Title of submission to PLOS journals

Name1 Surname[1,2◕], Name2 Surname[2◕], Name3 Surname[2,3¤], Name4 Surname[2], Name5 Surname[2‡], Name6 Surname[2‡], Name7 Surname[1,2,3*], with the Lorem Ipsum Consortium[¶]

1 Affiliation Dept/Program/Center, Institution Name, City, State, Country
2 Affiliation Dept/Program/Center, Institution Name, City, State, Country
3 Affiliation Dept/Program/Center, Institution Name, City, State, Country

◕These authors contributed equally to this work.
‡These authors also contributed equally to this work.
¤Current Address: Dept/Program/Center, Institution Name, City, State, Country
†Deceased
¶Membership list can be found in the Acknowledgments section.
* correspondingauthor@institute.edu

Abstract

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Curabitur eget porta erat. Morbi consectetur est vel gravida pretium. Suspendisse ut dui eu ante cursus gravida non sed sem. Nullam sapien tellus, commodo id velit id, eleifend volutpat quam. Phasellus mauris velit, dapibus finibus elementum vel, pulvinar non tellus. Nunc pellentesque pretium diam, quis maximus dolor faucibus id. Nunc convallis sodales ante, ut ullamcorper est egestas vitae. Nam sit amet enim ultrices, ultrices elit pulvinar, volutpat risus.

Author summary

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Curabitur eget porta erat. Morbi consectetur est vel gravida pretium. Suspendisse ut dui eu ante cursus gravida non sed sem. Nullam sapien tellus, commodo id velit id, eleifend volutpat quam. Phasellus mauris velit, dapibus finibus elementum vel, pulvinar non tellus. Nunc pellentesque pretium diam, quis maximus dolor faucibus id. Nunc convallis sodales ante, ut ullamcorper est egestas vitae. Nam sit amet enim ultrices, ultrices elit pulvinar, volutpat risus.

Introduction

Lorem ipsum dolor sit [1] amet, consectetur adipiscing elit. Curabitur eget porta erat. Morbi consectetur est vel gravida pretium. Suspendisse ut dui eu ante cursus gravida non sed sem. Nullam Eq (1) sapien tellus, commodo id velit id, eleifend volutpat quam. Phasellus mauris velit, dapibus finibus elementum vel, pulvinar non tellus. Nunc pellentesque pretium diam, quis maximus dolor faucibus id. [2] Nunc convallis sodales ante, ut ullamcorper est egestas vitae. Nam sit amet enim ultrices, ultrices elit pulvinar, volutpat risus.

$$\mathrm{P_Y} = \underbrace{H(Y_n) - H(Y_n|\mathbf{V}_n^Y)}_{S_Y} + \underbrace{H(Y_n|\mathbf{V}_n^Y) - H(Y_n|\mathbf{V}_n^{X,Y})}_{T_{X\to Y}}, \quad (1)$$

Materials and methods

0.1 Overview

We conducted an offline/online BCI experiment, recording the EEG (Unicorn gtec − 8 Channels) from 29 right-handed participants (14 female; mean age = 22) during a single recording session. The experiment aims to study the feasibility of using Action Words (AW) as a paradigm for BCI, comparing this with the traditional Motor Imagery (MI) and Motor Observation (MO) paradigms. The tasks for MI consist of imaging right-hand or leg movement, while that for AW is reading and mentally rehearsing the presented arm and leg-related action words, and for MO is watching the corresponding first-person perspective videos of the action words. Participants completed two offline and one online run of each experimental condition (MO, MI, AW), in a counterbalanced order. Each run consisted of 30 trials (10 for online runs) with a trial duration of 9 seconds (offline) or 10 seconds (online with neurofeedback). We collected the Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) and demographic information before the experiment. After the second run of each experimental condition, we collected NASA-TLX. At the end of the experiment, we asked usability questions about each condition. We evaluated the aforementioned paradigms using Movement-Related Potentials (MRP), Event-Related Spectral Perturbation (ERSP), classification rates (offline and online), NASA-TLX, and usability questionnaires. The experiment was approved by the Ethics Commission from both Potsdam University and Institution University of Envigado.

0.2 Participants

We collected EEG data from 29 healthy and right-handed participants (14 female) in a voluntary manner. They were Spanish speakers, mostly engineering students (only one lecturer, one lawyer, and one professional in marketing and business) from the Institution University of Envigado, Colombia. Their ages range from 18 to 30 years old (mean= 21.89, SD=3.91). All of them reported normal or corrected to normal vision. None of them reported neurological or psychiatric disorders or drug abuse. No one had previous experience using BCI; only one person had previously used EEG for other purposes. Participants were informed both orally and in writing about the procedure and the EEG recording. All participants gave written informed consent.

