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Data Article

Electroencephalography and psychological assessment datasets to determine the efficacy of a low-cost, wearable neurotechnology intervention for reducing Post-Traumatic Stress Disorder symptom severity

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ABSTRACT

The datasets described here comprise electroencephalography (EEG) data and psychometric data freely available on data.mendeley.com. The EEG data is available in .mat formatted files containing the EEG signal values structured in two-dimensional (2D) matrices, with channel data and trigger information in rows, and samples in columns (having a sampling rate of 250Hz). Twenty-nine female survivors of the 1994 genocide against the Tutsi in Rwanda, underwent a psychological assessment before and after an intervention aimed at reducing Post-Traumatic Stress Disorder (PTSD) symptom severity. Three measures of trauma and four measures of wellbeing were assessed using empirically validated standardised assessments.

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The pre- and post- intervention psychometric data were analysed using non-parametric statistical methods and the post-intervention data were further evaluated according to diagnostic assessment rules to determine clinically relevant improvements for each group. The participants were assigned to a control group (CG, $n = 9$), a motor-imagery group (MI, $n = 10$), and a neurofeedback group (NF, $n = 10$). Participants in the latter two groups received Brain-Computer Interface (BCI) based training as a treatment intervention over a sixteen-day period, between the pre- and post- clinical interviews. The training involved presenting feedback visually via a videogame, based on real-time analysis of the EEG recorded data during the BCI-based treatment session. Participants were asked to regulate (NF) or intentionally modulate (MI) brain activity to affect/control the game.

Specifications Table

Subject	Neuropsychology and Physiological Psychology
Specific subject area	Analysis of EEG data, recorded using a low-cost wearable EEG-based headset, to evaluate and compare the effectiveness of two BCI-based tasks in the reduction of PTSD symptom severity in a Rwandan population.
Type of data	Electroencephalography (EEG) data, and psychological assessment data.
How data were acquired	**EEG data** 1. g.tec g.Nautilus Pro Flexible, 32-channel active electrodes wearable headset [1] (mounted with g.scarabeo electrodes). 2. g.tech g.Nautilus Pro, 32 channel active electrode wearable headset [2] (mounted with g.ladybird electrodes) 3. NeuroCONCISE FlexEEG, 8 channel electrode EEG headset – 3 bipolar channels and 5 mono-polar channels [3]. A user datagram protocol (UDP) based communication was used to manage the communication between a Simulink [4] module, used for EEG data acquisition and online signal processing, and the experimental protocol controller application in Unity 3D Game Engine [5]. The NeuroSensi games platform was used to cue and present the feedback for both the NF and MI tasks [3]. **Psychological assessment data:** An interviewer recorded participant responses to the following series of standardised mental health tests, pre- and post- NF and MI training: 1. PTSD Diagnostic and statistical manual of mental disorders (5th edition - DSM-5) check list (PCL-5, 20-item self-report measure, [6]. 2. Harvard Trauma Questionnaire (HTQ, 40-item self-report measure,[7]). 3. Primary care PTSD screen for DSM-5 (5-item self-report PTSD Screen, [8]). 4. Warwick-Edinburgh Mental Well-being Scale (WEMWBS, 14-item self-report measure [9]). 5. Connor-Davidson Resilience Scale (CD-RISC, 10-item self-report measure, [10]). 6. Brief Resilience Scales (BRS, 6-item self-report measure, [11]). 7. General Self-Efficacy Scale (GSE, 10-item self-report measure, [12]). A questionnaire was completed by participants in the MI and NF training groups before and after each training session – to record their subjective measures of stress and mood.

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Data format	Raw EEG data: • [folder name: data_files] 2D EEG data structures in *.mat* format, with channel data and trigger information in rows (with trigger information in the last row), and samples in columns (sampling rate of 250Hz). • [folder name: workbooks] Excel workbooks for both the MI and the NF groups (MI_datasheets.*xlsx* and NF_datasheets.*xlsx*, respectively), with spreadsheets providing summary information and a rationale for the data runs that were excluded from analysis. Psychometric data – [folder name: workbooks] Excel workbook (psych-data-scores.*xlsx*) with the following spreadsheets: • Spreadsheet with the pre- and post- raw scores for all participant groups on each psychological assessment measurement. • Spreadsheet with tables for each participant group displaying the calculated means, standard deviations and ranges. • Spreadsheets with pre-post data extracted for each of the seven assessment measures. Subjective levels of mood and stress – [folder name: workbooks] Excel workbook containing a spreadsheet (mood-stress-data.*xlsx*) with the subjective mood and stress scores for participants for both the MI and the NF groups, pre- and post- each training session.
Parameters for data collection	Trained neuroimaging researchers visited Rwanda from the UK. PTSD patients who had scored at the higher end of the spectrum for PTSD in a previous UR led study were invited to take part in this study. Recruitment and data collection was confined to a four-week period. Recordings took place at three locations in community settings, and therefore, environmental factors were not under the researchers' control. Training sessions were delivered over a period of sixteen days (with no more than two days between sessions for either group).
Description of data collection	All participants ($N = 29$) completed pre- and post- intervention psychological assessments using three validated diagnostic measures of trauma, and four validated measures of wellbeing. Participants in the MI ($n = 10$) and NF ($n = 10$) training intervention groups completed 6 and 7 sessions, respectively. Data acquisition for each participant's training session involved a pre- and post- subjective measure of stress and mood, and EEG recordings while participants were engaged with the training programme.
Data source location	Institution: University of Rwanda, Huye Campus City/Town/Region: Huye Country: Rwanda Latitude and longitude: -2.61779, 29.74742 Institution: Casa Centre City/Town/Region: Rwamagana Country: Rwanda Institution: AVEGA clinic City/Town/Region: Kigali Country: Rwanda Latitude and longitude: -1.95883, 30.10650
Data accessibility	Repository name: [Mendeley Data] EEG and psychological assessment datasets: Neurofeeedback for the treatment of PTSD Data identification number: doi: 10.17632/gsxphk87mc.3 Direct URL to data: https://data.mendeley.com/datasets/gsxphk87mc/3
Related research article	*N. du Bois, A. D. Bigirimana, A. Korik, L. Gaju Kéthina, E. Rutembesa, J. Mutabaruka, L. Mutesa, G. Prasad, S. Jansen, and D. H. Coyle, Neurofeeedback with low-cost, wearable electroencephalography (EEG) reduces symptoms in chronic Post-Traumatic Stress Disorder, J. Affect. Disord., 295 (2021) 1319-1334.* [13] https://www.sciencedirect.com/science/article/pii/S0165032721008764

