Кортико-кортикальные функциональные связи в ходе серийного научения у взрослых испытуемых и детей 7-8 лет

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Cortico-cortical Functional Connectivity in the Course of Serial Learning in Adults and Children of 7-8 years old

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SERIAL LEARNING

Serial learning (aka sequence learning) occurs when we perform an initially unfamiliar ordered sequence of actions over and over again.

Sequence learning shows itself in reduction of error rate and/or reaction time.

At early stages of serial learning, that is prior to consolidating the sequence performance into a solid skill, the sequence of actions is stored in working memory.

Early stages of serial learning are characterized by an involvement of a set of specific brain structures (fronto-parietal, subcortical, cerebellar) with some age-related differences in the observed brain activity [*e.g. Thomas et al., 2004*].

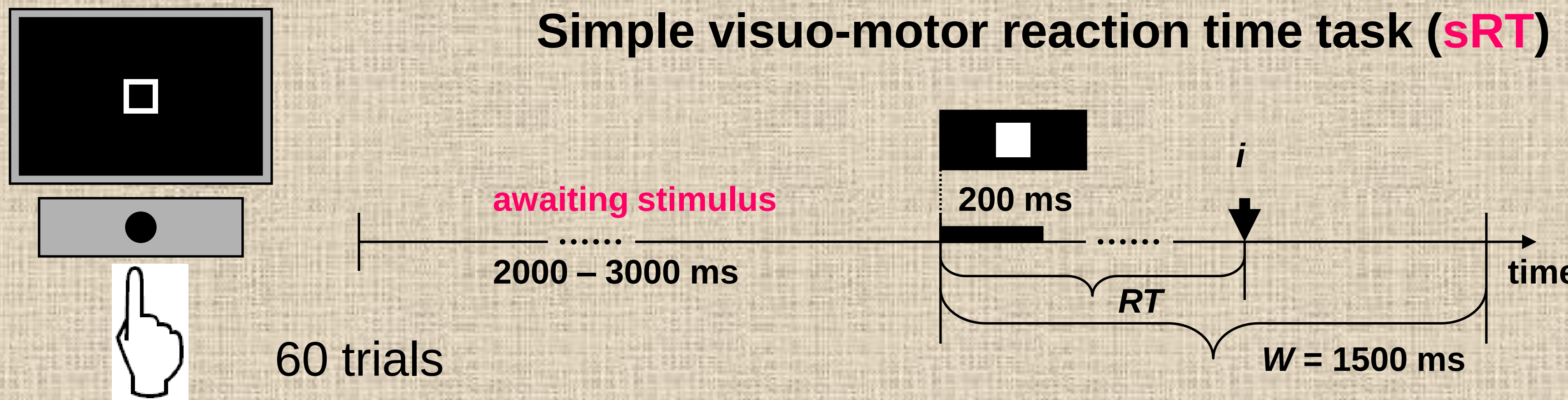
Very little is known about the functional connectivity among those structures both in adults and (especially) in children.

In this study we address the following major questions:
i. Do adults and young schoolchildren aged 7-8 show similar serial learning capabilities?
ii. Whether the characteristic patterns of functional connectivity in the course of serial learning are similar in the two groups of subjects?

