The Effects of Temporary Monocular Deprivation in a Multisensory Context

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Background

Neural plasticity is the ability of neurons and of neural circuits to modify their structural and functional properties in response to experience. Despite the plastic potential decreases after sensitive period closure (Reh et al., 2020), some degrees of plasticity persist in adulthood. Recent studies have shown that a brief period of monocular deprivation (MD) induces short-term plasticity within the visual system. A series of behavioral (Lunghi et al., 2011; Lunghi & Sale, 2015) and neural studies (Lunghi et al., 2015; Lunghi et al., 2015; Binda et al., 2018) have demonstrated that MD alters the interocular excitability balance. However, little is known about the effects of short-term plasticity on the interaction between different sensory modalities (Lo Verde et al., 2017; Opoku-Baah & Wallace, 2020). In everyday life our brain has to overcome the problem of integrate or segregate information coming from different modalities (Ernst & Banks, 2002), thus it is extremely important to understand how a brief period of anomalous visual experience can affect neural mechanisms associated to multisensory processing.

Aim

In the present study we used MD to manipulate the visual system excitability and tested whether MD effects are confined within the visual system or also extend to the interaction between vision and audition. We assessed the electrophysiological activity in visual and audio-visual processing using the well known "double flash illusion" (Shams et al., 2000).

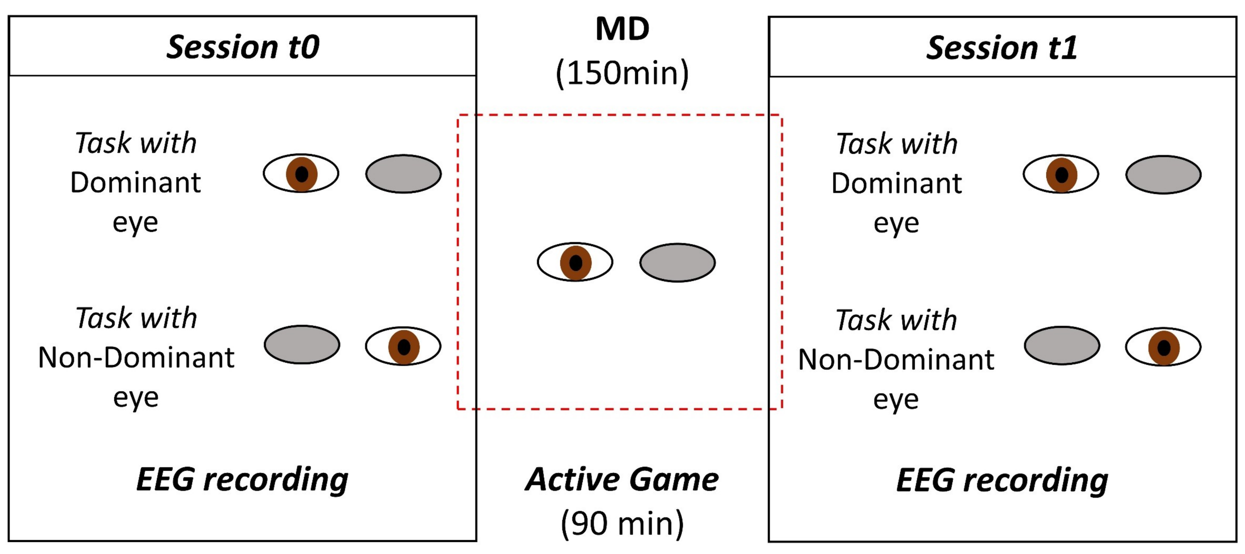
Methods

Partecipants

A sample of twenty young adults (age range 25-31 y).

10 males;
2 left eye dominant;
3 left handiness.