0.3 Materials

The Lancaster Sensorimotor Norms represent a set of sensorimotor strength evaluation from 39,707 concepts across six perceptual modalities (touch, hearing, smell, taste, vision, and interoception) and five action effectors (mouth/throat, hand/arm, foot/leg, head excluding mouth/throat, and torso), collected from a total of 3,500 individual participants (cite lancaster). We initially chose the set of 25 high-ranked words using the foot/leg and hand/arm action effect. Later, we selected the five most prominent and adequate for the current setup, considering that for Motor Observation, we planned to reproduce the action words in a first-person perspective video. Therefore, we selected the words (Spanish version in parentheses) "Write" (*Escribir*), "Throw" (*Lanzar*), "Cut" (*Cortar*), "Plug" (*Conectar*), "Clap" (*Aplaudir*) for hand/arm, and "Walk" (*Caminar*), "Sit" (*Sentar*), "Step" (*Paso*), "Jump" (*Saltar*), "Kick" (*Patear*) for foot/leg. Figure 1 shows the average ratings of Leg and Hand selected words from the Action, Perceptual, and Sensorimotor dimensions. We can perceive that in Action, the selected words reached over 4.0 in the corresponding factor; the ratings are similar for visual in the Perceptual and Sensorimotor, where similarly, like in Action, they reached over or close to 4.0 rating. This guarantees that these words represent a motor-related action and sensorimotor activity for each member, which will be crucial for the classification in BCI.

The English selected Action Words were translated into Spanish, where words like "Plug" and "Step" were adapted to the video's activity. For pluging, its more close word is "connect", which translates "Conectar", and similarly with Step, the more similar movement is "Marching" (upping and down the knees), where in Spanish translates as "Marchar". We recorded videos from a first-person perspective as Angelini and colleagues reported that the strongest sensorimotor responsiveness emerged from this perspective (cite). Additionally, we recorded these videos using different environments and persons executing the action, to generalize the action and user can not be distracted or overthink about the details around. Thus, a total of six videos for each AW were recorded for each limb (Legs and Hands). Also, the recording system (cameras) was different, but it kept high-quality videos. Some FP videos were affected by the natural movement of the body when it executes the actions. Finally, we created gender-matched videos to use with either women or men participants. The videos are available online at this link. (This will be updated for the OSF repository link). For Motor Imagery, we used arrows to indicate either arm (upward) or leg (downward) imaginary movement.

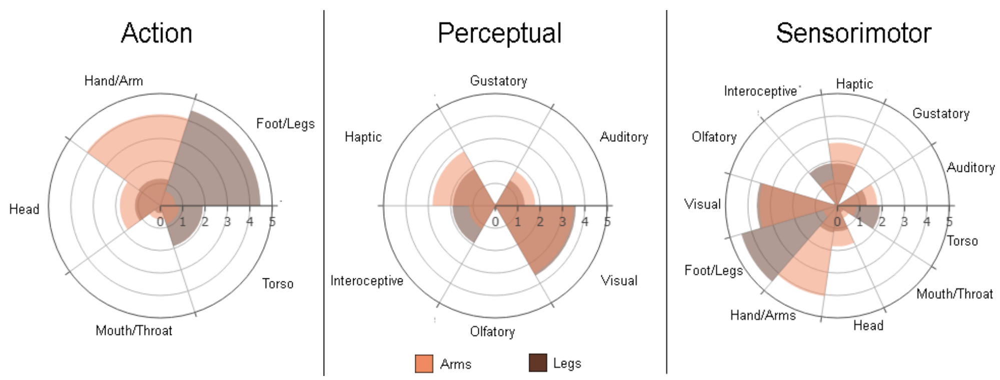

Fig 1. Sensorimotor Lancaster Norms ratings. Average ratings for the selected Arm and Leg Action Words. These ratings are represented in three dimensions: Action, Perceptual, and Sensorimotor. The average ratings evidence a clear distinction between Arm and Leg words for action and sensorimotor, and being similarly rated for visual in Perceptual and Sensorimotor.

0.4 Procedure

The subjects sat and were asked to make themselves comfortable and avoid any other movements during the recordings. The experiment ran on a laptop computer placed at 60-80 cm from the subject.