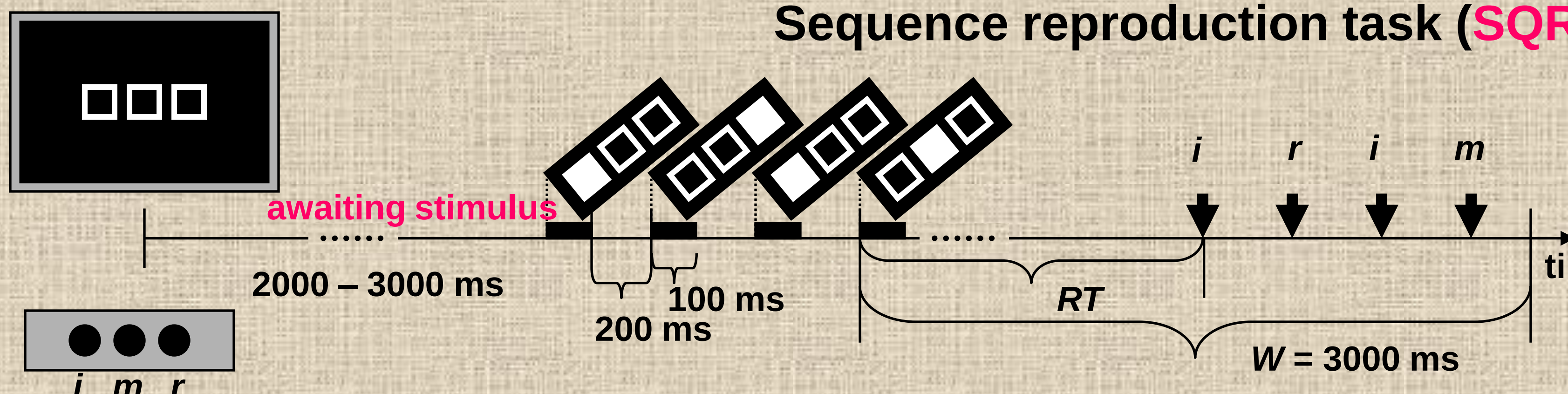
WE CONDUCTED EXPERIMENT IN WHICH

a total of 43 subjects, 21 young adults and 22 children aged from 7 to 8, performed the simple visual Reaction Time task (**sRT**) and the SeQuence Reproduction task (**SQR**)
All movements were performed with the right hand.

Simple visuo-motor reaction time task (sRT)

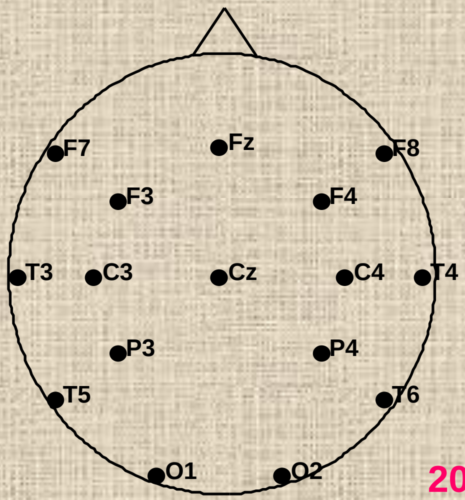


Sequence reproduction task (SQR)



