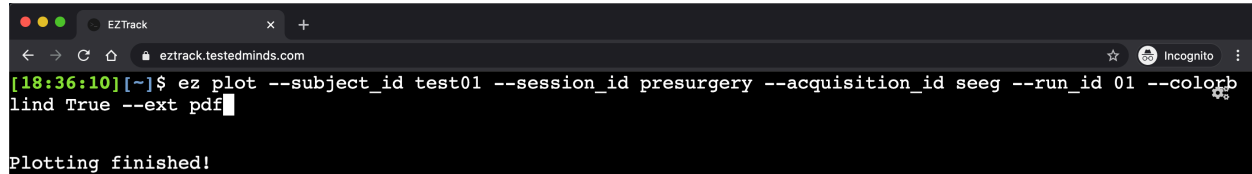
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instances to use already saved fragility results from a previous run command. The plot command allows the user to change the color scheme or the output format.

ez plot [options]

Example:

Options include:

- **subject_id** (<u>required</u>):

  This string is the unique identifier of the subject stored within the EZTrack server.

- **run_id** (<u>required</u>):

  This string is the number of recordings in the directory defined by the other BIDS identifiers used in the run command.

- **session_id** (optional, default = 'seizure'):

  This string is used to identify the session of the recording. While the method of splitting sessions is a decision for the user, EZTrack recommends using 'seizure' and 'interictal'

- **task_id** (optional, default = 'monitor'):

  This string defines the task the patient was performing during the recording. For EEG signals, the task will usually be 'monitor', but it may be different for different signal acquisitions.

- **acquisition_id** (optional, default = 'ecog'):

  This string defines the type of signal acquisition contained within the recording file. Current allowed acquisitions are 'eeg', 'ecog', and 'seeg'.

- **colorblind** (optional, default = False):

  This boolean value indicates whether the output heatmap should use a colorblind accessible color scheme (i.e. it does not contain both green and red). The default value, False, creates a heatmap using a specialized color scheme to distinguish between regions, but has both reds and greens.

- **ext** (optional, default = 'pdf'):

  This string value indicates the extension of the file that contains the plot image. Current allowed extensions are 'pdf' and 'png'.
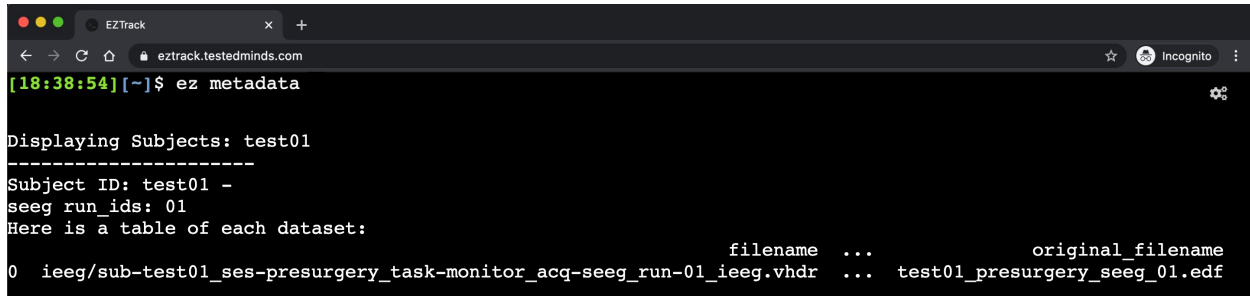
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4.1.7. Viewing Patient/Dataset Metadata

Viewing dataset-level metadata:

The metadata function prints out the metadata for each subject viewable by the current user. The output can be filtered by any column value, such as all subjects with age greater than 30 who are male. The structure of the metadata command is:

ez metadata [options]

Example:

Options include:

- **display_cols** (optional, default = False)

    This boolean value denotes whether to print just the column names which can aid in filtering large metadata sets

- **toggle_opts** (optional, default = None)

    This set of strings represent boolean filters on the metadata. For instance, the option 'age>30' will only display patient metadata for patients over 30 years of age.

