The Development of Audiovisual Integration Abilities in Neurotypical Children

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Introduction

- Our ability to integrate sensory informations is fundamental in order to respond optimally to external events[1,2,3].
- Infancy is a period of great changes in brain structures and functions reflected by the increase of processing capacities of the developing child. When the human brain integrates multisensory information after birth and how this develops over time has not been thoroughly examined so far[3]. To our knowledge, only few studies have documented the effects of development in infants and children on multisensory integration (MSI).
- Studying infant development is a great challenge because physiological and behavioural measures of infant cognition are technically difficult to obtain.
- With the use of event-related potentials (ERPs), electroencephalography can easily provide an insight into brain implicit responses to external events.

- The **aim** of the present study is to explore the developmental trajectory of audiovisual integration in growing infants and children aged between 3 months and 9 years-old using ERPs.
- We hypothesize that MSI development will not be measured in early infancy and will occur later during development as a consequence of environmental exposure.

Participants

Group	N	Mean Age	Male	Female
3-6 months-old	13	4.26 m/o	8	5
7-15 months-old	16	10.41 m/o	6	10
18-42 months-old	12	30.47 m/o	6	6
4-6 years-old	20	5.0 y/o	10	10
7-9 years-old	17	7.8 y/o	10	7
Adults	13	22.5 y/o	7	6

- ERPs recorded in 78 typically developing children and 13 healthy adults.
- Participants were screened for neurological and psychiatric disorders and all had normal hearing and vision or corrected-to-normal vision.

Methods

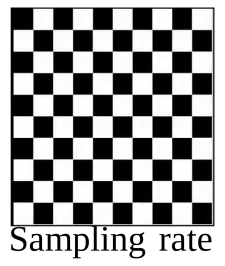
Paradigm

•**Visual condition**: 5 blocks of 35 visual stimuli. Visual ERPs were measured in response to a black and white checkerboard with each square subtending a visual angle of 2.0°

•**Auditory condition**: 5 blocks of 35 auditory stimuli. Auditory ERPs were measured in response to a 1000-Hz tone and presented binaurally at 65 dB sound pressure level through speakers.

•**Multisensory (audiovisual) condition**: 5 blocks of 35 audiovisual stimuli. Simultaneous presentation of the auditory and visual condition described above.

•Each type of stimulus was delivered in a pseudo-random order.



Electrophysiological recording & analysis

•128-channel Geodesic Sensor Net; Digital filtering 0.1-100 Hz; Sampling rate of 250 Hz; Off-line 50 Hz notch filter with a 1-50 Hz bandwidth; Re-referenced to both left and right mastoids.

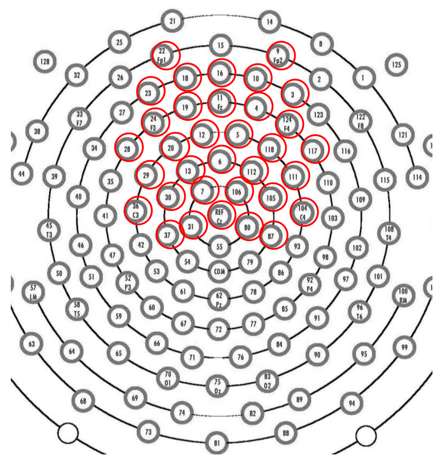
•EEG epochs of 600ms (including 100ms prestimulus) were averaged after ocular correction, artifact rejection (threshold of ±100 uV), and baseline correction.

•To examine integration, responses to simultaneous auditory and visual ERPs (M) were compared to the summed responses ERPs (A+V)[4,5,6].

•Electrodes of interest were selected based on the maximum amplitude corresponding to the scalp distribution. Analyses were focused on 8 regions of interest (ROI) with time windows between 100-200ms (T1) and 200-300ms (T2).

•Auditory and visual stimuli have been demonstrated to generate multiple event-related oscillations in theta and alpha frequency ranges. ERPs (M) and ERPs (A+V) were analyzed by applying the wavelet stimulus-lock method based on time-frequency decomposition. Amplitude-frequency characteristics of auditory, visual and multisensory ERPs manifest a compound peak in the theta (L1: 4-7 Hz) and alpha (L2: 8-14 Hz) band.