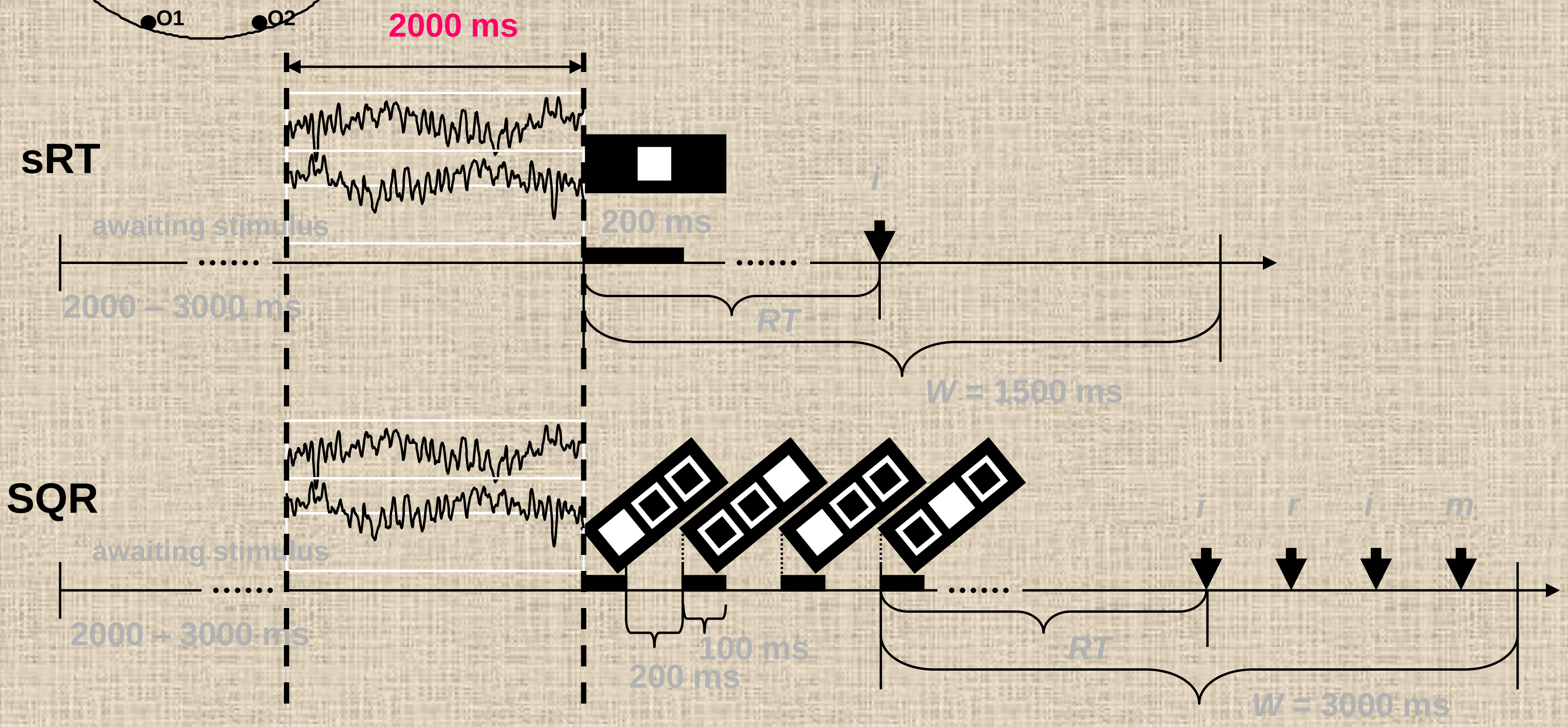
60 trials in which two different sequences,
i-r-i-m and *i-r-m-m*, were presented in a random order

