Action video-games improves reading and global perception in children with dyslexia: An electroencephalographic study

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Introduction

- Developmental dyslexia (DD) is associated with an altered functionality of right-lateralized magnocellular-dorsal (MD) pathway [1], [2], [3], which would impact the processing of low spatial/high temporal frequencies stimuli such as global configurations and motion, essential for an adequate development of reading skills [4].
- Recent studies have shown that a visual-attentional training based on the use of action video games (AVG) in subjects with DD is able to improve reading skills, probably by acting directly at the level of the MD pathway [4], [5], [6], [7].
- To date, although these studies are promising, less is known about the neural effects of such training.

Aim of the study

We used electroencephalography (32 channels-EEG) in a sample of children with DD to investigate whether AVG training can effectively translate into better MD functionality at the neurophysiological level.

Methods

Participants:

- 14 children with DD (6 females and 8 males; age 10.41 ± 1.71).

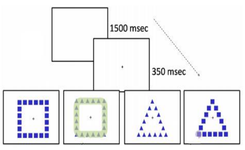
Videogames:

- The treatment involved the use of the commercial video game *Rayman Raving Rabbids*, created for the Wii ™ entertainment platform.
- This video game consists of several minigames, which have been categorized as AVG or NAVG using the criteria developed by Green, Li and Bavelier [8]. 7 children with DD were randomly assigned to AVG training, and 7 children to non-AVG training (NAVG).
- The training lasted a total of 12 hours, in 9 sessions of 80 minutes per day distributed over a period of two weeks.

Stimuli and procedure:

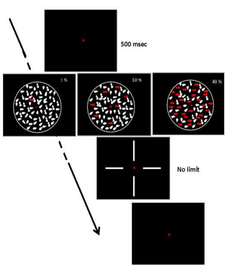
EEG signal was recorded before (T1) and after (T2) the training sessions, both at rest and during a coherent dot motion (CDM) task. At T1 and T2 we also measured reading skills using an Italian clinical battery [9], phonological decoding skills using two pseudoword texts and two lists, and the efficiency of global perception in a Navon Task.

Navon Task



- *This task is characterized by a recognizable global form, composed of smaller geometric figures that can be the same or different;*
- *Global and local figures could be congruent or incongruent;*
- *Children were instructed to indicate the global or local figure;*
- *80 trials per condition.*

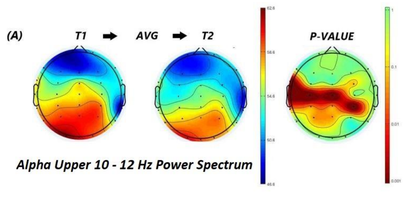
Coherent Dot Motion Task



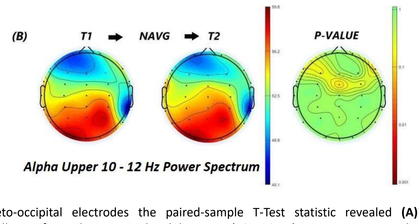
- *Participants had to indicate the direction of the coherent dots (upward, downward, left, or right);*
- *Levels of coherence of movement: 1%, 10%, 40%;*
- *80 trials per condition.*

Results

EEG Resting State Power Spectrum – AVG vs. NAVG between T1 and T2



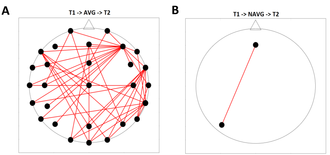
Alpha Upper 10 - 12 Hz Power Spectrum



Alpha Upper 10 - 12 Hz Power Spectrum

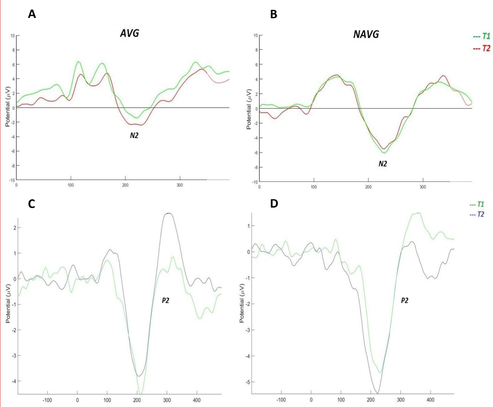
In parieto-occipital electrodes the paired-sample T-Test statistic revealed **(A)** a statistically significant decrease in the alpha upper (10 – 12 Hz) power spectrum only for the AVG group between T1 and T2 (t(6) = 3.478, p= .013; T1 M = 9.53, SD = 3.03; T2 M= 7.02, SD = 4.31), **(B)** and no significant effect in the treatment condition NAVG (t(6) = .473, p= .653; T1 M = 6.74, SD = 3.02; T2 M = 6.22 , SD = 4.39).