Value of the Data

- These data provide evidence of the effectiveness of neurofeedback as a treatment for PTSD in Rwanda, where prevalence is estimated at 37% among survivors of the 1994 genocide perpetrated against the Tutsi.
- Given the lack of infrastructure and the large treatment gap for mental health in Rwanda, these data support the implementation of a treatment solution for patients with PTSD that can be delivered at scale.
- The efficacy of the FlexEEG low-cost wearable EEG headset has been demonstrated, thus offering the potential for affordable neurofeedback as a treatment for PTSD within the Rwandan Health Care system.
- Based on the clinically relevant results obtained from these data, future research should consider conducting a randomized controlled trial, to test the robustness of the findings.

1. Data Description

The dataset titled "EEG and psychological assessment datasets: Neurofeeedback for the treatment of PTSD" is freely available and hosted on Mendeley Data. The dataset contains EEG data [folder name: data_files], with signal values compiled in *.mat* matrices to allow for ease of pre- and post- processing, and analysis. The data is structured into 2D matrices with EEG channel data in rows (and trigger information in the final row), and samples in columns, sampled at a rate of 250 Hz. A second folder [name: workbooks] contains workbooks which have been used to organise the computed data values extracted from the preprocessed EEG data for the NF analyses, available on spreadsheets in the NF_datasheets.*xlsx* workbook, and for the MI analyses in the MI_datasheets.*xlsx* workbook. Also in this folder is the psych-data-scores.*xlsx* workbook, where the psychometric data has been organised.

EEG recording devices: Three EEG headsets were used in this data collection. On the first day of recording (session1) high resolution EEG was recorded using both the g.tec g.Nautilus Pro [2] and Pro Flexible [1], 32 active electrodes wearable headset systems. For all other training sessions, EEG was recorded using the FlexEEG 8 channel EEG headset (3 bipolar channels and 5 mono-polar channels) [3], for all participants with the exception of participant number 17, as, due to this participant's hairstyle, there were difficulties fitting the FlexEEG headset correctly. For all three EEG headsets, the reference electrode was fixed on the right earlobe and the ground electrode was positioned over the AFz electrode location according to the international 10/20 EEG standard. For the g.tec headsets the EEG was amplified (gain: 20000), filtered (Butterworth, 0.5-100Hz, eighth order), and sampled (A/D resolution: 24 Bits, sampling rate: 250 samples/s). The FlexEEG signal was amplified (gain: 24), filtered (Butterworth, 4-38Hz, eighth order), and sampled (A/D resolution: 16 Bits, sampling rate: 250 samples/s).

EEG data for statistical analyses: The EEG data and trigger information [folder name: data_files] are organised into two folders, one for the NF data and the other for the MI data (see Table 1). The samples in these *.mat* files are in microvolts.

The NF_datasheets.*xlsx* workbook contains a summary table of the data used for statistical analyses of the NF data, plus details on the data runs that were included in the analyses. The MI_datasheets.*xlsx* workbook contains a summary table of the data used for statistical analyses of the decoding accuracies (DA's) and the theta-alpha ratio index change, plus details on the data runs that were included in the analyses (see Table 2).

Psychometric data for statistical analyses: The raw scores for the psychological assessments conducted during the pre- and post- intervention clinical interviews, are provided in the workbook titled psych-data-scores.*xlsx* [folder name: workbooks]. The workbook includes a spreadsheet with tables for each participant group displaying the calculated means, standard deviations and ranges, and separate spreadsheets for the pre-post data extracted for each of the seven as-

Table 1
Folder paths and file structures within the repository.