Our main objective is to check the feasibility of using Action Words instead of Motor Imagery or Motor Observation for BCI. To test this, we asked the subjects to perform right-hand and leg imaginary movement in each paradigm accordingly to the stimuli. Action words are presented at the center of the screen in Arial, white color with black as background, and a visual angle of approximately 3.0 to 6.0 degrees. Videos were presented in the middle of the screen with a resolution of 800x800 pixels. Similarly, cross and arrows for Motor Imagery were placed in the middle, rendered in white color. We used Psychopy 2023 to visualize the stimuli. We had two experiment modes: offline and online. During online, we presented the accuracy percentage as neurofeedback. Following Alimardini and colleagues (cite), who demonstrated that positive-biased leads to higher self-regulation motor imagery brain patterns, we include pseudo-random feedback based on the real accuracy + number generator from 0-20, keeping the upper limits of a real accuracy value (below 100). Both modes shared the same experimental protocol, with online including the feedback part (2 secs more). Each trial began with a black screen for 3 seconds, followed by the attention cue where a cross fixation appears and a beep sound is reproduced by 1 - 1.5 secs. Later, the motor cue is presented for three seconds: either the Action Word (AW), the arrow and cross fixation (Motor Imagery), or the video (Motor Observation). After this, during online, the feedback appears for 2 secs, and then the trial ends with 1.0 to 1.5 secs for inter-trial interval (Fig 3).

For AW, Participants were instructed to read mentally the word and rehearsal the motor action. While for MO, merely observing the video. And for MI, following Neuper et al. [**?**], we encouraged the subjects to perform the kinesthetic experience strategy during the execution of the imagery tasks, as this showed better performance in the classifiers. Participants completed two offline and one online runs of each experimental condition (MO, MI, AW) in a counterbalanced order. Each run consisted of 20 trials (10 for online runs) with a trial duration of 9 seconds (offline) or 12 seconds (online with neurofeedback). Between each run, a resting period of 5 minutes took place. The participants filled up demographics and Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) at the beginning. Later, after the second run of each paradigm, they completed the NASA-TLX. Finally, subjective and usability questions were asked in a final questionnaire.

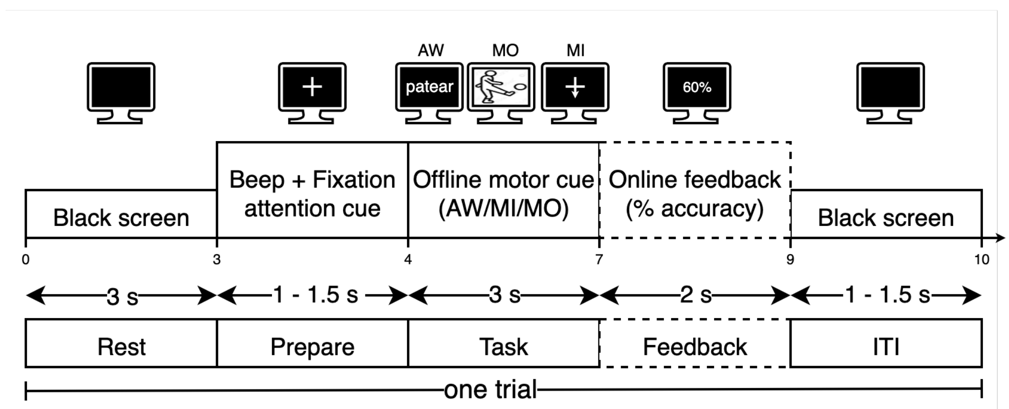

Fig 2. Experimental timing. The trial is composed of three seconds for resting (gray screen), 1.0 to 1.5 seconds for preparing (a beep sound plus the visual cue), followed by three seconds for performing the task (motor action), plus two seconds for feedback (only for online), and finally an inter-trial interval for 1.0 to 1.5 seconds. In total, each trial lasts nine seconds for offline and 10 for online.

0.5 Data Acquisition and Analysis

0.5.1 Apparatus

We collected the EEG data using a g.tec Unicorn Hybrid Black 24-bit board at a sampling rate of 250 Hz. Following the 10-20 EEG placement system, eight hybrid electrodes were used and placed on the scalp over areas that cover the Frontal (Fz), Central (C3, Cz, C4), Parietal (PO7, Pz, PO8), and Occipital (Oz) cortices. Left and right mastoids were used as reference and ground electrodes, respectively. Labstreaminglayer (LSL) is used for recording and synchronizing the EEG data with Psychopy.