Procedure



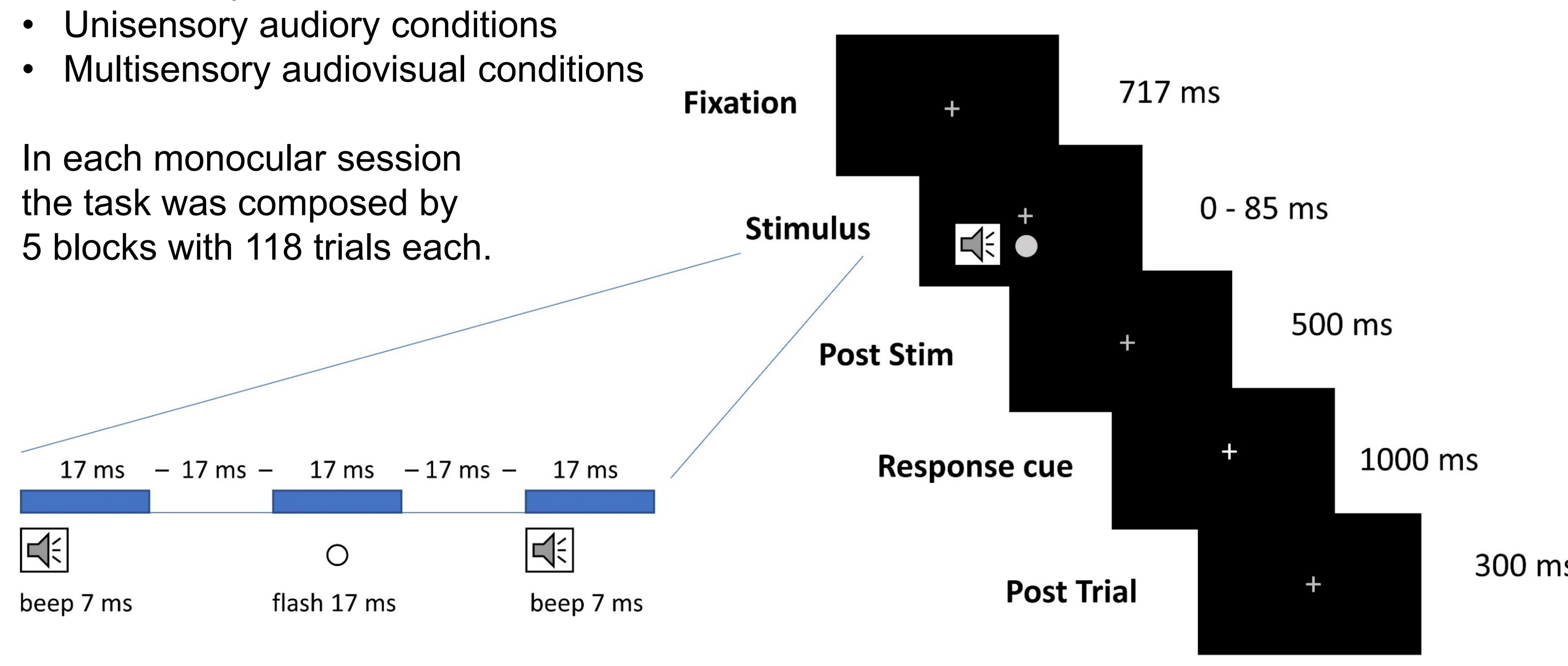
A visual discrimination task was performed monocularly while neural activity was recorded using a 64-channel Hydrocel Geodesic Sensor Net EEG.
Between the t0 and t1 sessions, the Dominant eye was monocularly deprived (MD) for 150 minutes.
The order of the task performed with the Dominant and Non-Dominant eye, within each session, was balanced across participants.

Task

Participants were asked to report the number of perceived flashes (0, 1 or 2) while task irrelevant beeps (0, 1 or 2) were presented. Flashes and beeps could be presented coupled or isolated resulting in:

- Unisensory visual conditions
- Unisensory audiory conditions
- Multisensory audiovisual conditions

In each monocular session the task was composed by 5 blocks with 118 trials each.



Results

Behavioral results

In order to test if there was a change of sensitivity due to MD we computed the d prime index (d') before (t0) and after (t1) MD, both in unisensory visual trials and in audiovisual trials related to the double flash illusion.