ROI	Electrodes
Fronto-anterior	Fp1, Fp2, Fz, AFz, AF3, AF4
Frontal Left	F1, F3, FFC3h, FFC5h, AFF5h
Frontal Right	F2, F4, FFC4h, FFC6h, AFF6h
Frontal	Fz, AFz, F1, F2, FCC1h, FCC2h
Fronto-central	FC1, FC2, FCz, FCC1h, FCC2h, FFC1h, FFC2h
Central	Cz, CCP1h, CCP2h, FCC1h, FCC2h
Central Left	C3, FC3, FCC3h, CCP3h
Central Right	C4, FC4, FCC4h, CCP4h



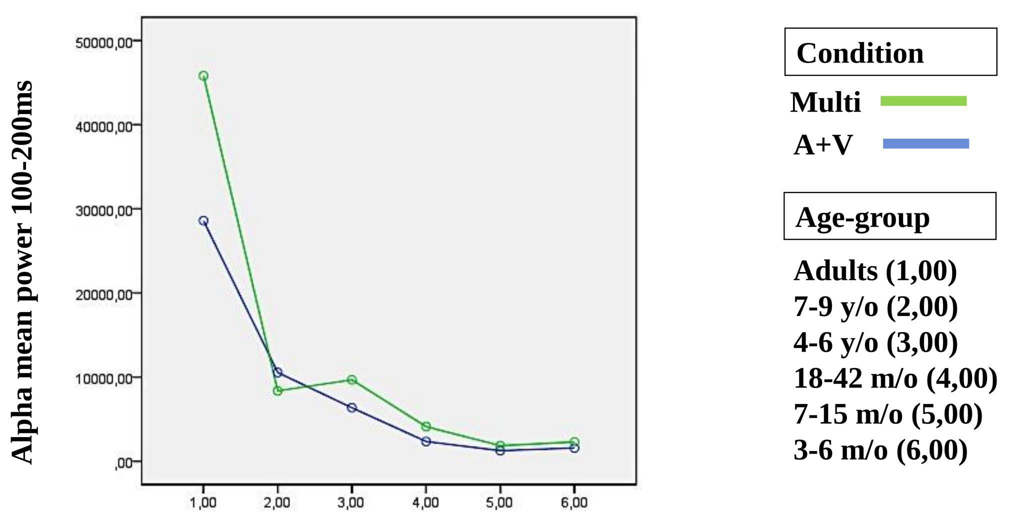
Results

- An age-group (6) X Condition (2: Multisensory vs A+V) X ROI (8 regions of interest) ANOVA with Greenhouse-Geisser correction was performed.
- There was no significant interaction of age-group and condition in T1L1 and T2L1.
- A significant age-group X condition interaction was found in T1L2 ($F(5,85) = 5.7$, $p = 0.0001$) and T2L2 ($F(5,85) = 6.2$, $p = 0.0001$).

Interaction Age-group X Condition in alpha between 100-200ms (T1L2)

Age-groups	M > A+V
Adults	p=0.000
7-9 years-old	p=0.404
4-6 years-old	p=0.169
18-42 months-old	p=0.569
7-15 months-old	p=0.824
3-6 months-old	p=0.812