Viewing subject-level metadata:

The patient summary command outputs data about each of a specific patient's scans. The structure of the patient summary command is:

ez pat-summary [options]

Example:

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```
●●●        ● EZTrack              ×   +

←  →  C  ⌂   🔒 eztrack.testedminds.com                                          ☆  🔒 Incognito  ⋮

[18:38:54][~]$ ez pat-summary --subject_id test01                                           ⚙️

Subject test01 Summary:
  participant_id  age  sex hand
0     sub-test01  n/a  n/a  n/a


Summary of Snapshots for test01

No scalp EEG data to summarize.
---------------------------
iEEG data summary.
----------------
                                                          filename  \
0  ieeg/sub-test01_ses-presurgery_task-monitor_acq-seeg_run-01_ieeg.vhdr

            acq_time            original_filename TaskName Manufacturer  \
0  1920-06-13T03:42:19  test01_presurgery_seeg_01.edf  monitor          n/a

  PowerLineFrequency  SamplingFrequency SoftwareFilters  RecordingDuration  \
0                 60             1000.0             n/a            480.999

  RecordingType iEEGReference  ECOGChannelCount  SEEGChannelCount  \
0    continuous           n/a                 0               126

  EEGChannelCount  EOGChannelCount  ECGChannelCount  EMGChannelCount  \
0               0                0                0                0