0.5.2 Signal processing

We used EEGLAB (2024.2.1) [?] under Matlab 2023b to process the raw EEG data. The initial processing steps involved loading the data and removing epochs and events that were not part of the experimental conditions (Arm and Leg). We applied a band-pass filter from 1 to 40 Hz using a finite impulse response (FIR) filter. Line noise at 60 Hz was addressed using the Cleanline plugin to avoid the creation of band-holes and distortions that can occur with notch filters. The data was then re-referenced using a common average reference (CAR). Artifact rejection was performed using the Cleanraw plugin with specific criteria (BurstCriterion=25, WindowCriterion=0.2) to automatically identify and remove corrupted data segments. The percentage of retained data and the variance reduction in decibels (dB) from this process were calculated and stored for each participant. After this procedure, in average, 17% of Arm events were rejected while 18% of Legs events. This data processing stage aligns with the principles of Makoto's EEGLAB pipeline for EEG data processing. [?]

0.5.3 Feature Extraction and Classification

This study integrates two distinct types of electroencephalography (EEG) features: Event-Related Potentials (ERP) and oscillatory activity, characterized by Event-Related de-Synchronization/Synchronization (ERD/ERS) and analyzed through Filter Bank Common Spatial Pattern (FBCSP) features. While ERD/ERS patterns are commonly used in Motor Imagery (MI) Brain-Computer Interfaces (BCIs) to capture changes in alpha and beta frequency bands, ERPs are stimulus-locked components that provide additional temporal information. The inclusion of Action Words as a paradigm introduces both of these components, making it beneficial to analyze both stimulus-locked and time-locked EEG signals to comprehensively evaluate the neural response and improve classification accuracy.

ERP features were extracted from a specific set of channels, including Fz, C3, Cz, C4, Pz, and Oz. This was done on epochs with a time window from -0.5s to 2.5s relative to the cue, using a baseline correction from -0.5s to 0s. The features were computed as the mean amplitude within a sliding window of 0.5s with a step size of 0.5s. As a result, we had 36 features (6 time windows x 6 channels). FBCSP features were extracted from channels C3, Cz, C4, PO7, Pz, and PO8. The signal was filtered into multiple frequency bands: 8-12 Hz, 12-16 Hz, 16-20 Hz, 20-24 Hz, 24-28 Hz, and 13-30 Hz. The spatial patterns were then computed using CSP on a time window from 0.5s to 3.0s after the cue. As a result, we had 24 features (6 filter bands x 4 CSP components). To reduce the dimensionality and improve separability, mRMR (minimum Redundancy Maximum Relevance) feature selection was applied to both ERP and FBCSP feature sets, selecting the top 10 features for each. Before feature selection, the features were scaled using a StandardScaler.

Then, we used a Support Vector Machine (SVC) with a linear kernel (no hyperparameterization) to distinguish leg and arm signals. The model's performance was evaluated for each of the three paradigms (AW, MI, MO) using three different feature sets: i) only FBCSP features; ii) only ERP features; and iii) a combined feature set of both FBCSP and ERP features. The classification was carried out in two phases: offline and online. Offline classification uses A 10-fold stratified cross-validation on the offline data to assess the performance of each model configuration. While online classification uses the models trained on the offline data to classify unseen online epochs. We simulate an online scenario using an over-time classification, where the classifier was applied to a 2.5s sliding window with a step size of 0.25s over a 5s period of the online data. For Action Words, the online performance was further analyzed by differentiating between "seen" words (those present in the offline training set) and "new" words (not present in the offline training set). This represents a real generalization because most Motor Imagery BCI systems use the same cue during offline and online, where the classifiers reproduce a memorization task instead of predicting new unseen data.

0.5.4 Movement-related Potential and Event-related spectral perturbation

To effectively analyze the neurophysiological correlates of the three paradigms, we conducted two distinct but complementary analyses. Motor Imagery (MI) is traditionally associated with modulations of oscillatory activity in the alpha (8-12 Hz) and beta (13-30 Hz) frequency bands, known as Event-Related Desynchronization/Synchronization (ERD/ERS) patterns. However, paradigms involving linguistic processing, such as Action Words (AW), have been shown to elicit both these oscillatory patterns and time-locked temporal components, known as Event-Related Potentials (ERPs). Therefore, examining both spectral and temporal responses provides a more comprehensive understanding of the neural activity elicited by each task. It is important to note that the term Movement-Related Potential (MRP) is also used to refer to the temporal components preceding and accompanying movements. In this context, our ERP analysis serves to capture these temporal dynamics.

