# Cortical correlates of translating point-light walker. An event-related potentials study

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# Abstract

# Introduction

-Action is not only described as a particular geometry (the body with the limb in a particular posture) to move but also the motion itself (limbs trajectory in the 3D space);

-the stimuli usually displayed do not correspond to a nominal locomotor pattern as no horizontal translation is present.

From a motor point of view there is no optical flow…..

From a perceptual point of view, this kind of locomotion would correspond to someone walking without goal, in the reverse direction of an airport treadmill, that is rather unusual visual stimulus.

# Materials and methods

## Subjects

13 right-handed volunteers (7 females, 6 males, mean age: 27, standard deviation: 3.5), with normal or corrected to normal vision, took part in this study. All participants provided written informed consent before the experiment began. The experimental protocol was approved by the local ethical committee ASL-3 (“Azienda Sanitaria Locale”, local health unit), Genoa.

## Experimental protocol: Stimuli and task

Participants were presented with point-light animations (PLAs) obtained by recording (for 4.5 seconds) an actor walking naturally with a VICON Motion Capture System (ten cameras at 100 Hz sampling frequency). The actor had 13 passive infrared reflective markers placed at the main joints and other landmarks. This data was processed through Matlab scripts (The Mathworks, Inc.) to build the stimuli, which were displayed using the Psychophysics Toolbox (Brainard, 1997) on an LCD monitor, with a refresh rate of 60 Hz. Point-lights were white against a black background. Four types of stimuli were created: a centered walker, a centered scrambled walker, a translating walker, and a translating scrambled walker (see figure 1), which will be now on referred to as *cwalker*, *cscramble*, *twalker*, and *tscramble,* respectively. Each PLA was 1 second long. Following Hirai et al. 2003, in order to avoid a possible bias in the results due to the initial starting positions of the point-lights, each PLA had 10 different starting positions obtained by shifting the animation by steps of 6 frames. The *cwalker* animation was built by translating all the dots of the *twalker* animation by the opposite of the vector defining their center of mass with respect to the center of the screen, at each frame: the *cwalker* animation looked like a person walking on a treadmill. The *cscramble* animation was built by changing randomly the initial positions of the dots in the *cwalker* animation but keeping their velocity vectors unchanged; the dots’ trajectories were constrained to remain inside the vertically-oriented rectangle in which the *cwalker* animation was inscribed. The *tscramble* animation was built by changing randomly the initial positions of the *twalker* animation in an analogous way. During the experiment, participants were sitting comfortably in a darkened room, in front of the monitor where PLAs were displayed, approximately 60 cm apart. The experiment was organized in ten blocks. Each block consisted of 48 PLAs (12 of each of the 4 types) presented in pseudo-random order. In order to avoid possible expectation effects due to extremely regular timing in the presentation of the stimuli (Basar et al., 1997), the inter-stimulus interval (ISI) varied randomly in length between 2 and 4 seconds (uniform distribution).

***Attention task.*** In each block, a random number of animations (between 2 to 4) changed color from white to green during 250 milliseconds. This change of color occurred in a randomly determined period of the animations. Hereafter, these changing-color stimuli will be referred to as *odd stimuli.* Once an odd stimulus was presented, after a random number of stimuli a question was presented in the screen asking the participant which was the last animation among the four types which changed color. Since the question arose randomly, it was possible that between two odd stimuli no question was presented. Therefore, the number of questions was variable across blocks, and was less than or equal to the number of odd stimuli presented in the respective block. EEG traces corresponding to odd stimuli were discarded from analysis. Participants gave their answers through a keyboard, by pressing a key number between 1, 2, 3 and 4, corresponding to *cwalker*, *twalker*, *cscramble* and *tscramble*, respectively. The four types of stimuli were clearly identifiable, and the correspondence between key numbers and stimuli was learnt by each participant during a training session before starting the actual experiment. They did not receive feedback on their performance during the actual experiment, while they did during the training session instead.