  MiscChannelCount  TriggerChannelCount
0               14                    0
```

Options include:

- **subject_id** (required)

  This string is the unique identifier of the subject stored within the EZTrack server.

Downloading Heatmaps - Viewing and Downloading Fragility Heatmap

Once EZTrack has run to completion, fragility heatmaps can be downloaded. In addition, users may access their saved heatmaps through the same SFTP process they used to upload data. Users will be asked for their username and password. Then users may download the heatmaps for selected patients that they uploaded.

User Tips

Following are some basic tips for using EZTrack:

- Keep your browser up-to-date: Since EZTrack is run via your web-browser, it is a good idea to keep it up-to-date, as we will comply with security protocols whenever browsers are upgraded.

- Keep your data organized: EZTrack is an adjunctive tool, and so requires user input. It does not determine which channels are non-EEG, or relevant signals. It is necessary to

keep a well-documented list of channels that are in the EDF file, but not of interest.

- Refer to other EEG analysis tools. Use the EZTrack solutions in conjunction with other EEG tools, or the results from other imaging modalities.

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5. FRAGILITY ANALYSIS INTERPRETATION

The notion of fragility is derived from the concept that an epileptic network is inherently imbalanced with respect to connectivity between inhibitory and excitatory populations (nodes) somewhere in the brain. That is, if a specific node or set of nodes is perturbed, over excitation may occur manifesting in a seizure. Fragility of a specific region is defined as the minimum amount of energy required to be applied, such that the entire network becomes unstable. EZTrack assumes each recording electrode region is a node, while its connections are estimated from data over time.

Fragility is a network metric over time for all the electrode regions you include into the algorithm. It will produce over time, values between 0 and 1. The closer the values get to 1, the more fragile a certain electrode region is at that time point.

For examples of fragility heatmaps, see User Tutorial and Section on Heatmap Visualization.

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6.   HEATMAP VISUALIZATION

The heatmaps are spatiotemporal 2D visualizations of fragility of the recording signals. EZTrack outputs heatmaps in two colormaps:

1. 'Turbo' (default)
2. 'Viridis'

If you are colorblind, then you may submit a `**colorblind True**` option to the EZTrack command line when visualizing the heatmap, which will generate a new heatmap with the Viridis colormap.

'Turbo' is an RGB colormap developed at Google that overcomes some limitations with the popular colormap 'Jet', such as visual discontinuities in the color spectrum. Although 'Turbo' is the default colormap, it has both reds and greens and is therefore not colorblind friendly, so it is recommended to use 'Viridis' as the colormap if you are colorblind. Heatmaps are visualized with recording electrodes on the y-axis and time on the x-axis. Here is an example of a 20 second snapshot of a fragility heatmap, and corresponding raw EEG snapshot.
