Numerical distance effect in the blind: An ERSP study

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An abstract, amodal semantic representation of magnitude and number meaning has been demonstrated to rely on neural circuits residing in the bilateral parietal cortex. However, it is a debated question whether the ability to represent numerical information evolves during the ontogenetic development of initially aspecific brain areas or whether it is the phylogenetic heritage of our species. Current models hypothesize that the development of the parietal number representation relies heavily on areas initially involved in the processing of visual information. In three experiments we investigated whether magnitude judgements have similar behavioral characteristics and event-related brain potential (ERP) as well as event-related spectral perturbation (ERSP) and intertrial-coherence (ITC) signatures in congenitally blind and matched control subjects. If the blind demonstrate semantic numerical (distance) effects similar to the controls that would heavily support the evolutionary explanation of number representation.

In Experiment (Exp.) 1 twelve normal subjects decided if visually presented digits (1-9) were smaller or larger than 5. We showed a numerical distance effect for Hungarian subjects. In Exp. 2. eight congenitally blind and eight matched control subjects carried out a similar task with acoustically presented numbers. The profile of the distance effect was the same in both groups.

In Exp. 3. numbers 1, 4, 6 and 9 and letters a, d, f and i were used. 8 congenitally blind and 8 normal subjects decided if numbers were smaller or larger than 5 or if letters stood before or after letter e in the alphabet. EEG was sampled at 32 channels at 500 Hz, accepted between ±70 μv. The Controls kept their eyes closed dunring the experiment. ERPs, ERSP and ITC was calculated relative to a -100 to 0 ms baseline interval. Numerical (Distance1 vs. Distance 4: 1 vs. 4 and 6 vs. 9) and alphabetical distance effects were evaluated.

The topography of ERPs was the same in both groups. The blind showed an ERSP decrease over somatosensory areas (electrodes C3 and C4). This was absent in the controls. This effect raises the possibility

that the blind relied more on somatonsensory representations of numbers than the controls. This is a plausible finding as the blind learn numerical relations via touch.

The controls showed a series of ERSP distance effects over more electrode sites in more frequency ranges. The localization of the effects was in great coherence with former fMRI findings in number comparison tasks. There were right parietal, as well as a right and left frontal recurrent distance effects. On the one hand, the blind showed numerical distance effects of delayed timing but with similar localization than the controls did. On the other hand, there was no similarity in letter distance effects between the blind and the controls. There was an extended left-hemispheric distance effect in the blind, not present in the controls. Our results support the hypothesis that the processing of numbers relies on evolutionarily hardwired representations undergoing limited plasticity while e.g. processing of letter information is not hardwired and is subject to plasticity to a greater extent.

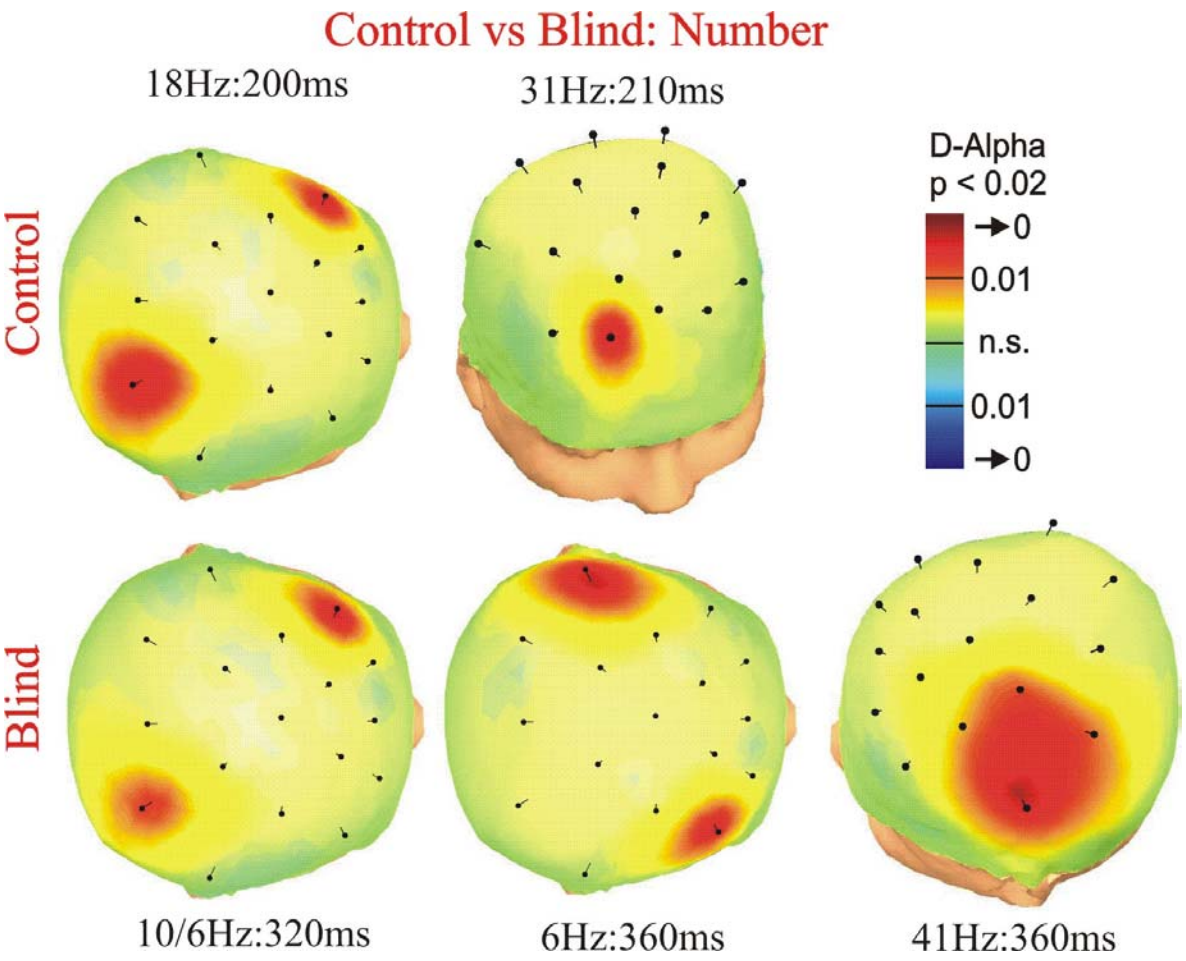

Figure 1. ERSP distance effects in the blind and in the controls. Directional alpha (D-Alpha) is the alpha value multiplied by the sign of the t-value computed in a matched t-test (Distance 1 vs Distance 4).