Condition	Root Folder	Sub-folder Structure	Data Structure
CG (n = 9)			No training
NF (n = 10)	data_files	NF_EEG_data (mat)	**Load:** EEG_sb*(x)*x_ss*n*__EEG_relax.*mat* **Matrix name:** EEG_relax **Load:** EEG_sb*(x)*x_ss*n*__EEG_game.*mat* **Matrix name:** EEG_game
MI (n = 10)	data_files	MI_EEG_data (mat)	**A combination of two or more of the following files:** EEG_sb*(x)*x_ss*n*__relax1.*mat* EEG_sb*(x)*x_ss*n*__relax2.*mat* EEG_sb*(x)*x_ss*n*__relax1_run1_feedback.*mat* EEG_sb*(x)*x_ss*n*__run1_nofeedback.*mat* EEG_sb*(x)*x_ss*n*__run1_feedback.*mat* EEG_sb*(x)*x_ss*n*__run1_feedback_relax2.*mat* EEG_sb*(x)*x_ss*n*__run2_feedback.*mat* EEG_sb*(x)*x_ss*n*__run2_feedback_relax2.*mat* EEG_sb*(x)*x_ss*n*__run2_relax2.*mat* EEG_sb*(x)*x_ss*n*__run2_relax2_feedback.*mat* **Load:** *.mat* file **Matrix name:** EEG_rec

For file names 'EEG_sb*(x)*x_ss*n*__', the participant number is denoted by *(x)*x, which can be a single digit (e.g., 8) or a double digit (e.g., 11), and the session number is denoted by *n*, which can be 1 to 7, depending on condition. For the NF data, when loaded, the pre-training resting-state data is presented in a matrix called EEG_relax, and the training data plus the post-training resting-state data, are presented in the matrix EEG_game. For the MI data, the file name describes the period of the recording, as this varied across trials – usually the data for the baseline resting-state (relax1) and the first run (with or without feedback) were recorded together followed by the second run (with feedback) and the post-resting-state (relax2) were recorded together. However, on occasion the resting-state period was recorded separately. When loaded, the data is presented in a matrix called EEG_rec.

Table 2
Description of the spreadsheets in each workbook.

Workbook	Worksheet	Description
NF_datasheets.*xlsx*	NF_summary-table	**Description of column headers:** **Summary_ID**: Index number **sb**: Participant number **ss:** Session number **EEG_ch**: EEG channel number **R1_tr_sec**: Baseline resting-state duration in seconds **G0_tr_sec**: Task duration in seconds **R2_tr_sec**: post-NF resting-state duration in seconds **oneCh_R1**: Alpha power measured from Pz electrode during baseline resting-state **oneC_G0**: Alpha power measured from Pz electrode during task period **oneCh_R2**: Alpha power measured from Pz electrode during post-NF resting-state **allCh_R1**: Alpha power measured from all electrodes during baseline resting-state **allCh_G0**: Alpha power measured from all electrodes during task period **allCh_R2**: Alpha power measured from all electrodes during post-NF resting-state **Gn_tr_sec**: **Gn** = run number, **tr_sec** = trial duration in seconds **oneCh_Gn**: Averaged alpha power for that run, as measured at the Pz electrode location **allCh_Gn**: Averaged alpha power for that run, as measured at across all electrode locations

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Table 2 (*continued*)

Workbook	Worksheet	Description
	NF_used-data	Session data with a summary_ID for sessions included in analysis. **Description of column headers:** **summary_ID**: The index number for that data in the NF_summary-table **SubjID**: Participant number **Session**: Session number
MI-datasheets.*xlsx*	DA_1-sec-classification-window	The calculations in this worksheet have been made using a 1-second classification widow. **Description of column headers:** **sb_ID**: Participant ID **ss**: Session information **Classes**: The number of classes **allTrials**: Number of trials **trPerClass**: Trials per class (left, right) **tetsTrials**: Test trials per fold: i.e., allTrials / numberOfFolds (where numberOfFolds = 6) **tetsTrPerClass**: Test trials per fold per class: i.e., allTrials/numberOfFolds/numberOfClasses (where numberOfFolds = 6, numberOfClasses = 2) **refPoint_sec**: Timestamp for the onset of the reference period, from trial onset **taskStart_sec**: Timestamp for the onset of the task, from trial onset **DA_peak_sec**: Timestamp for the peak DA, from trial onset **ORIG_refPeak_DA_mean**: Mean peak DA for the reference baseline period **ORIG_refPeak_DA_std**: Standard deviation of the peak DAs for the reference baseline period **ORIG_Peak_DA_mean**: Mean peak DA for the task period **ORIG_Peak_DA_std**: Standard deviation of the peak DAs for the task period
	DA_2-sec-classification-window	**Same as above** – the calculations here are based on a 2-second classification window.
	DA_summary-table	**Description of column headers:** **Summary_ID**: index number **ss_ run**: EEG data information **sb_ID**: Participant ID **ss**: Session number **run**: Run number
	DA_used-runs	**Column B** contains the summary_ID, from the the DA_summary-table, for the data included in the analysis of all runs. **Column E** contains the summary_ID, from the the DA_summary-table, for the data included in the analysis of significant runs, i.e., runs for which the classifier has detected the imagined movement with >70% accuracy, and the peak DA value during the task period is significantly higher than the peak DA value during the corresponding reference baseline period ($p < .05$).
psych-data-scores.*xlsx*	raw-scores	**Column A**: Participant ID **Column B**: Group assignment **Rows 4-12**: Control participants **Rows 17-26**: MI participants **Rows 31-40**: NF participants **Columns C to EB**: Pre-intervention questionnaire scores **Columns ED to JC**: Post-intervention questionnaire scores
	M+SD	Tables of the means, standard deviations, and the minimum and maximum scores for pre- and post- scores for each group on each questionnaire measure.