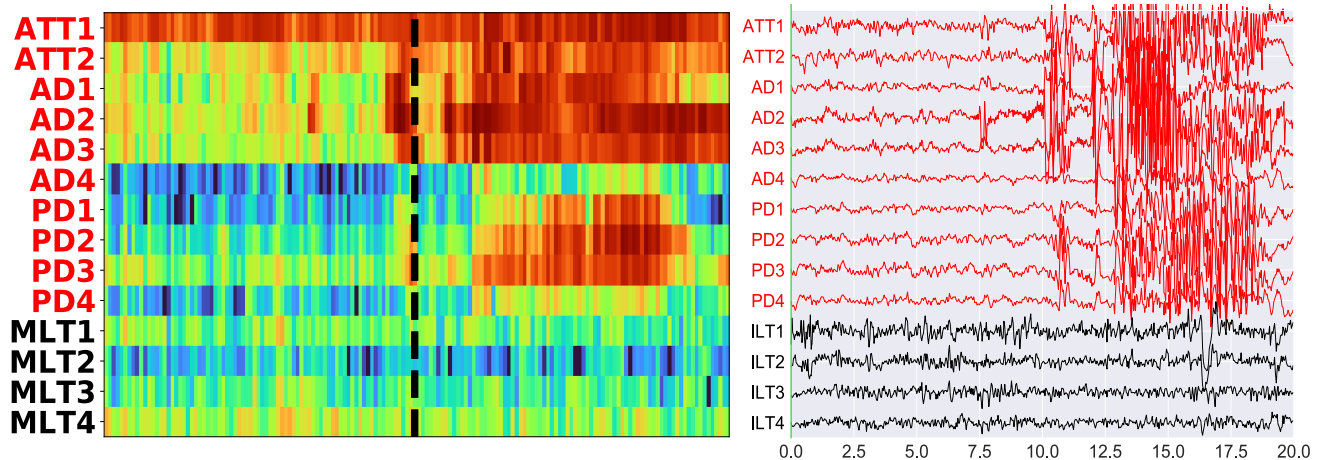

Figure: Fragility heatmap color-coded with values in the range 0 and the maximum fragility value (less than 1) with red indicating more fragile (closer to 1). The most "fragile" channels (by a row sum) were highlighted on the y-axis in red in both EEG and heatmap for simple demonstration purposes. In addition, the red channels were annotated by clinicians as part of the clinically hypothesized seizure onset zone. In this example, the seizure onset zone highly overlaps with fragility analysis. The x-axis is 20 seconds of time. The y-axis is a zoomed in snapshot of 14 channels. Heatmap data is shown in the turbo colormap.

Figure: An example of a whole snapshot recording of 2 minutes with channels on the y-axis and time (A.U.) on the x-axis. Color ranges between 0 and the maximum fragility value seen in the data. Data is shown in the turbo colormap.
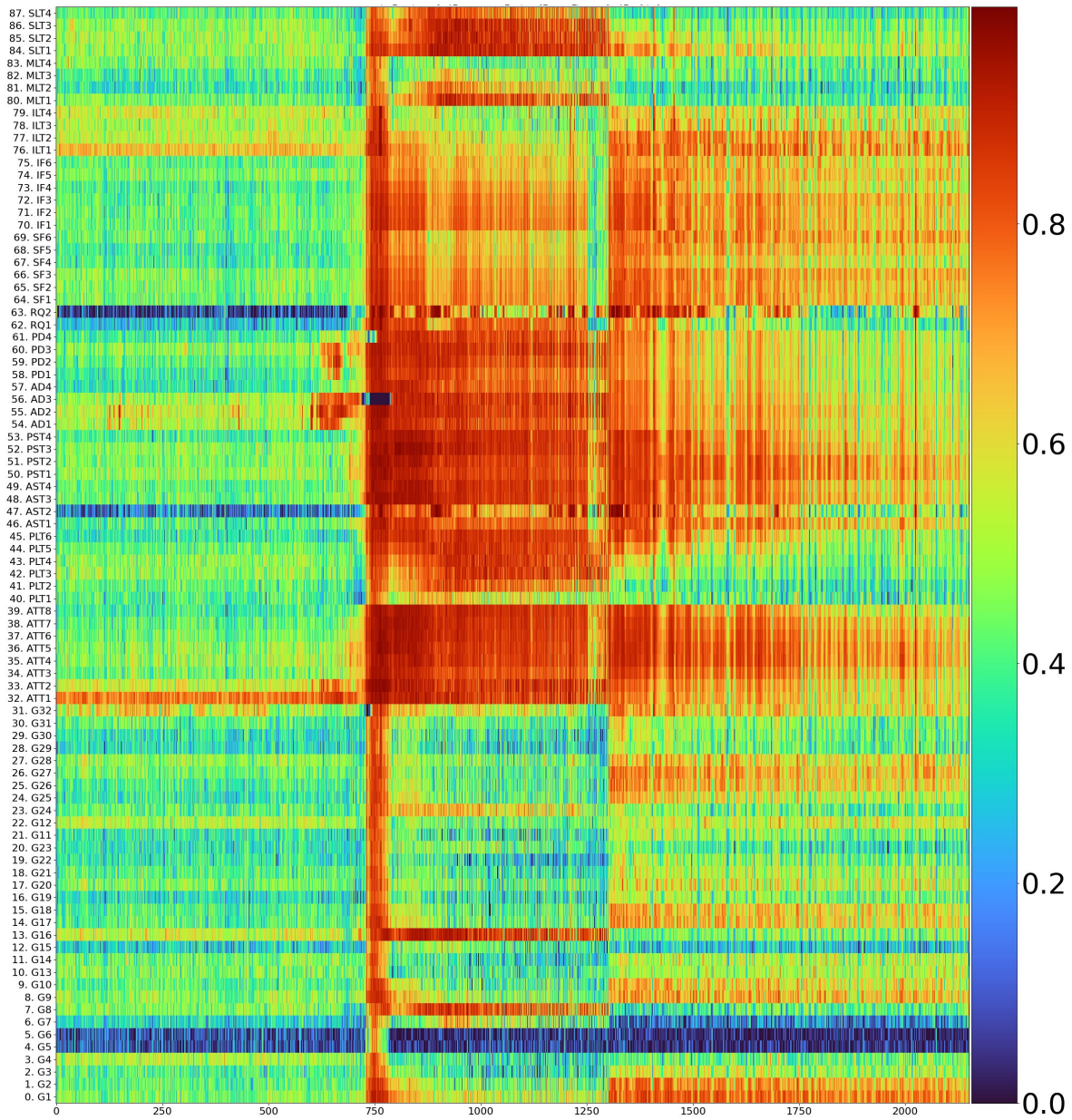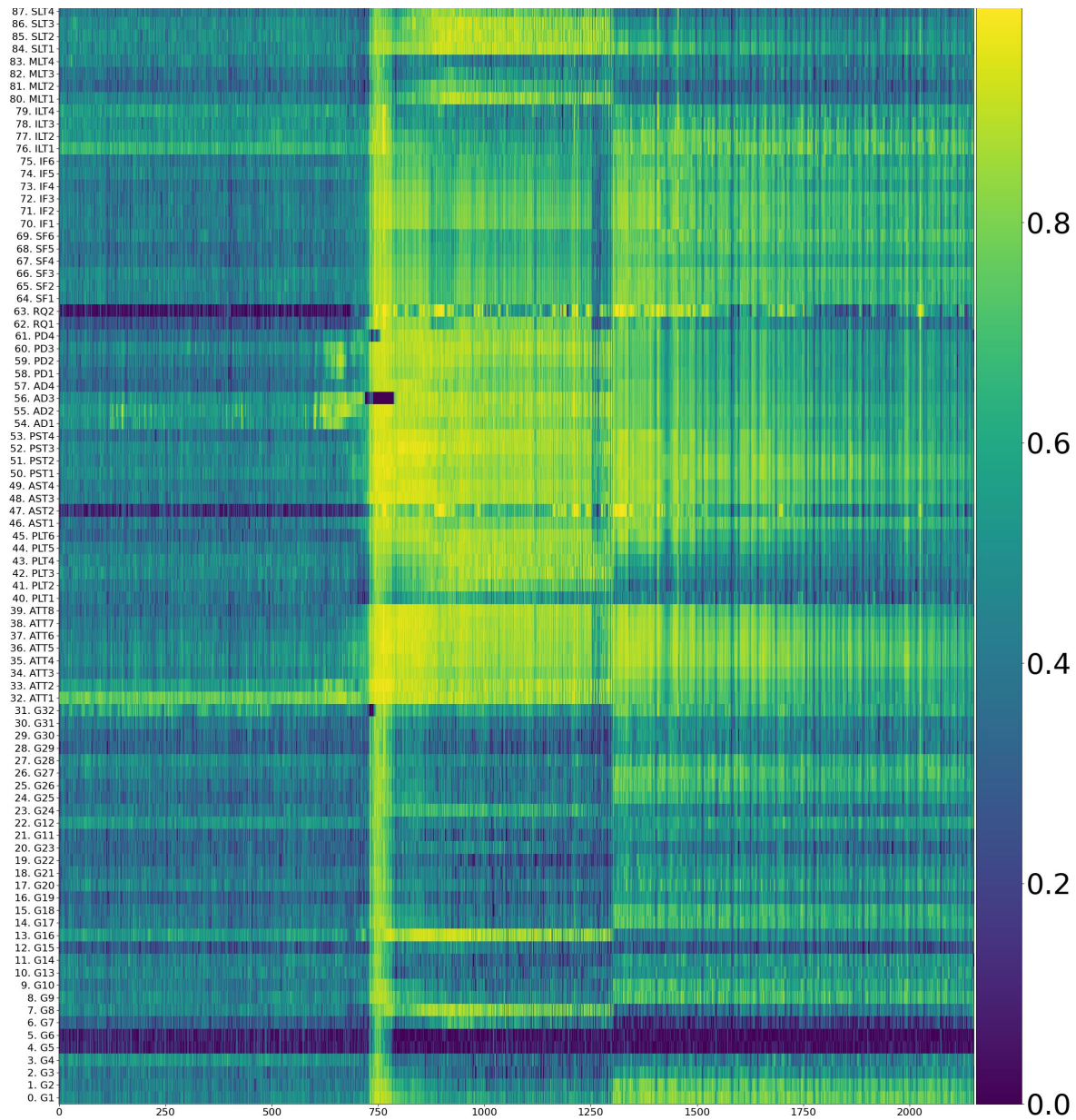
Figure: An example of a whole snapshot recording of 2 minutes with channels on the y-axis and time (A.U.) on the x-axis. Color ranges between 0 and the maximum fragility value seen in the data. Data is shown in the viridis (colorblind) colormap.

Reference:

- https://ai.googleblog.com/2019/08/turbo-improved-rainbow-colormap-for.html

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7.   EZTRACK FILE ORGANIZATION

Input Files

EZTrack accepts standardized formats for EEG data:
- European data format (.edf)
- Brain Vision (.vhdr)

European Data Format (.EDF)

The European Data Format (EDF) is a simple and flexible format for exchange and storage of multichannel biological and physical signals. EDF was published in 1992 in Electroencephalography and Clinical Neurophysiology 82, pages 391-393. Since then, EDF became the de-facto standard for EEG and PSG recordings in commercial equipment and multicenter research projects.

Reference: https://www.edfplus.info/

Brain Vision (.VHDR, .VMRK, .EEG)

An EEG recording consists of three separate files:
- Header file (*.vhdr): This is a text file containing recording parameters and further meta-information. It has the same base name as the raw EEG data file.
- Marker file (*.vmrk): This is a text file describing the events that have been collected during the EEG data recording. It has the same base name as the raw EEG data file.
- Raw EEG data file (*.eeg): This is a binary file containing the EEG data as well as additional signals recorded along with the EEG.

Reference:
https://www.brainproducts.com/files/public/products/more/BrainVisionCoreDataFormat_1-0.pdf

Note: All EDF data is automatically converted to Brain Vision format and also de-identified by anonymizing the record date and removing any subject-related information in the file headers when run through EZTrack.

Output Files

EZTrack outputs the following file formats:

- A portable document format (.pdf), support vector graphics (.svg), or portable network graphic (.png) for its heatmap

You can save these files to any folder you choose.