EEG RECORDING

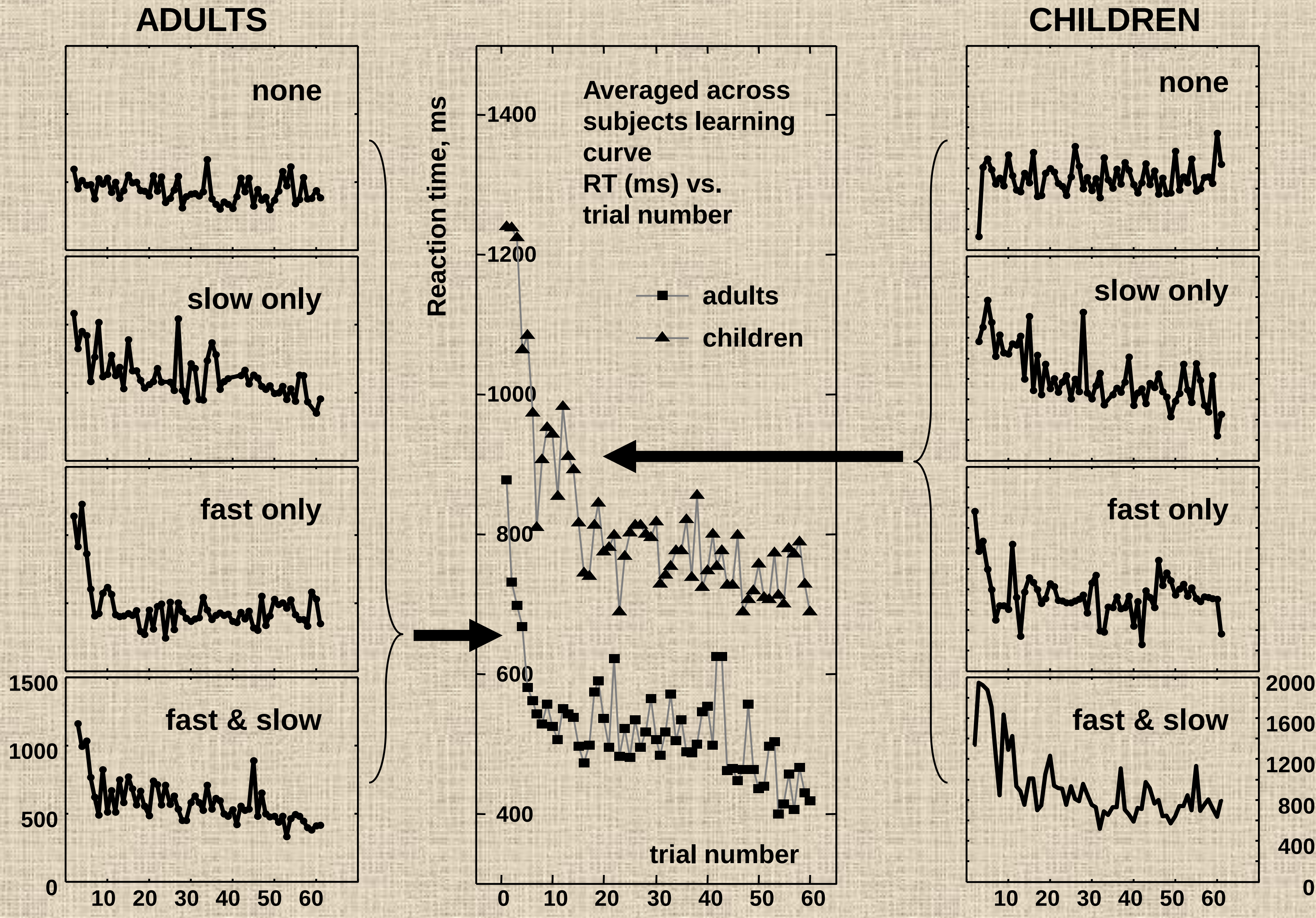


16-channel EEG was recorded while subjects were awaiting visual stimulus (stimuli)

2 second long time-interval immediately preceding the onset of the first visual stimulus was analyzed



LEARNING CURVE DIVERSITY



One more question addressed in this study

The observed diversity in learning curves may be related to

- explicit vs. implicit learning strategy [*e.g. Elliassen, 2001*]
- the nature of internal representation of a sequence: stimuli-based, motor-based, abstract [*e.g. Hikosaka, 2002*]
- the way working memory is used: [*Kurgansky & Grigal, 2009*]

across trials vs. within a single trial only

and

what is stored in the working memory:

sequence as a whole

separate chunks of the two sequences: i-r, i-m, m-m

whether a pattern of functional connectivity is predictive to a particular strategy of serial learning that a subject may employ?

EEG Data Processing

We assessed the functional connectivity by fitting Vector AutoRegressive model (VAR) of the 20-th order to the individual artifact-free 16 channel EEG segments (2 sec. long) for every subject

The VAR coefficients and covariance matrix of residuals were used to estimate **directed connection strength** by computing the partial directed coherence PDC (*Baccala & Sameshima, 2001*), the direct transfer function, DTF (*Kaminski et al., 2001*), the ordinary coherence function, COH and the imaginary part of the complex-valued coherence function, ImCOH (*Nolte et al., 2004*).

The scale-invariant versions of the PDC and DTF measures were used (*Kurgansky, 2009, submitted for publication*).

Due to a non-stationarity of functional connectivity measures in SQR the first 10 segments were excluded from the further analyses.