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Table 2 (*continued*)

Workbook	Worksheet	Description
	PCL-5	PTSD Diagnostic and statistical manual of mental disorders (5th edition – DSM-5) check list (PCL-5), data for each group. **Column M:** Clinical relevance.
	PC-PTSD	Primary care PTSD screen for DSM-5, data for each group. **Column M:** Clinical relevance.
	HTQ	Harvard Trauma Questionnaire (HTQ), data for each group. **Column M:** Clinical relevance.
	WEMWBS	Warwick-Edinburgh Mental Well-being Scale (WEMWBS), data for each group. **Column M:** Relevance.
	CD-RISC	Connor-Davidson Resilience Scale (CD-RISC), data for each group. **Column N:** Pre- post- change score.
	BRS	Brief Resilience Scales (BRS) data for each group. **Column N:** Pre- post- change score.
	GSE	General Self-Efficacy Scale (GSE), data for each group. **Column N:** Pre- post- change score.
mood-stress-data.*xlsx*	mood-stress	**Column A**: Participant ID A table of data for self-reported mood and stress levels, before and after each intervention session.

sessment measures (see Table 2). Pre- and post- training session measures of perceived mood and stress are available in the workbook titled mood-stress-data.*xlsx* (see Table 2).

2. Experimental Design, Materials and Methods

A previous study led by the team at the University of Rwanda, investigating the transgenerational transmission of PTSD, had involved a sample of women who had been pregnant at the time of the genocide. The women who had presented with severe PTSD at the time of the previous study were invited to community meetings. Given the lack of interaction with technology the average person in Rwanda has in general, a demonstration of the FlexEEG was given to the invited women, at these community meetings, in the company of the clinical psychologists with whom they have built a relationship. Two researchers from Ulster University (UU), with training in EEG recording, travelled to Rwanda for the demonstrations and data collection phase, and trained a UR research assistant in the delivery of the NF and MI protocol, to help with data collection. Community meetings were hosted in Kigali, Rwamagana, and Huye, during which a demonstration of the FlexEEG was given and the women were offered a chance to ask questions. They were invited to contact their clinical psychologist the next day if they were interested in taking part in the research study. Training sessions took place in public buildings; Casa Centre in Rwamagana, and AVEGA clinic in Kigali.

2.1. Participants

Participants ($N = 29$) had a clinical diagnosis of PTSD. Given the logistics of reaching participants in three separate locations, i.e., Kigali, Rwamagana, and Huye, for practical reasons group assignment was quasi-randomised. The researchers collecting data were based in Kigali. The Huye district is a three-hour drive from Kigali – therefore, these seven participants were assigned to the control group. Rwamagana is a one-and-a-half-hour drive from Kigali and the Rwamagana group was larger ($n = 14$). Therefore, two participants from Rwamagana (P21 and P29) were quasi randomly assigned to the control group (CG), and two (P26 and P28) were

quasi-randomly assigned to the MI group, and the remainder were assigned to the NF training group ($n = 10$). The remaining Kigali based participants ($n = 8$) were assigned to the MI group. Thus, the sample size per group was as follows; CG ($n = 9$), NF ($n = 10$), and MI ($n = 10$), ($N = 29$, all female).

2.2. Study protocol

The following protocol was adhered to, and an overview is given in Fig. 1.

1. Informed consent was received from all participants. A pre-intervention assessment date was scheduled at each of the three locations: the University of Rwanda, Huye Campus Huye, the Casa centre, Rwamagana, and the AVEGA clinic, Kigali. All participants from each location attended the assessment on the day allocated for that location.
2. On the allocated days, the pre-intervention clinical interviews were conducted by trained personnel. Participants at the Kigali and Rwamagana locations were given the date for their first training session.
3. Training sessions at the Casa centre in Rwamagana and the AVEGA clinic in Kigali, were held on alternating days. With the exception of Christmas day and New Year's Day, there were no gaps. The first training day was at the Casa centre in Rwamagana.
4. On the first day of training, participants were asked to switch their phones off while in the training room. Researchers explained the training protocol to each participant and gave them an opportunity to ask questions. Participants in the MI group completed a practice session on the first training day, prior to the training, for the configuration of the online model.
5. On all other training days, and additionally on the first training day, participants in the MI and NF training groups completed a short mood and stress questionnaire (see section 0), prior to training, and again following training. Participants had variations in literacy, therefore, a researcher assisted them in this task.
6. Participants were then seated at a desk with the game laptop in front of them. At the Kigali site, there were two desks at opposite ends of the training room and a seated area in the centre, for participants who were waiting for their training, or completing a pre/post mood and stress questionnaire. At the Rwamagana centre, there was a seated area outside the training room, and there were three desks in the training room. Therefore, at any given time one to three participants were completing their training sessions at the same time.
7. Following each training session, participants again completed a mood and stress questionnaire, assisted by a researcher. Any residual gel was cleaned from their hair.
8. Following the final training session, the post-intervention clinical interviews were scheduled. On the allocated date, these assessments were again conducted by trained personnel.