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8.   TROUBLESHOOTING

Identifying the Problem
- Isolate the problem. Try to repeat and define the problem.
- Document the problem. Carefully record the sequential details of the isolated problem.
- Report the defined problem. Contact Neurologic Solutions Inc. (NSI) by email.

NSI Support Email	support@neurologicsolutions.co

Browser Issues

If you are having browser issues, we recommend that you carry out the following steps:

1. Check your internet connectivity: since EZTrack is a cloud-based system, an Internet connection is necessary

2. Check browser version: bugs are commonly fixed and patched in modern-day browsers. Check that you have the latest version of your web browser (recommended Google Chrome).

3. Report the problem: report where you are attempting to use EZTrack, the operating system you are using, the browser you are using to NSI.

My fragility map does not look correct

If you have a fragility map, and you notice that regions that are fragile do not make sense, or that the map is incorrect, then it could be due to a variety of issues:

- Do you have any bad channels related to noise, white matter, or non-gray matter signals in the dataset?

  - If you do, please follow instructions to annotate bad channels and then re-run the analysis.

- Most epilepsy centers annotate channels anatomically via a T1 MRI image. If there are contacts on the edge of any "bad channel" region, then it could potentially alter your analysis"

A fragility heat map, might look incorrect if:

- There is a very low to no variability in the fragility seen across all channels. This can occur if there are very flat signals (e.g. from channel not being attached to the brain).

If further problems are present, then please contact NSI by email and provide us with your username, dataset that you are attempting to run, and a description of the problem you are facing.

My fragility map does not match our clinically-based analysis

If a clinically based analysis is done, and does not match the fragility map you see, then it can be due to a variety of issues:

- Check if the fragility map matches the specific seizure it was analyzed on?

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- o Many seizures present with different semiologies and a fragility map on only one seizure may agree with your particular analysis of that one seizure, but perhaps not your overall assessment of the patient.

- Check the raw EEG data and other supporting data again to see if the fragility map can refine your decisions?

    - o The goal of EZTrack is to provide another view of the raw EEG data to support clinical analyses and downstream decisions. If the fragility map of certain patients cause you to relook at data to reconsider decisions, we would like to know. Please tell us via email.

- Does the raw EEG data and other supporting data completely disagree?

    - o It is possible that your data contains electrode contacts that are defined as non-essential signals that should be removed. Refer to Section "Annotating Bad Channels" on how.