The initial step for both analyses involved segmenting the cleaned data into epochs based on the visual cue for either arm or leg movements. These epochs, spanning from -1000 ms to 3000 ms relative to the cue, were then grouped by paradigm (AW, MO, MI) and task (arm or leg) for further processing. The Event-Related Spectral Perturbation (ERSP) was calculated using the newtimef function in EEGLAB. This analysis was performed on the C3, Cz, and C4 electrodes, which are located over the sensorimotor cortex. The function computed the changes in spectral power in a time-frequency domain for a frequency range of 4-40 Hz and a time window of -1000 ms to 3000 ms relative to the cue. A baseline correction was applied using the interval from -1000 ms to 0 ms. For each condition, the data from all subjects and trials were merged to generate a grand average ERSP.

Event-Related Potentials (ERPs) were computed in the time domain for a broader set of channels: Fz, C3, Cz, C4, Pz, and Oz. For each subject and condition, all trial epochs were averaged to generate an ERP waveform. A baseline correction was applied using the time window from -500 ms to 0 ms. Finally, a grand average ERP was calculated by averaging the ERPs across all subjects to examine the overall temporal brain response for each task. A moving average with a window of 10 samples was then applied to the ERP waveform to smooth the data.

0.6 Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) and NASA Task Load Index

Vividness of Movement Imagery Questionnaire-2 (VMIQ-2) is a self-report scale designed to measure a person's ability to vividly imagine themselves performing simple motor tasks. The questionnaire assesses three distinct types of imagery on a 5-point Likert scale (1 = No image at all, 5 = Perfectly clear and as vivid as seeing it): internal visual imagery, external visual imagery, and kinesthetic imagery. The VMIQ-2 is an updated version of the original VMIQ, developed in 2008 by Roberts and colleagues. It consists of 36 items, with 12 items for each of the three subscales. The VMIQ-2 is a practical tool for subjectively assessing a person's motor imagery capacity before they participate in motor imagery-based BCI experiments, as it can help identify individuals who might have difficulty with the task.

On the other hand, the NASA-TLX (Task Load Index) is a commonly used subjective method to measure perceived workload. It evaluates workload across six dimensions: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. Each of these dimensions is rated on a 10-point scale, with anchors ranging from "low" to "high" or "good" to "poor" for performance. In addition to the ratings, the NASA-TLX includes a pairwise comparison procedure. Participants are asked to identify which of the six dimensions contributed most to the overall workload of a task. The number of times a dimension is selected in these comparisons is used to weight its corresponding rating, resulting in a single, comprehensive workload score.

Results

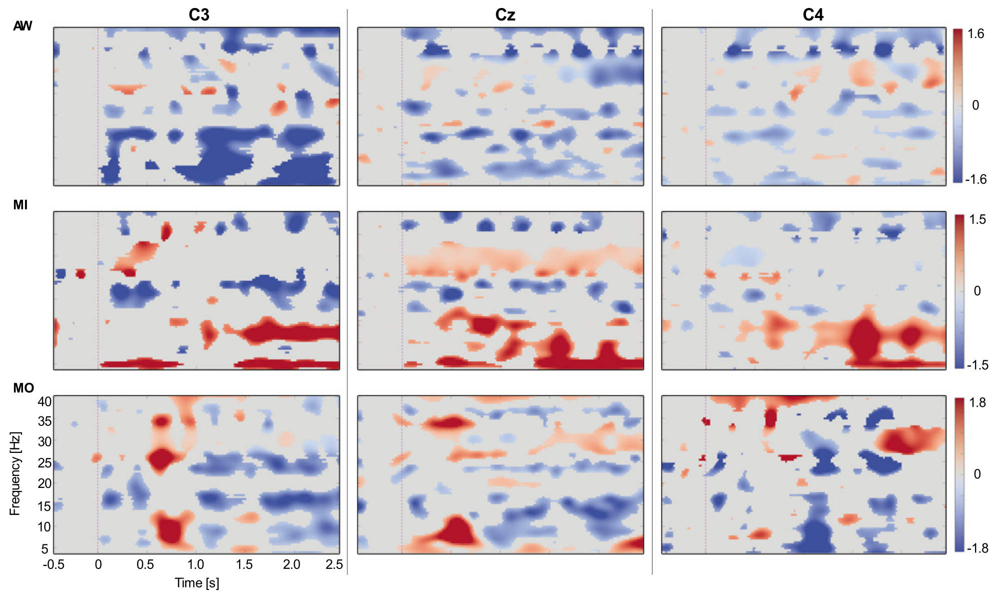

Fig 3. Experimental timing. The trial is composed of three seconds for resting (gray screen), 1.0 to 1.5 seconds for preparing (a beep sound plus the visual cue), followed by three seconds for performing the task (motor action), plus two seconds for feedback (only for online), and finally an inter-trial interval for 1.0 to 1.5 seconds. In total, each trial lasts nine seconds for offline and 10 for online.