2.3. Psychological assessment questionnaires

During the pre- and post- clinical interviews, the following standardised measures of psychological assessment were administered:

- PTSD Diagnostic and statistical manual of mental disorders (5th edition - DSM-5) check list (PCL-5, 20-item self-report measure [6]); for a diagnosis of PTSD, a minimum of one question from category B items (questions 1-5), one from category C item (questions 6-7), two from category D items (questions 8-14), and two from category E items (questions 15-20), must be scored during the assessment – with a cut-off score of 30, as a general rule. To determine a clinically relevant improvement due to treatment, a reduction of 10 points in post treatment scores is the recommended minimum. Given the impact of the base-rate prevalence of PTSD within a given population on cut-off scores, and the natural tendency of sub-Saharan populations to describe suffering in terms of its physical effects, a reduction of 10 points or more in

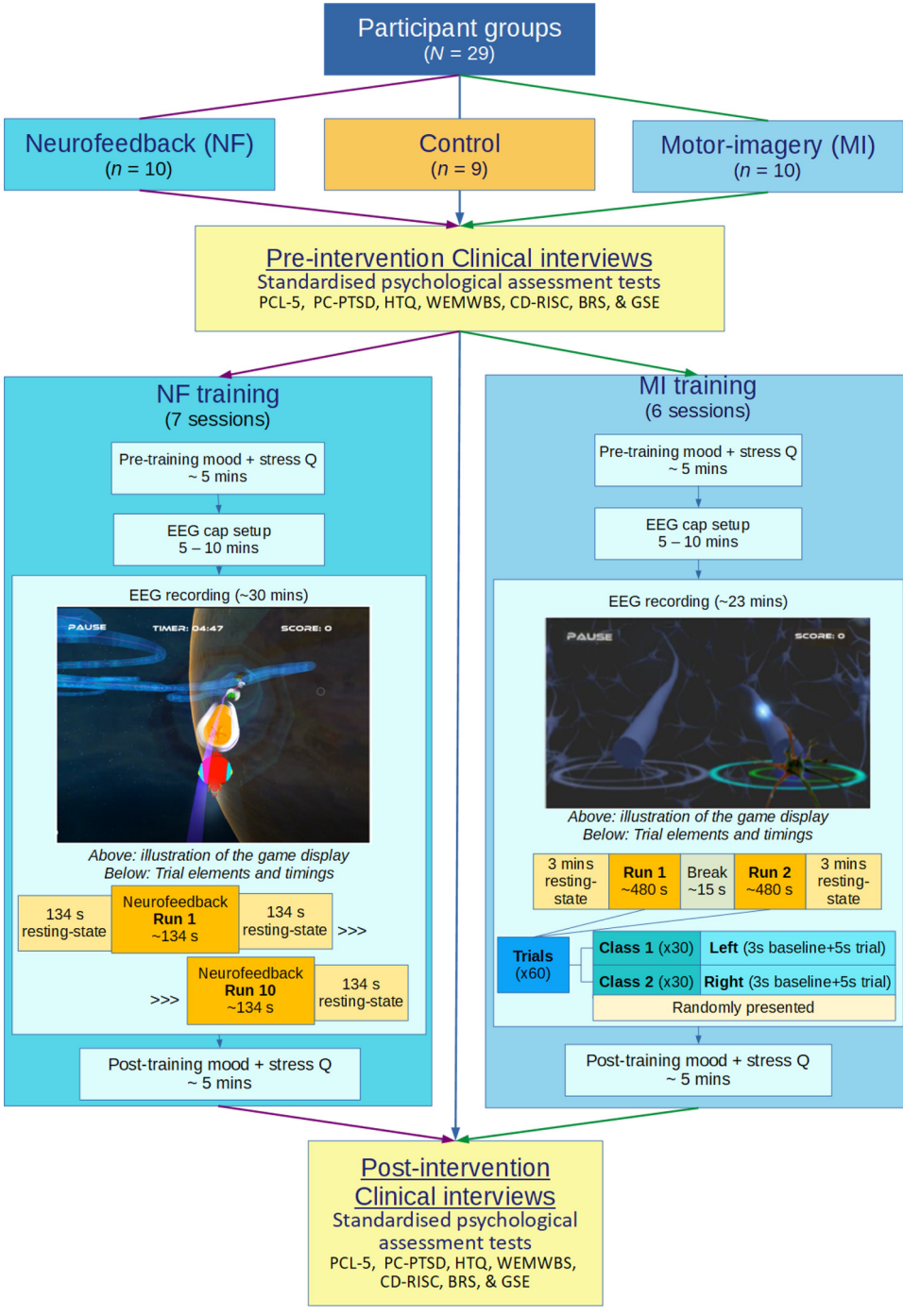

Fig. 1. Overview of the data acquisition procedure for all three participant groups.

post-treatment scores on the PCL-5 compared to pre-treatment scores, was considered more relevant for the Rwandan population [14, 15].
- Harvard Trauma Questionnaire (HTQ, 40-item self-report measure [7]), which has a recommended cut-off score of 2.2.
- Primary care PTSD screen for DSM-5 (PC-PTSD, 5-item self-report PTSD Screen [8]), which has a recommended cut-off score of 3, within the American population.
- Warwick-Edinburgh Mental Well-being Scale (WEMWBS, 14-item self-report measure [9]) – having an average population mean of 51 [16].
- Connor-Davidson Resilience Scale (CD-RISC, 10-item self-report measure [10]) – scores range from 0 to 40, with higher scores indicating greater resilience.
- Brief Resilience Scales (BRS, 6-item self-report measure [11]) – scores range from 1 to 5, with higher scores indicating greater resilience.
- General Self-Efficacy Scale (GSE, 10-item self-report measure [12]) – scores range from 10 to 40, with higher scores indicating greater self-efficacy.