If further problems are present, then please contact NSI by email and provide us with your username, dataset that you are attempting to run, and a description of the problem you are facing.

Uploading the data does not work

When you are uploading your data, file transfer occurs securely via encryption. Please check the following if uploading data does not work:

1. Authentication keys: For every computer with a connection to EZTrack, there should be a stored set of authentication keys that allows EZTrack to verify that the data is coming from a valid user. Please check that the keys are still in the specified location on your computer. Contact your IT staff to check the installation was carried out properly, according to Section Installation.

2. Log in: In order to ensure that your data is securely transferred, you must be authenticated.

3. Upload command: If you are on a Mac, or Linux workstation, please check that the corresponding "SFTP" upload command was entered correctly into your terminal.

4. Report the problem: report where you are attempting to use EZTrack, the operating system you are using, and any additional information that would be helpful in diagnosing why you are having issues, such as: the upload command that you are using.

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APPENDIX A: EEG Channels and Bad Channels

In any EDF file, there are a set of channels that are stored with a certain sampling rate (in Hz). Reference channels, or other biological signal (non-EEG) channels should be excluded from analysis. For example these can include: DC or REF for reference channels, and EKG or EOG channels for electrocardiogram, and electrooculogram signals.

In many cases, certain electrodes may be faulty due to manufacturing, or attachment process. They may be visibly noisy, or simply not be recording any signals. These should be excluded from analysis. EZTrack does not detect these within its algorithm.

Depth electrodes: When implanting SEEG electrodes, or depth electrodes, it is common for certain channels to contain white matter signals. All channels that are designated in white matter regions, should be excluded from EZTrack analysis. EZTrack does not detect these within its algorithm.

APPENDIX B: Clinical Metadata Sheet

The clinical metadata sheet is a user specific file that contains important metadata for each recording session uploaded by that user. As stated in Section 4.3.1, the file should have the name clinical_metadata.xlsx

The sheet must be formatted with clinical metadata fields as columns and subject sessions as rows. The following columns are expected:

- **SUBJECT_ID: (required)** This is the identifier of the subject within the EZTrack system. Must match the subject's data files exactly.

- **SESSION_ID: (required)** This is the identifier of the subject's recording session within the EZTrack system. Must match the subject's session identifier exactly.

- **ACQUISITION: (required)** This is the type of recording acquired during the session, whether it be seeg, ecog, or eeg.

- **ONSET_AGE: (optional)** The age of the patient when they were first symptomatic

- **CURRENT_AGE: (optional)** The current age of the patient