## Data recording

The electroencephalogram (EEG) was recorded from 62 Ag/AgCl active electrodes (actiCAP, Brain Products, Munchen, Germany) placed on the scalp, mounted on a cap according to the international 10-20 system. Figure 2 displays a scheme of electrodes’ placement. The EEG was amplified with two BrainAmp MR plus amplifiers (Brain Products), digitized at 1000 Hz. Impedances of all electrodes were kept below 15 kOhms. A common average reference was then calculated.

## Data analysis

Raw EEG signals were band-pass filtered between 0.5 and 45 Hz through a Butterworth filter as implemented in Brain Vision Analyzer software (Brainproducts). An Ocular ICA (XXXXXXXXX) correction was applied to remove eye-movement related artefacts. Data were downsampled to 250 Hz and then imported into EEGLAB software for further analyses. A visually inspected artefact removal was performed based on the topographical and spectral distribution and of the time series of the independent component calculated with the ICA algorithm implemented by EEGLab (XXXXXXXXX). Epochs, from -400 to 1000 ms with respect to stimulus presentation, were then extracted and grouped together according to stimulus type, baseline-corrected (from -400 to 0) and then averaged in order to produce the corresponding ERP. Moreover, electrodes activity was clustered in seven regions named according to the cortical areas approximately beneath each of them. Cluster name and composition is depicted in Figure 2 and summarized in Table 1.

|  |  |
| --- | --- |
| Cluster name | Electrodes |
| VIS | O1, Oz, O2, PO3, POz, PO4 |
| EBA | PO7, P7, TP7, P5, PO8, P8, TP8, P6 |
| pSTS | P5, TP7, CP5, T7, P6, TP8, CP6, T8 |
| IPL | P5, P3, CP5, CP3, P6, P4, CP6, CP4 |
| SPL | P3, P1, CP3, CP1, P4, P2, CP4, CP2 |
| PMC | FC5, FC3, FC6, FC4 |
| IFG | FT7, F7, F5, AF7, FT8, F8, F6, AF8 |

Legenda: VIS: primary visual areas EBA: extrastriate body areas, pSTS: posterior Superior Temporal Sulcus, IPL: inferior parietal lobe, SPL: superior patietal lobe, PMC: premotor cortex, IFG: inferior frontal gyrus.

## Statistical analysis

A 2x2 design, investigating the effect of the within subjects MOTION (centered, translating) and SHAPE (walker, scrambled) factors and their interactions, was created in EEGLab and analyzed through a bootstrap analysis employing 5000 permutations. This design was first tested in preliminary analysis over all the timepoints within the whole exported time window (-400-1000 ms). This analysis allowed refining the time intervals of the ERP components previously described in the literature. Second, the same design was tested with the mean activity of each cluster within each time interval previously selected. In both the analyses, the original statistic threshold (p<0.05) was corrected for the number of multiple comparisons employed. In the preliminary analysis, a more conservative version (Benjamini & Yekutieli, 2001) of the classical false discovery approach was used for both the number of timepoints and cluster investigated. In the second analysis a Bonferroni approach was used for both the domains.

# Results

## Behavioral results

## ERP results

The preliminary analysis did not reveal any significant differences in any clusters among our conditions before the 200 ms. Differences concentrated around 200, 330, 410 and 600 ms in the proximity of corresponding main deflections. The components will be named using the polarity showed in temporo-parieto-occipital electrodes and with a number representing the approximate latency of their peak. Investigated components and their latency of interest are summarized in Table 2.

|  |  |
| --- | --- |
| Name | Time interval |
| N200 | 200-230 |
| P330 | 300-360 |
| N400 | 390-450 |
| N600 | 550-800 |