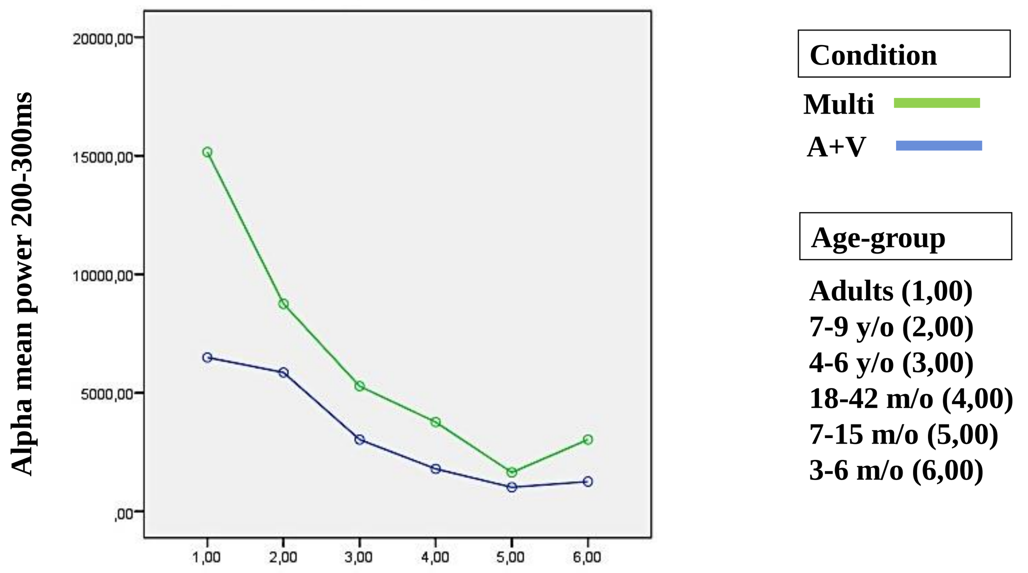
T1L2: Interaction age-group X condition



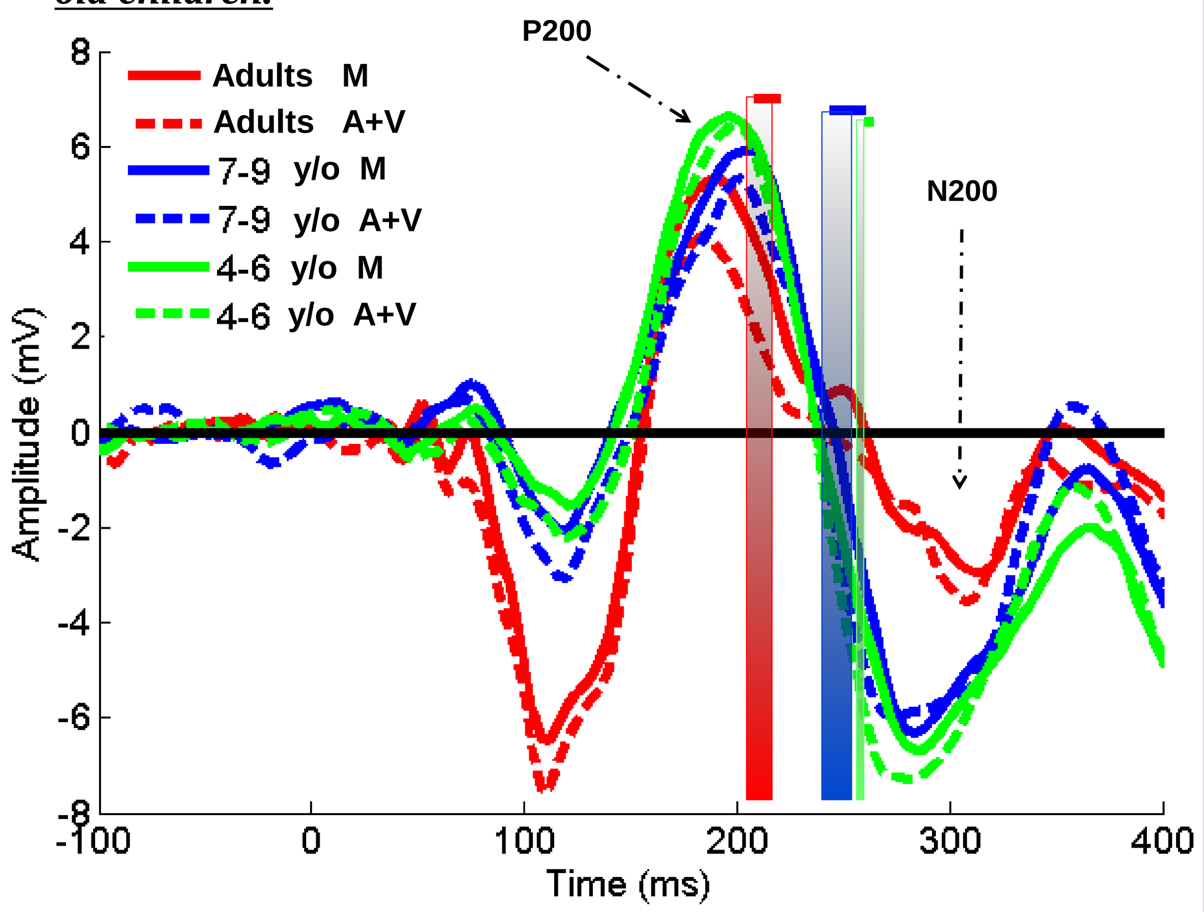
Interaction Age-group X Condition in alpha between 200-300ms (T2L2)

Age-groups	M > A+V
Adults	p=0.000
7-9 years-old	p=0.006
4-6 years-old	p=0.019
18-42 months-old	p=0.110
7-15 months-old	p=0.557
3-6 months-old	p=0.134

T2L2: Interaction age-group X condition



Grand-averaged ERPs for M and A+V in adults and 4 to 9 years-old children.



- Permutation tests (*vertical boxes on the graph*) was perform separately on each age-group on FCz. Significant difference between the M and A+V responses where found in the time window between P200 and N200 (Adults: 208-220ms; 7-9 years-old: 244-260ms; 4-6 years-old: 260-264ms).

Conclusions

- Our results suggest a relationship between the age and neuronal processes underlying MSI. A significant difference between the power spectrum of the multisensory and A+V sum responses was found in adults and children aged between 4 and 9 years-old.
- More specifically, we observed a significant difference of power in the alpha frequency ranges (8-14Hz) between 100-200ms in adults and between 200-300ms in adults, 7-9 years-old and 4-6 years-old.
- During childhood, marked changes in both cognitive processes and neural reorganization have been reported in neuroimaging studies[7]. Thus, the observed dip in MSI around 4 years-old may be related to this neural and cognitive reorganization that takes place during childhood, disrupting the coordination between higher order cognitive processes (e.g., attention, decision making) and action.

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