$$d' = z(p \text{ Hit rate}) - z(p \text{ False alarm rate})$$

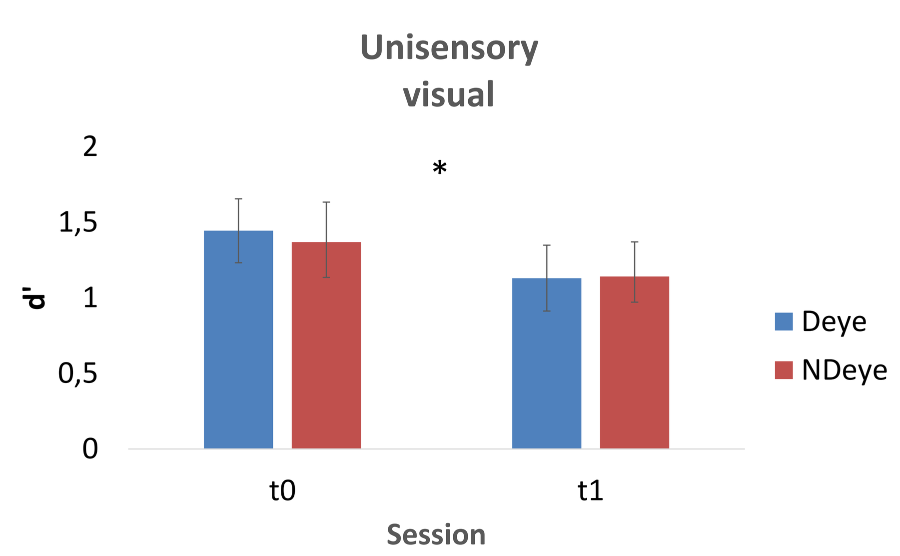
Hit = response 2 flashes when 2 flashes were shown

False alarm = response 2 flashes when only 1 flash occurred

We performed two repeated-measure ANOVA on d' with Session (t0 vs. t1) and Eye (Dominant vs. Non-Dominant) as within factors, one on the unisensory visual d' and the other on the double flash illusion d'.

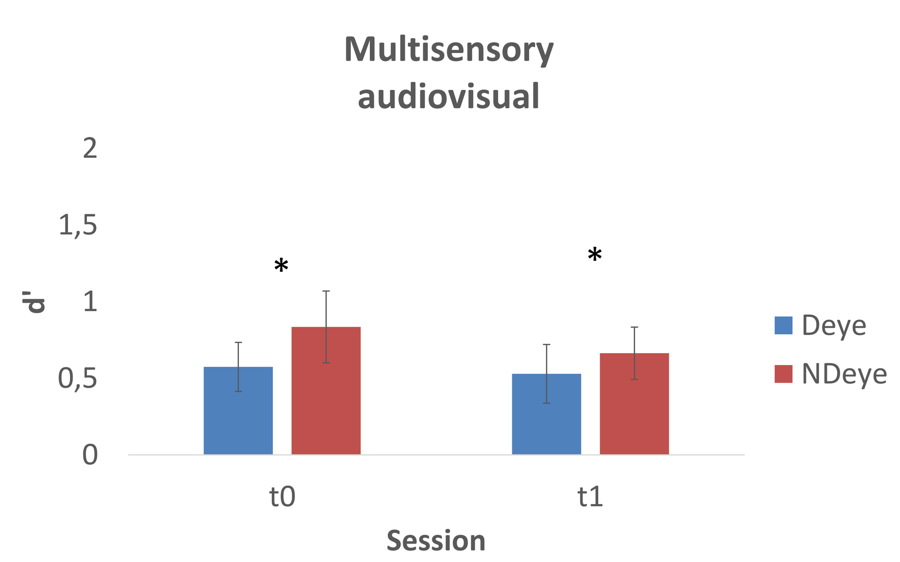
Unisensory visual

The results showed a significant main effect of Session ($F_{(1,18)}$ = 19.032, p<0.001), revealing a general decrease of sensitivity between session t0 an t1.



Multisensory audio-visual

No effects associated to the MD were found. The analysis showed a significant main effect of Eye ($F_{(1,18)}$=5.233, p=0.034), revealing a higher degree of double flash illusion in the Dominant eye.



