**Reliability, Effect size, And Data quality In EEG (READIE) toolbox**

Wenyi Xu

READIE Toolbox User Manual

Updated August 7th 2024

1. **Introduction**

The READIE Toolbox is a user-friendly computational solution designed to enhance the reporting and analysis of EEG data quality metrics. Developed with a user-friendly interface, it has been integrated into HAPPE EEG preprocessing pipelines (Gabard-Durnam et al., 2018; Monachino et al., 2022) facilitating the automated estimation of reliability, effect size, and Standard Measurement Error (SME) (Luck et al., 2021)for EEG datasets. This innovative tool simplifies the computational process and aids in interpreting data quality metrics, such as effect size, reliability, and SME, providing insights into the optimal number of trials for detecting significant effects and establishing reliable measures. By offering overall and bootstrapped reliability, effect size across increasing numbers of trials, and SME estimates at the participant level (output cross checked with sample dataset provided by Luck et al., 2021), we aim to expand the current set of toolboxes for EEG data quality metric analysis, providing a toolbox that is intuitive and user-friendly for researchers.

A diagram of data processing

Description automatically generated

Figure 1: READIE Overall Flowchart

1. **Download the Toolbox**

The READIE Toolbox can be downloaded here: https://github.com/Bead-Lab/The-READIE-Toolbox-Reliability- Effect-size-And-Data-quality-In-EEG. The toolbox has been tested with MATLAB R2022 on macOS Ventura Version 13.4.1(c).

For READIE to run properly, **Version MATLAB R2022** should be used, and MATLAB add-ons, including **Parallel Computing Toolbox, Statistics and Machine Leaning Toolbox, and Signal Processing Toolbox** must be downloaded ahead before running READIE.

The updated version of HAPPE with data quality metrics calculation capabilities can be found here: https://github.com/PINE-Lab/HAPPE.

1. **Analyzing Data** 
   1. **Preparing Your Data for READIE**

There are three methods to prepare your data for the READIE Toolbox:

**1. Data Processed by the readieERP Script**

The readieERP script is an adaptive version of the HAPPE + ER generateERP script (Gabard-Durnam et al., 2018; Monachino et al., 2022) with functionalities tailored to facilitate the use of READIE.

For demonstration purposes, we used publicly available Visual-Evoked Potential (VEP) Event-Related Files from the General Anesthesia and Brain Activity (GABA) Study dataset (Monachino et al., 2021), which can be found [here](https://zenodo.org/records/5172962). The data has been preprocessed using HAPPE software, and the processed data can be found within the data file: Preprocessed\_Individual\_trial\_data\_readieERP folder.

To prepare your data using this method:

* Run the readieERP script on your dataset.
  + Data should be in a data folder with single-subject, trial-level information, similar to the sample dataset provided:

A screenshot of a computer

Description automatically generated

Figure 2. Single-subject, Trial-level Data Sample

* For data with conditions, create separate folders and put individual trial data separated by condition into each folder. Run readieERP separately for each folder:A screenshot of a phone

  Description automatically generated

Figure 3: Individual Trial- level Data Separated by Condition

Note: The readieERP script accepts .txt and .set files, which are in the BIDS standard format and are commonly used output formats for multiple preprocessing pipelines.

**2. Data Processed by the generateERP Script**

If your dataset has been processed using the generateERP script, ensure the following settings are selected so that READIE can properly read the data:

* **Trial type:** Individual
* **Export format:** Multiple .csv files
* **Subjects:** Rows as trials, columns as values split by subject

By following these guidelines, you can ensure that your data is correctly formatted and ready for analysis using the READIE Toolbox.

**3. Data Preprocessed by Other Pipelines**

READIE can accept any output format similar to HAPPE + ER's: a data folder with single-subject, trial-level information. Please refer to the sample dataset Preprocessed\_Individual\_trial\_data\_readieERP for formatting details.

* 1. **Visualize Your Processed Data**

1. **Data Processed by the readieERP Script**

ReadieERP creates output files within the same location where the data is saved, in the readieERPs - ERP\_calculatedVals folder.

A screenshot of a computer

Description automatically generated

Figure 4: ReadieERPs Output folder

Within the readieERPs - ERP\_calculatedVals folder, each CSV file contains the trial-level information for each participant (Figure 5) that READIE takes.A screenshot of a computer

Description automatically generated

Figure 5: Mean Amplitude Trial-level Information for Each Participant

A screenshot of a computer

Description automatically generated

Figure 6: Participant Level Trial-level Data, which Row as trial number and Column as Mean Amplitude Window

1. **Data Processed by the generateERP Script**

The generateERP script outputs files in the same format as the readieERP script. Therefore, follow the previous instructions for preprocessed mean amplitude individual data for READIE to process.

1. **Data Preprocessed by Other Pipelines (mean amplitude individual level data)**

Make sure the data format is similar to the readieERP output (Figure 5 and Figure 6), with each file representing mean amplitude trial-level information for each participant. Within each file, rows should represent trial numbers, and columns should represent mean amplitude windows.

Within each participant's individual CSV files, each line should correspond to one trial, and there can be multiple measurements per line, e.g. mean amplitude for windows 75 – 130 and 100 – 230 (Figure 6).