Nulla mi mi, venenatis sed ipsum varius, Table 1 volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero.

Table 1. Table caption Nulla mi mi, venenatis sed ipsum varius, volutpat euismod diam.

Heading1				**Heading2**			
$cell1row1$	cell2 row 1	cell3 row 1	cell4 row 1	cell5 row 1	cell6 row 1	cell7 row 1	cell8 row 1
$cell1row2$	cell2 row 2	cell3 row 2	cell4 row 2	cell5 row 2	cell6 row 2	cell7 row 2	cell8 row 2
$cell1row3$	cell2 row 3	cell3 row 3	cell4 row 3	cell5 row 3	cell6 row 3	cell7 row 3	cell8 row 3

Table notes Phasellus venenatis, tortor nec vestibulum mattis, massa tortor interdum felis, nec pellentesque metus tortor nec nisl. Ut ornare mauris tellus, vel dapibus arcu suscipit sed.

LOREM and IPSUM nunc blandit a tortor

3rd level heading

Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque. Quisque augue sem, tincidunt sit amet feugiat eget, ullamcorper sed velit. Sed non aliquet felis. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Mauris commodo justo ac dui pretium imperdiet. Sed suscipit iaculis mi at feugiat.

1. react
2. diffuse free particles
3. increment time by dt and go to 1

Sed ac quam id nisi malesuada congue

Nulla mi mi, venenatis sed ipsum varius, volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero.

- First bulleted item.
- Second bulleted item.
- Third bulleted item.

Discussion

Nulla mi mi, venenatis sed ipsum varius, Table 1 volutpat euismod diam. Proin rutrum vel massa non gravida. Quisque tempor sem et dignissim rutrum. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi at justo vitae nulla elementum commodo eu id massa. In vitae diam ac augue semper tincidunt eu ut eros. Fusce fringilla erat porttitor lectus cursus, vel sagittis arcu lobortis. Aliquam in enim semper, aliquam massa id, cursus neque. Praesent faucibus semper libero [3].

Conclusion

CO_2 Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla

Table 2. Linguistic features of action words in English and Spanish.

Word_En	Word_Sp	AW_limb	Log_freq_En	Log_freq_Sp	Syllabes_En (letters)	Syllabes_Sp (letters)
JUMP	SALTAR	Leg	4.629	4.438	1 (4)	2 (6)
KICK	PATEAR	Leg	4.514	3.595	1 (4)	3 (6)
MARCH	MARCHAR	Leg	4.960	4.235	1 (5)	2 (7)
SIT	SENTAR	Leg	5.036	4.627	1 (3)	2 (6)
WALK	CAMINAR	Leg	5.089	4.858	1 (4)	3 (7)
CLAP	APLAUDIR	Arm	3.391	3.777	1 (4)	3 (8)
CONNECT	CONECTAR	Arm	4.368	4.740	2 (7)	3 (8)
CUT	CORTAR	Arm	5.279	4.639	1 (3)	2 (6)
THROW	LANZAR	Arm	4.787	4.718	1 (4)	2 (6)
WRITE	ESCRIBIR	Arm	5.061	5.424	1 (4)	3 (8)