- **RACE: (optional)** The race of the patient – 0 for Caucasian, 1 for African American, 2 for Asian, 3 for Hispanic

- **HAND: (optional)** The handedness of the patient - R or L

- **GENDER: (optional)** The gender of the patient – M or F

- **BAD_CONTACTS: (optional)** The list of contacts containing bad signal. Can be listed out one by one or simplifying when possible. For instance, contacts A1, A2, A3, A4, and A5 can be simplified to A1-5.

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- **WM_CONTACTS: (optional)** The list of contacts that were implanted in white matter. Follows same listing scheme as BAD_CONTACTS.

- **OUT_CONTACTS: (optional)** The list of contacts that are outside the brain and contain no signal. Follows same listing scheme as OUT_CONTACTS.

- **CLINICAL_CATEGORIZATION: (optional)** The clinical category of the patient's epilepsy – 1 for lesional, 2 for focal temporal, 3 for focal non-temporal, and 4 for multi-focal

- **OUTCOME: (optional)** The outcome of the treatment for that patient, either S for success or F for failure.

Not all fields will be available for every patient and are therefore optional. The purpose of this sheet is both to add metadata to the recordings within the EZTrack database, but also to keep records of the successfulness of treatments. It is therefore advised to continue adding to the sheet even after the surgical treatment.

APPENDIX C: Software Technical Support

Before contacting EZTrack please check this manual's contents for coverage of your issue or question. You can also perform an electronic search using Find or Search in the PDF version of this manual.

If you need more help, EZTrack recommends the following:
- Isolate the problem. Try to repeat and define the problem.
- Document the problem. Carefully record the sequential details of the isolated problem.
- Report the defined problem. Contact EZTrack by email.

APPENDIX D: BIDS Format

The Brain Imaging Data Structure (BIDS) provides an easy method for naming and organizing neuroimaging data to create a searchable file structure. BIDS was created to standardize the storage of complicated neuroimaging data. Each EEG dataset in BIDS can be uniquely identified by the following parameters:
- Subject
- Session
- Task
- Acquisition
- Run

The kind of the file is determined by the acquisition using the following rules:
- If acquisition is 'ecog' or 'seeg', kind is 'ieeg'
- If acquisition is 'eeg', kind is 'eeg'

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EZTrack allows a subset of the BIDS compliant file types. The European Data Format is a single file format with extension '.edf'. The BrainVision Core Data Format has three files with extensions '.vhdr', '.vmrk', and '.eeg'.

This results in the following file(s) name:

      sub-*<subject>*_ses-*<session>*_task-*<task>*_acq-*<acquisition>*_run-*<run>*_*<kind>*.*<ext>*

which would be stored in a file-structure with the following format:

      sub-*<subject>*/
          ses-*<session>*/
             <kind>/
                <filename>

More information about BIDS can be found at the site: https://bids.neuroimaging.io/