A copy of each questionnaire is available in portable document format (pdf) in the data repository [folder name: questionnaires]. The PLC-5, PC-PTSD and the HTQ are standardised measures of PTSD symptom severity.

2.4. Pre- post- session questionnaire

Participants in the BCI training groups completed a short questionnaire before and after each training session, which recorded a measure of their perceived mood and level of stress. These pre- post- questionnaires and an excel spreadsheet containing the data, mood-stress-data.*xlsx*, are available in the data repository.

2.5. Training Tasks

The NeuroSensi games platform, developed by NeuroCONCISE Ltd. [3], presented the participants with either the neurofeedback or the motor-imagery protocol, depending on group assignment. For more detailed information on the NeuroSensi game paradigms, please refer to du Bois et al. (2021) [13].

2.5.1. Neurofeedback task

Each training session began and ended with an eyes-open resting-state EEG recording, both 134 s in duration. Between resting-state recordings, there were 10 NF training runs, each 134 s in duration. Runs were separated by breaks of approximately 15 s in duration (see Fig. 1). The task for each run involved keeping the game character (an astronaut) on a track in space, collecting rewards and avoiding hazards. The participant's alpha bandpower (8-12 Hz) was recorded from the Pz electrode (located over the midline parietal cortex). The time-varying alpha bandpower (calculated from successive 500 ms epochs of the band-pass filtered EEG signal) was used to calculate the mean alpha bandpower – which was used to modulate the feedback the participant received as follows. For each run, the alpha bandpower threshold was set to a value that was less than 60% of the mean alpha bandpower in epochs of the previous run (or the resting-state recording, in the case of the first run). When the mean alpha bandpower, extracted in real-time from the sliding-window epoch, was below this pre-set threshold, the game character behaved correctly. When the mean bandpower was above threshold, noise was added to cause the character to veer off track. Thus, participants were trained to self-regulate their alpha activity by supressing real-time alpha bandpower.

2.5.2. Motor-imagery task

Motor-imagery training sessions began and ended with an eyes-open resting-state EEG recording, both 3-minutes in duration. Between resting-state recordings, participants completed

two training runs, each approximately 480 s in duration, and separated by a ~15 s break (see Fig. 1). The motor-imagery paradigm was designed to train participants to modulate sensorimotor rhythms/oscillations by imagining movement. The NeuroSensi MI game interface has a representation of a neural axon on both sides of the display, and a 'neuron' (cell body and dendrites) game character that can move horizontally along the bottom of the display – between the bases of each neural axon. One trial has duration of 8 s and is comprised of a baseline period (3 s duration), and a task period (5 s duration). Following the 3 s baseline period, the task period begins with a light appearing at the far end of one of the neural axons – representing a neural spike/action potential. The participant is thus cued to begin the motor-imagery task for the corresponding hand, i.e., a light at the top of the axon on the left-hand side of the screen is the cue to imagine a left-hand movement. During the 5 s task period, the light travels down the axon. To perform an imagined movement, participants were instructed "to imagine lifting a mug", and they were asked not to tense their muscles throughout the imagined movement. During the task period, the neuron character moves horizontally left or right based on the participant's MI performance, thus providing the participant with continuous feedback. The participants objective while 'playing' the game, is to collect as many 'action potentials' crossing the axons as possible. Points are awarded when the neuron character is moving in the correct direction and for the proximity of the character to the 'action potential' when it each arrives at the end of the axon (see top right-hand corner of the game display in Fig. 1).

2.6. Analysis methods

2.6.1. Psychological assessment data

Non-parametric tests were chosen due to the small sample size. Group baseline measures for each questionnaire were compared using the Mann-Whitney U test to determine equivalence prior to intervention. The pre- post intervention measures for each questionnaire, for each group combination, were analysed using the Wilcoxon signed-rank test (2-tailed).

2.6.2. Pre- post- session questionnaire data

Due to the small sample size of each group, and some missing values in the data, a Friedman test was conducted on pre- training self-report measures to evaluate changes in perceived mood and stress levels from one session to the next, followed by the Wilcoxon signed-rank test (2-tailed) on each combination. To evaluate perceived changes in both mood and stress levels following each training session, the Wilcoxon signed-rank test (2-tailed) was applied to each pre- post- dataset combination, for each group.

2.6.3. Neurofeedback EEG signal processing and data analysis methods

Neurofeedback data: The directory path and file structures for the NF group's EEG data files are described in Table 1.