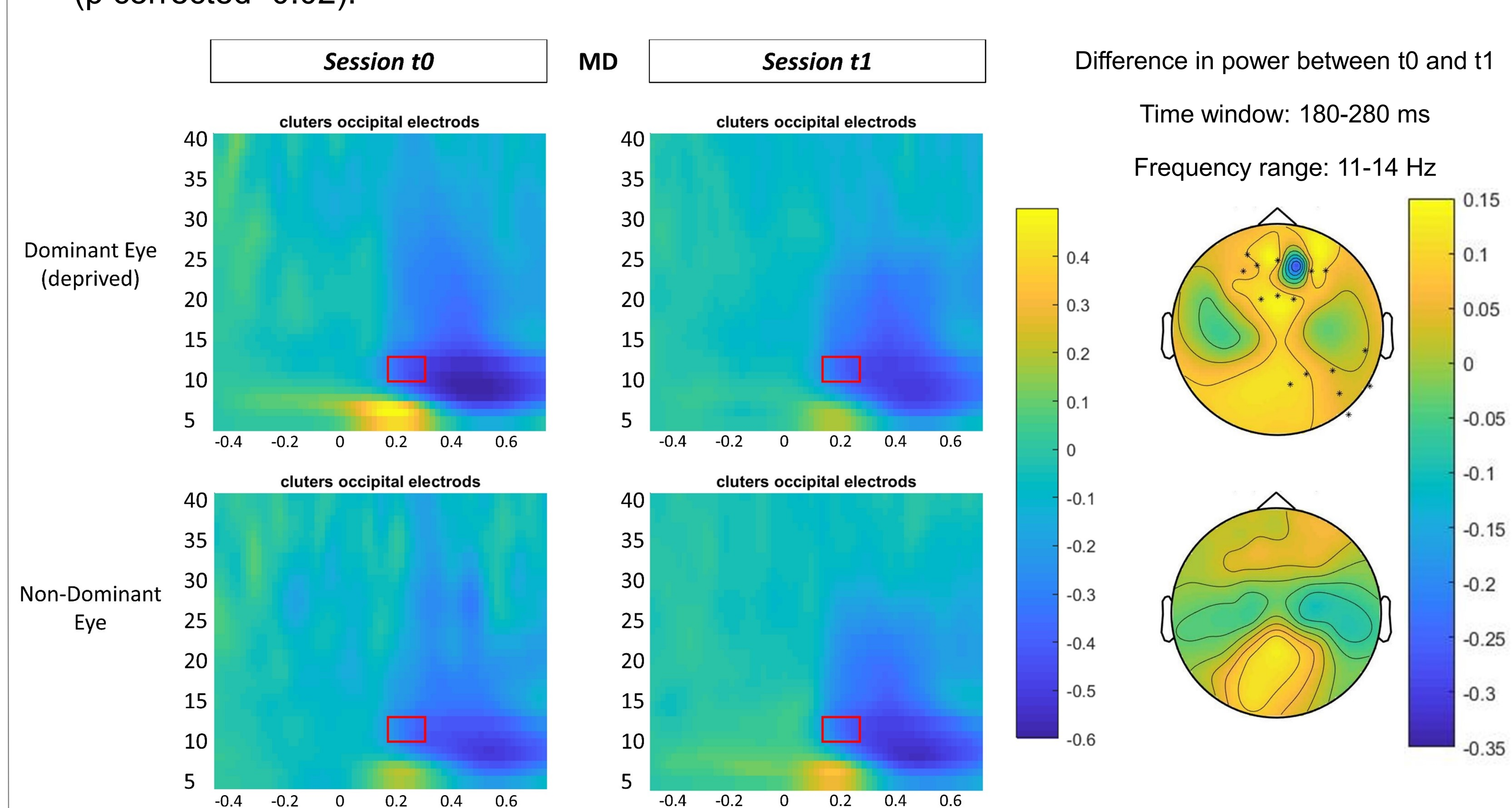
Oscillatory activity

In order to assess the MD effects on visual and audio-visual processing, we performed two cluster-based permutation analyses contrasting t0 - t1 Deye vs. t0 - t1 NDeye. Then, additional cluster-based permutation analyses on the t0 - t1 difference in each eye were also run.
All analyses were curried out on the post-stimulus activity in the time window between 0-600 ms, on a broad frequency range between 5 and 40 Hz and across all electrode locations.

Unisensory visual

The analysis t0 - t1 Deye vs. t0 - t1 NDeye showed a significant positive cluster

(p corrected=0.02).



Multisensory audio-visual

No significant cluster emerged.

Conclusions

Despite our behavioral results did not shown any specific effect of MD on the deprived eye, the oscillatory activity associated to visual processing in the deprived eye was impacted by MD. Indeed, comparisons of the differences between t0 and t1 sessions revealed a significant decrease within a low-frequency range (5-15Hz) selectively for the deprived eye. On the contrary, when oscillatory activity associated to the audio-visual stimulation (inducing double flash illusion) was tested no significant effects were found. On the one hand, our results confirm that MD induces homeostatic plasticity in the visual system with an eye-specific impact. On the other hand, this short-term plasticity effect does not seem to be sufficient to alter the interactions between audio and visual processing, and in particular the neural mechanisms underpinning the double flash illusion. These electrophysiological data are in support of a relative independence between the levels of visual analyses affected by a short-term MD and basic audio-visual interactions.

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