**For datasets with more than one condition**, the condition information must be consistently present in the filename with observable pattern, e.g., if we have two conditions, correct and incorrect, the filenames should look something like this:

1212\_generatedERPvals\_correct.csv

1213\_generatedERPvals\_correct.csv

1212\_generatedERPvals\_incorrect.csv

1213\_generatedERPvals\_incorrect.csv

READIE can process datasets with multiple conditions placed in the same folder as long as the condition names are consistently represented in the files, as showcased above.

1. **Start the Toolbox**

Once you have the participant-level trial-level data, you can go to the READIE Toolbox to start reliability, effect size, and SME computation.

**3.1 Setup Parameters**

To start the READIE Toolbox, open the downloaded MATLAB file master.m.

A screenshot of a computer program

Description automatically generated

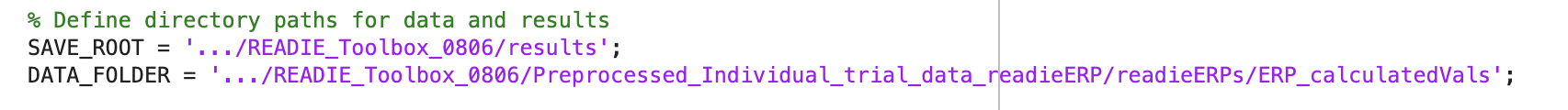
Figure 7: The READIE Toolbox Setup Script

In the setup script, you will be inputting the following information:

**Folder and file setup:**

SAVE\_ROOT: the location where you want to save the files.

DATA\_FOLDER: the location where your participant trial-level data is stored (for data that’s been preprocessed by readieERPs script, data should be present in readieERPs - ERP\_calculatedVals folder.



FILENAME\_DIVIDER: any text before the divider will be treated as the subject name. For example:

A close-up of a number

Description automatically generated

IGNORE\_CONTAINS: Put the name of the files that you want to exclude from analysis. Don’t include the .csv extension.

**Conditions in file:**

CONDITIONS: List **ALL** conditions of your dataset.

**If you only have one condition in your dataset, DON'T put anything into it.**

A close-up of a computer screen

Description automatically generated

**Column(s) of interest:**

VALUE\_COLUMNS: Specify columns that you are interested in for data analysis.A close-up of a window

Description automatically generated

**Parameters for bootstrapping:**

Set the number of iterations you want for data analysis.

NUM\_ITERATIONS = 1000; A close-up of a white background

Description automatically generated

**Parameters for reliability estimates:**

N\_FROM = 10; \* Start of bootstrap trials.

N\_TO = 100; \* End of bootstrap trials.

N\_BY = 10; \* Increments of bootstrapping.

In this example, reliability and effect size will be calculated at intervals of 10, 20, 30, ... up to 100 trials.

A close-up of a white background

Description automatically generated

**Other Parameters:**

Other parameters, including color for graph plotting and the number of CPUs, have also been set in the script (no need to modify).

**A screenshot of a computer code

Description automatically generated**

After updating all the information, click **'Run'** in MATLAB.

In the command window, you will see the progress of reliability, effect size and SME computation. A screenshot of a computer program

Description automatically generated

**3.2 Review Results**

Go to your designated folder to view results based on your selection. A complete set of results of the sample dataset includes:

Each column of interest is the folder name: **A screenshot of a phone

Description automatically generated**

Figure 8: Sample Output Folder Layout

Each folder contains:

Effect size (overall and trial level).

Summary of effect size (overall and trial level).

Reliability (overall and trial level).

Summary of reliability (overall and trial level).

Graphs of trial-level reliability and effect size.

SME per participant.

**A screenshot of a computer

Description automatically generated**

Figure 9: Sample Output

**Citations**

Gabard-Durnam, L. J., Mendez Leal, A. S., Wilkinson, C. L., & Levin, A. R. (2018). The Harvard Automated Processing Pipeline for Electroencephalography (HAPPE): Standardized processing software for developmental and high-artifact data. *Frontiers in Neuroscience*, *12*, 97.

Luck, S. J., Stewart, A. X., Simmons, A. M., & Rhemtulla, M. (2021). Standardized measurement error: A universal metric of data quality for averaged event‐related potentials. *Psychophysiology*, *58*(6), e13793. https://doi.org/10.1111/psyp.13793

Monachino, A. D., Lopez, K. L., Pierce, L. J., & Gabard-Durnam, L. J. (2022). The HAPPE plus Event-Related (HAPPE+ER) software: A standardized preprocessing pipeline for event-related potential analyses. *Developmental Cognitive Neuroscience*, *57*, 101140. https://doi.org/10.1016/j.dcn.2022.101140

Monachino, A. D., Lopez, K. L., Underwood, E., Tao, A., Nelson, C., Berde, C., Cornelissen, L., Hensch, T., & Gabard-Durnam, L. (2021). *Visual-Evoked Potential (VEP) Event-Related Files from the General Anesthesia and Brain Activity (GABA) Study and Infant Sibling Project (ISP)* (HAPPE 2.0) [dataset]. Zenodo. https://doi.org/10.5281/zenodo.5931539