For the datasets acquired with the FlexEEG, rows 1-8 are EEG channels and channel 9 is the trigger channel – the names of the 8 channels are: 'FC3', 'FCZ', 'FC4', 'P3', 'O1', 'P7', 'OZ', 'PZ'. For the datasets acquired with the g.tec headsets, rows 1-32 are EEG channels and channel 33 is the trigger channel – the names of the 32 channels are: 'FP1', 'FP2', 'AF3', 'AF4', 'F7', 'F3', 'FZ', 'F4', 'F8', 'FC5', 'FC1', 'FC2', 'FC6', 'T7', 'C3', 'CZ', 'C4', 'T8', 'CP5', 'CP1', 'CP2', 'CP6', 'P7', 'P3', 'PZ', 'P4', 'P8', 'PO7', 'PO3', 'PO4', 'PO8', 'OZ'.

The EEG_relax.*mat* 2D structures contain the data for the pre-training resting-state (relax1) recordings. Triggers were not necessary; therefore, the trigger values remain at zero. Data for the training runs, and the post-training resting-state (relax2) recordings are in the EEG_game.*mat* 2D structures. During the training session, a technical glitch caused a trigger to be sent following the end of a run (before the beginning of the next run). Following the last run, this trigger indicates the beginning of the post-training resting-state period (relax2). The occurrence of this trigger following runs 1 to 9 should be ignored. For each training run, the beginning of the run is indicated by an odd trigger value and the end of the run is marked by the next even trigger

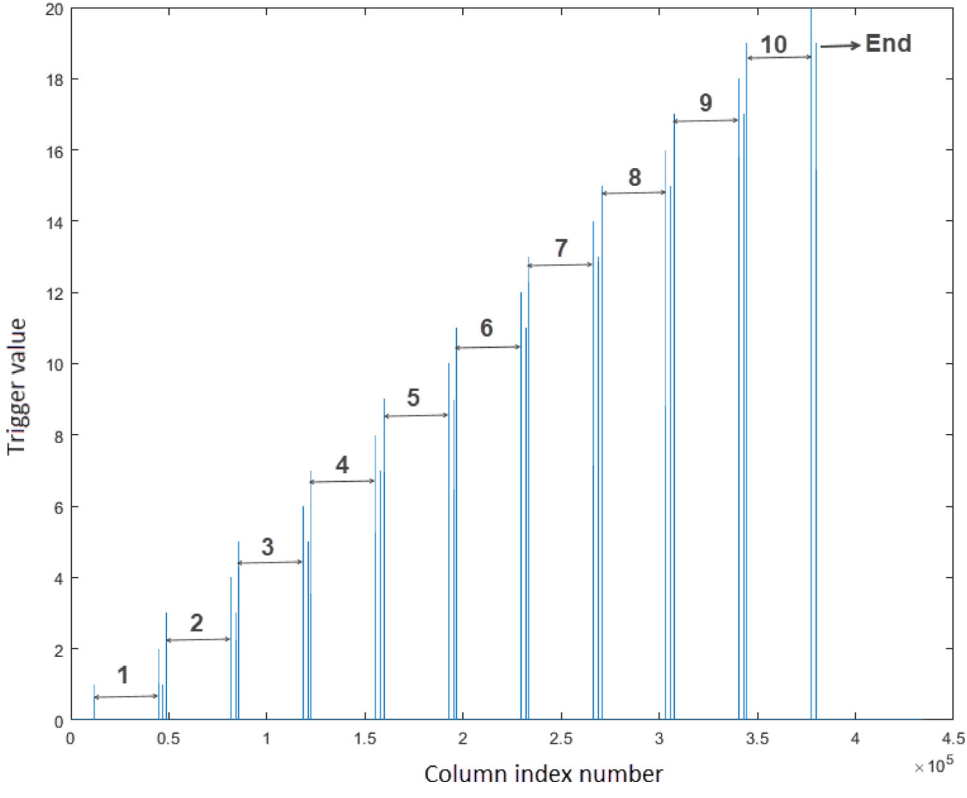

Fig. 2. Trigger values plotted for participant 23, session 6, training runs. Odd trigger values indicate the beginning of a run, even trigger values mark the end of a run, and every third trigger is ignored – except the final trigger, which indicates the end of the training.

value (see Fig. 2 as an example). Trigger information in the EEG_game.*mat* 2D structures, can be plotted in Matlab.

The post-training resting-state (relax2) period can be epoched as the 33,500 samples (134s x250 samples per second) following trigger 30. The following data structures are exceptions; EEG_sb16_ss5_EEG_game.*mat*, EEG_sb24_ss3_EEG_game.*mat*, and EEG_sb19_ss1_EEG_game.*mat*. In the case of the first two of these exceptions, a couple of triggers were sent (with high values) prior to the first trigger with a value of 1. These triggers are to be ignored. In the latter case (EEG_sb19_ss1_EEG_game.*mat*), the end of the trigger preceding the first trigger with a value of 1, marks the beginning of the first run.

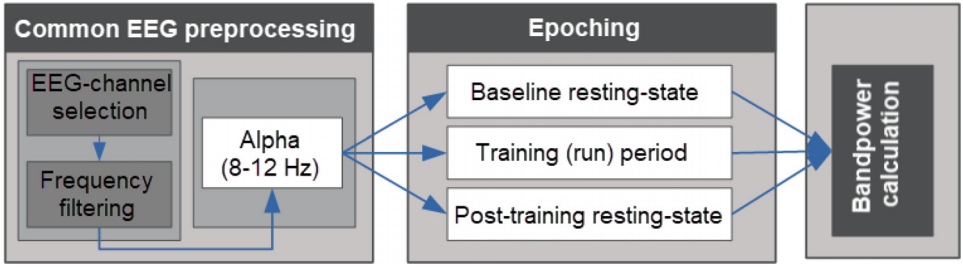

Fig. 3. Illustration of the steps outlined for the preprocessing of the NF data for analysis.