Table 3. Linguistic features action words in

Word	Foot_leg (sd)	Hand_arm (sd)	Head (sd)	Mouth (sd)	Torso (sd)	Max_strength	Exclusivity	Dominant
JUMP	4.85 (0.489)	1.7 (1.689)	1.3 (1.75)	0.3 (0.923)	2.55 (1.849)	4.85	0.425	Foot_leg
KICK	4.75 (0.786)	0.15 (0.366)	0.55 (1.146)	0 (0)	0.65 (0.933)	4.75	0.779	Foot_leg
MARCH	3.6 (2.137)	1.55 (1.761)	1.35 (1.843)	0.55 (1.146)	1.35 (1.899)	3.6	0.363	Foot_leg
SIT	4.211 (0.976)	1.263 (1.593)	1.368 (1.571)	0.263 (0.733)	3.684 (1.701)	4.211	0.366	Foot_leg
WALK	4.947 (0.229)	1.368 (1.461)	1.105 (1.243)	0.526 (1.02)	1.263 (1.368)	4.947	0.48	Foot_leg
CLAP	0.3 (0.923)	4.55 (1.05)	1.5 (2.013)	0.25 (0.639)	0.55 (1.05)	4.55	0.601	Hand_arm
CONNECT	0.75 (1.02)	2.3 (1.838)	1.8 (1.908)	1.25 (1.713)	0.55 (1.276)	2.3	0.263	Hand_arm
CUT	1.263 (1.727)	4.211 (1.273)	1.842 (1.922)	1.053 (1.58)	1.316 (1.668)	4.211	0.326	Hand_arm
THROW	0.864 (1.246)	4.591 (1.246)	1.545 (1.969)	0.227 (0.869)	1.409 (1.623)	4.591	0.505	Hand_arm
WRITE	0.227 (0.752)	4.727 (0.703)	2.364 (2.06)	0.273 (0.767)	0.409 (0.854)	4.727	0.562	Hand_arm

pulvinar lectus consectetur pellentesque. Quisque augue sem, tincidunt sit amet feugiat eget, ullamcorper sed velit.

Sed non aliquet felis. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Mauris commodo justo ac dui pretium imperdiet. Sed suscipit iaculis mi at feugiat. Ut neque ipsum, luctus id lacus ut, laoreet scelerisque urna. Phasellus venenatis, tortor nec vestibulum mattis, massa tortor interdum felis, nec pellentesque metus tortor nec nisl. Ut ornare mauris tellus, vel dapibus arcu suscipit sed. Nam condimentum sem eget mollis euismod. Nullam dui urna, gravida venenatis dui et, tincidunt sodales ex. Nunc est dui, sodales sed mauris nec, auctor sagittis leo. Aliquam tincidunt, ex in facilisis elementum, libero lectus luctus est, non vulputate nisl augue at dolor. For more information, see S1 Appendix.

Supporting information

S1 Fig. Bold the title sentence. Add descriptive text after the title of the item (optional).

S2 Fig. Lorem ipsum. Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque.

Table 4

Word	Auditory (sd)	Gustatory (sd)	Haptic (sd)	Interoceptive (sd)	Olfactory (sd)	Visual (sd)	Max_strength	Exclusivity	Dominant
JUMP	1.556 (1.617)	0 (0)	1.389 (1.787)	2.833 (1.724)	0 (0)	3.944 (1.392)	3.944	0.406	Visual
KICK	0.895 (1.15)	0.211 (0.631)	3.526 (1.611)	1.842 (1.608)	0.158 (0.501)	3.632 (1.461)	3.632	0.338	Visual
MARCH	2.722 (1.776)	0 (0)	0.611 (1.501)	0.944 (1.474)	0.278 (1.179)	4.111 (1.676)	4.111	0.474	Visual
SIT	0.611 (1.337)	0.194 (0.889)	2.306 (1.895)	1.417 (1.888)\	0.222 (0.959)	3.194 (1.737)	3.194	0.378	Visual
WALK	0.765 (1.437)	0 (0)	1.588 (2.002)	2.529 (1.807)	0.176 (0.728)	3.118 (1.965)	3.118	0.381	Visual
CLAP	4.625 (0.924)	0 (0)	2.833 (1.880)	0.625 (1.173)	0 (0)	3.75 (1.294)	4.625	0.391	Auditory
CONNECT	1.158 (1.500)	0.263 (0.733)	1.579 (1.644)	1.105 (1.595)	0.211 (0.713)	2.842 (2.218)	2.842	0.368	Visual
CUT	0.95 (1.276)	0.05 (0.224)	3.45 (1.820)	2.15 (2.134)	0.1 (0.308)	3.25 (1.773)	3.45	0.342	Haptic
THROW	1.059 (1.749)	0 (0)	3 (1.936)	0.882 (1.536)	0 (0)	4 (1.225)	4	0.447	Visual
WRITE	1.116 (1.636)	0.279 (1.054)	3.163 (1.772)	1.186 (1.763)	0.256 (0.875)	3.651 (1.771)	3.651	0.352	Visual