Table 2. Windows of interest

### The Shape effect

A significant effect of Shape was observed in both pSTS (p<0.001) and EBA (p<0.001) during the N200 component, with the walker conditions showing a more negative deflection compared to the scrambled one (W>S). Posthoc analysis of the interaction between shape and motion revealed that such effect was observed only in the centered condition (p<0.001). In EBA cluster only, the same difference emerged also during the N400. In the same period (N400), a similar shape effect (W>S) was evident also in IFG and SPL clusters. In the latter cluster, interaction analysis restricted such effect to the translating condition only. IFG cluster, also during the N600 walker induced higher negative deflections compared to scrambled conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | W>S | Within centered | Within translating |
| N200 | pSTS, EBA | pSTS, EBA |  |
| P330 |  |  |  |
| N400 | SPL, IFG | EBA | SPL |
| N600 | IFG |  |  |

Table 3. Summary of Shape effect

### The motion effect

Around 200ms, translating stimuli evoked an higher deflection compared to centered one in pSTS, and the parietal lobule. Posthoc analysis . At a later stage, around 300 ms, the parietal lobule and the ventral PMC showed higher deflection during translaction that postdoc analyses restricted to the walker condition. Only when the shape was scrambled, besides IPL, also pSTS resulted more involved in translating compared to centered. At around 400 ms, PMC sensitivity to translation persisted in all the two conditions (within walker and within scrambled), while SPL ones was present only within the walker stimuli.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | T>C, **C>T** | Within walker | Within scrambled |
| N200 | pSTS, IPL, SPL | IPL |  |
| P330 | PMC, IFG, IPL, SPL | PMC, IPL, SPL | IPL, pSTS |
| N400 | PMC, VIS, SPL | PMC, SPL | PMC |
| N600 | PMC, VIS | PMC, VIS | PMC, VIS, EBA |

Table 4. Summary of Motion effect

# Discussion

# Supplementary materials

## Eye movement analysis.

Since half of the PLAs translated along the screen, some subjects tended to follow the point-lights with their eyes as these translated. In order to rule out an effect of a different eye movement behavior correlating with one of the two experimental variables manipulated in the present study (namely, factor Translation), we elaborated an index with the purpose of measuring, for each subject, the magnitude of this difference of eye movements during the centered and the translating conditions. Therefore, we proceeded as follows. First, for each subject, we gathered EEG trials from the centered conditions on one side, and EEG trials from the translating conditions on the other, in order to build two EEG data sets. For convenience of notation, we will denote these two data sets, or experimental conditions, as C\* and T\*, respectively. Then, we computed for each trial the time course of the electric potential at electrode AF7 referenced to AF8. Due to the positions of electrodes AF7 and AF8 on the scalp (near the left and right eye, respectively; see figure 2), it is not difficult to realize that this time course correlates strongly with the time course of an ordinary horizontal electrooculogram (HEOG), obtained by computing the difference between electric potentials recorded at two electrodes on the outer canthi of the eyes. Thus, we computed the mean, across trials, of the time course of AF7-AF8.

Since stimuli in the T\* condition were moving always towards the right, the eye movements made by subjects who did not follow strictly the instruction about fixating the red cross at the center of the screen (figure 1) moved their sight towards the right. Therefore, in single trials from the translating conditions, it is expected to see the time course of AF7-AF8 deflecting coherently with the direction of movement: in this case, a horizontal eye movement towards the right would provoke a increase of voltage near AF8 and a decrease of voltage near AF7, due to the pointing direction of the corneo-retinal dipoles in the eyes (see Croft and Barry, 2000), and consequently the voltage at AF7 with respect to AF8 (i.e., AF7-AF8) would be negative.

After computing the mean time courses of AF7-AF8 across trials for the C\* and the T\* conditions separately, we defined the sought index as the sum, in the 300 ms – 1000 ms time window, of the absolute values of the difference between these two mean time courses. In other words, this index is proportional to the area between the two mean time courses. The larger this index, the more different were the eye movements between the C\* and the T\* conditions. Figure 6 displays, for each subject, the mean of AF7-AF8 across trials, for the T\* and the C\* conditions separately. Subjects’results are ordered according to increasing value of the index described in this section.