Full details outlining the steps involved in the data preprocessing, epoching and band-power calculations (illustrated in Fig. 3), as well as the neurofeedback analysis methods, are provided in du Bois et al. (2021), reference [13]. Furthermore, a summary of the calculated values used for statistical analyses of the NF data, is available in the NF_datasheets.*xlsxI* workbook provided.

2.6.4. Motor-Imagery EEG signal processing and data analysis methods

The directory path and file structures for the NF group EEG data files are described in Table 1., and trigger information can be plotted in Matlab.

The MI recording periods varied somewhat across trials. Usually, the data for the baseline resting-state (relax1) and the first run (with or without feedback) were recorded together followed by the second run (with feedback) and the post-resting-state (relax2), recorded together. However, on occasion the resting-state period was recorded separately. When loaded, the data is presented in a matrix called EEG_rec.*mat*. Trigger values 1 and 2 indicate the onset of the tasks belonging to class1 (left-hand imagined movement) and class2 (right-hand imagined movement), respectively. Trigger information for the relax1.*mat* dataset was not necessary, and therefore, the trigger values remain at zero. When the baseline resting-state (relax1) period and run periods were recorded in the same file, 33,500 samples (134s x250 samples per second) can be epoched from the start of the recording for the baseline resting-state period. The value of the trigger marking the beginning of the post-training resting-state period is 11, therefore, the post-training resting-state period can be epoched as the 33,500 samples following this trigger. However, occasionally the trigger did not send and on those occasions the post-training resting-state period can be calculated as the 33,500 samples prior to the end of the recording.

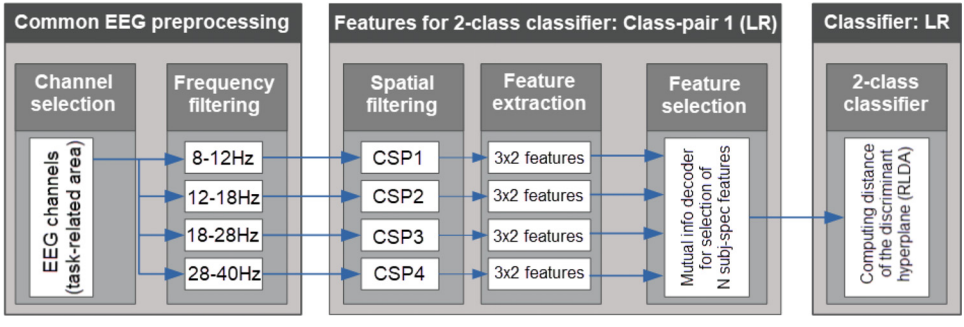

Fig. 4. Illustration of the FBCSP based multi-class classification method using mutual information (FBCSP-MI) selection and the regularized linear discriminant analysis (RLDA) based 2-class classifier.

For full details on the channel selection and frequency filtering processes, the offline signal processing, feature extraction and selection methods, and online signal processing, as well as the MI data analysis methods (illustrated in Fig. 4), refer to du Bois et al. (2021), reference [13]. As with the NF data values, the MI data values calculated for statistical analyses are provided in the MI-datasheets.*xlsx* workbook. (Figs. 3 and 4).

Ethics Statement

Approval for all protocols was granted by the Ulster University (UU) Research Governance Committee (ref REC/19/0102) and by the University of Rwanda - College of Medicine and Health Sciences (UR-CMHS) Institutional Review Board. Written informed consent was received from all participants prior to participation.

CRediT Author Statement

Damien Coyle: Supervision, Conceptualization, Methodology, Software, Hardware, Funding acquisition, Project management and administration, Writing- Reviewing and Editing. **Naomi du Bois:** Funding acquisition, Methodology, Data curation, Formal analysis, Visualisation, Writing-Reviewing and Editing. **Alain D. Bigirimana:** Funding acquisition, Software, Data curation, Formal analysis, Visualisation, Writing- Reviewing and Editing. **Attila Korik:** Software, Formal analysis, Visualisation, Writing- Reviewing and Editing. **Lisette Gaju Kéthina:** Data curation, Formal analysis, Visualisation, Writing- Reviewing and Editing. **Eugène Rutembesa:** Project administration, Writing- Reviewing and Editing. **Jean Mutabaruka:** Project administration, Writing- Reviewing and Editing. **Leon Mutesa:** Writing- Reviewing and Editing. **Girijesh Prasad:** Writing-Reviewing and Editing. **Stefan Jansen**: Supervision, Project administration, Writing- Reviewing and Editing.

Declaration of Competing Interest

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Prof Damien Coyle is Founder, CEO and shareholder of NeuroCONCISE Ltd, the supplier of the FlexEEG wearable Neurotechnology used in this study. The other authors declare no other conflict of interest.

Data Availability

EEG and psychological assessment datasets: Neurofeeedback for the treatment of PTSD (Original data) (Mendeley Data).

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