Table 5. ta

Word	Auditory (sd)	Gustatory (sd)	Haptic (sd)	Interoceptive (sd)	Olfactory (sd)	Visual (sd)	Foot_leg (sd)	Hand_arm (sd)	Head (sd)	Mouth (sd)	Torso (sd)	Max_strength	Exclusivity	Dominant
JUMP	1.556 (1.617)	0 (0)	1.389 (1.787)	2.833 (1.724)	0 (0)	3.944 (1.392)	4.85 (0.489)	1.7 (1.689)	1.3 (1.75)	0.3 (0.923)	2.55 (1.849)	4.85	0.237	Foot_leg
KICK	0.895 (1.15)	0.211 (0.631)	3.526 (1.611)	1.842 (1.608)	0.158 (0.501)	3.632 (1.461)	4.75 (0.786)	0.15 (0.366)	0.55 (1.146)	0 (0)	0.65 (0.933)	4.75	0.29	Foot_leg
MARCH	2.722 (1.776)	0 (0)	0.611 (1.501)	0.944 (1.474)	0.278 (1.179)	4.111 (1.676)	3.6 (2.137)	1.55 (1.761)	1.35 (1.843)	0.55 (1.146)	1.35 (1.899)	4.111	0.241	Visual
SIT	0.611 (1.337)	0.194 (0.889)	2.306 (1.895)	1.417 (1.888)	0.222 (0.959)	3.194 (1.737)	4.211 (0.976)	1.263 (1.593)	1.368 (1.571)	0.263 (0.733)	3.684 (1.701)	4.211	0.214	Foot_leg
WALK	0.765 (1.437)	0 (0)	1.588 (2.002)	2.529 (1.807)	0.176 (0.728)	3.118 (1.965)	4.947 (0.229)	1.368 (1.461)	1.105 (1.243)	0.526 (1.02)	1.263 (1.368)	4.947	0.285	Foot_leg
CLAP	4.625 (0.924)	0 (0)	2.833 (1.880)	0.625 (1.173)	0 (0)	3.75 (1.294)	0.3 (0.923)	4.55 (1.050)	1.5 (2.013)	0.25 (0.639)	0.55 (1.05)	4.625	0.244	Auditory
CONNECT	1.158 (1.5)	0.263 (0.733)	1.579 (1.644)	1.105 (1.595)	0.211 (0.713)	2.842 (2.218)	0.75 (1.020)	2.3 (1.838)	1.8 (1.908)	1.25 (1.713)	0.55 (1.276)	2.842	0.191	Visual
CUT	0.95 (1.276)	0.05 (0.224)	3.45 (1.820)	2.15 (2.134)	0.1 (0.308)	3.25 (1.773)	1.263 (1.727)	4.211 (1.273)	1.842 (1.922)	1.053 (1.58)	1.316 (1.668)	4.211	0.212	Hand_arm
THROW	1.059 (1.749)	0 (0)	3 (1.936)	0.882 (1.536)	0 (0)	4 (1.225)	0.864 (1.246)	4.591 (0.796)	1.545 (1.969)	0.227 (0.869)	1.409 (1.623)	4.591	0.261	Hand_arm
WRITE	1.116 (1.636)	0.279 (1.054)	3.163 (1.772)	1.186 (1.763)	0.256 (0.875)	3.651 (1.771)	0.227 (0.752)	4.727 (0.703)	2.364 (2.06)	0.273 (0.767)	0.409 (0.854)	4.727	0.255	Hand_arm

S1 File. Lorem ipsum. Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque.

S1 Video. Lorem ipsum. Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque.

S1 Appendix. Lorem ipsum. Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque.

S1 Table. Lorem ipsum. Maecenas convallis mauris sit amet sem ultrices gravida. Etiam eget sapien nibh. Sed ac ipsum eget enim egestas ullamcorper nec euismod ligula. Curabitur fringilla pulvinar lectus consectetur pellentesque.

Acknowledgments

Cras egestas velit mauris, eu mollis turpis pellentesque sit amet. Interdum et malesuada fames ac ante ipsum primis in faucibus. Nam id pretium nisi. Sed ac quam id nisi malesuada congue. Sed interdum aliquet augue, at pellentesque quam rhoncus vitae.

References

1. Conant GC, Wolfe KH. Turning a hobby into a job: how duplicated genes find new functions. Nat Rev Genet. 2008 Dec;9(12):938–950.

2. Ohno S. Evolution by gene duplication. London: George Alien & Unwin Ltd. Berlin, Heidelberg and New York: Springer-Verlag.; 1970.

3. Magwire MM, Bayer F, Webster CL, Cao C, Jiggins FM. Successive increases in the resistance of Drosophila to viral infection through a transposon insertion followed by a Duplication. PLoS Genet. 2011 Oct;7(10):e1002337.