EEG Resting State Functional Connectivity (PLV) – AVG vs. NAVG between T1 and T2



- We analyzed the Phase Locking Value (PLV) [10] to investigate changes in synchronization between electrodes in Upper Alpha band between T1 and T2 by comparing the differences between the two groups.
- The graphs show the differences revealed by the paired-sample T-Test analysis of PLV changes between T1 and T2 for the AVG group **(A)** and the NAVG group **(B)**. The red lines indicate an increase in connectivity between electrodes between T1 and T2 (p <0.05).

Event-Related Potentials in CDM task– AVG vs. NAVG between T1 and T2



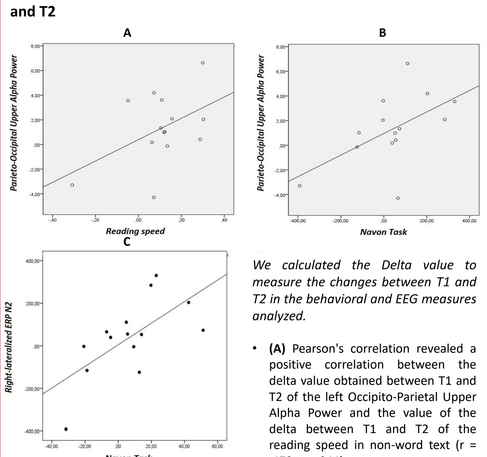
Right-Lateralized N2 Latency

- Repeated measures Analysis of Variance (ANOVA) on the right-lateralized N2 latency for the correct answers in the high coherence condition (40%) of the CDM task revealed a time (T1 and T2) x group (AVG and NAVG) interaction effect (F(7.57) = 1.12, p = .018).
- Paired-sample t-test within the groups between T1 and T2 revealed a significant decrease of right-lateralized N2 latency (t(6) = 3,012, p= .024) in the AVG group **(A)**, and no significant changes in the NAVG group **(B)**.

Parietal P2 Amplitude

- Repeated measures Analysis of Variance (ANOVA) on the parietal P2 amplitude for the correct answers in the high coherence condition (40%) of the CDM task revealed a time (T1 and T2) x group (AVG and NAVG) interaction effect (F(5.68) = 0.321, p = .035).
- The figure shows the change in the amplitude of P2 between T1 and T2 of the parietal electrodes (Tp7 and Tp8) **(C)** in the AVG group, **(D)** and in the NAVG group.

Correlation between EEG/ERP and Behavioral Measures between T1 and T2



We calculated the Delta value to measure the changes between T1 and T2 in the behavioral and EEG measures analyzed.

- **(A)** Pearson's correlation revealed a positive correlation between the delta value obtained between T1 and T2 of the left Occipito-Parietal Upper Alpha Power and the value of the delta between T1 and T2 of the reading speed in non-word text (r = .473 p = .044).
- **(B)** Pearson's correlational analysis between the delta value obtained between T1 and T2 of the left Occipito-Parietal Upper Alpha Power and the delta value between T1 and T2 of global performance at the Navon task revealed a positive correlation (r = .553, p = .04).
- **(C)** Statistically significant relationship emerged from the analysis of the variations between T1 and T2 of the latency of the N2 and the global perception measured at the Navon task (r = .654, p = .027).

Conclusions

- Our results demonstrated that at the neurophysiological level AVG training produces functional changes that are positively related to reading skills.
- The relationship that emerged between the decrease in alpha upper activity and the improvement in the reading speed of the non-word text, could indicate the possibility that AVGs, through this neurophysiological effect, are able to modulate the sub-lexical route through the improvement of the spatial and temporal processing of visual information, by acting on the MD system.
- The relationship between the EEG results and the improved global perception that emerged from the Navon task could indicate that the improvement in perceptual processing may be modulated by the decrease in parietal alpha activity and the improvements shown in functional connectivity and ERP components during CDM task.
- AVG training, by acting on the perceptual-attentional components, could modulate the activity of the MD system, improving the reading processes.

References:
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