The sRT task was chosen as a reference point against which SQR task can be compared. The reason for that is because although both tasks require a visual attention sRT does neither require any memorization nor it involves any learning.

Only the **DTF**-based functional connectivity data are discussed in this presentation

Direct Transfer Function (DTF)

for math-loving ones…

$$x(n) = [x_1(n), x_2(n), \ldots, x_M(n)]^T$$

$$e(n) = [e_1(n), e_2(n), \ldots, e_M(n)]^T$$

$$x(n) = \sum_{p=1}^{p=P} a(p)\, x(n-p) + e(n)$$

$$A(f)\, X(f) = E(f)$$

$$H(f) = A(f)^{-1}$$

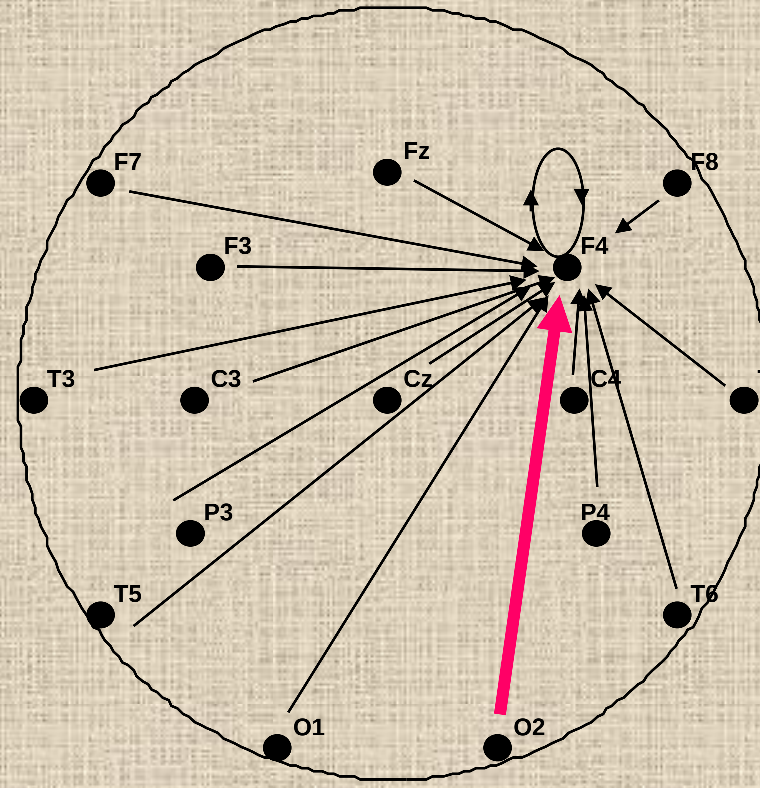
$$X(f) = H(f)\, E(f)$$

$$DTF_{k \leftarrow m}(f) = |H_{km}(f)| \Big/ \sqrt{\sum_{j=1}^{j=M} |H_{kj}(f)|^2}$$

$$A_{km}^{\sigma}(f) = (\sigma_{mm}/\sigma_{kk})\, A_{km}(f)$$

$$H_{km}^{\sigma}(f) = (\sigma_{mm}/\sigma_{kk})\, H_{km}(f)$$

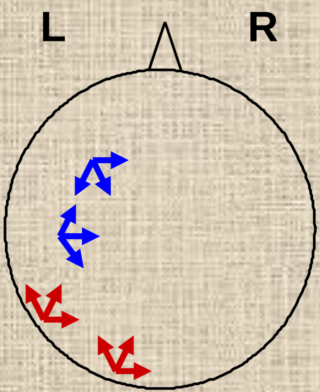
$$DTF_{k \leftarrow m}^{\sigma}(f) = |H_{km}^{\sigma}(f)| \Big/ \sqrt{\sum_{j=1}^{j=M} |H_{kj}^{\sigma}(f)|^2}$$

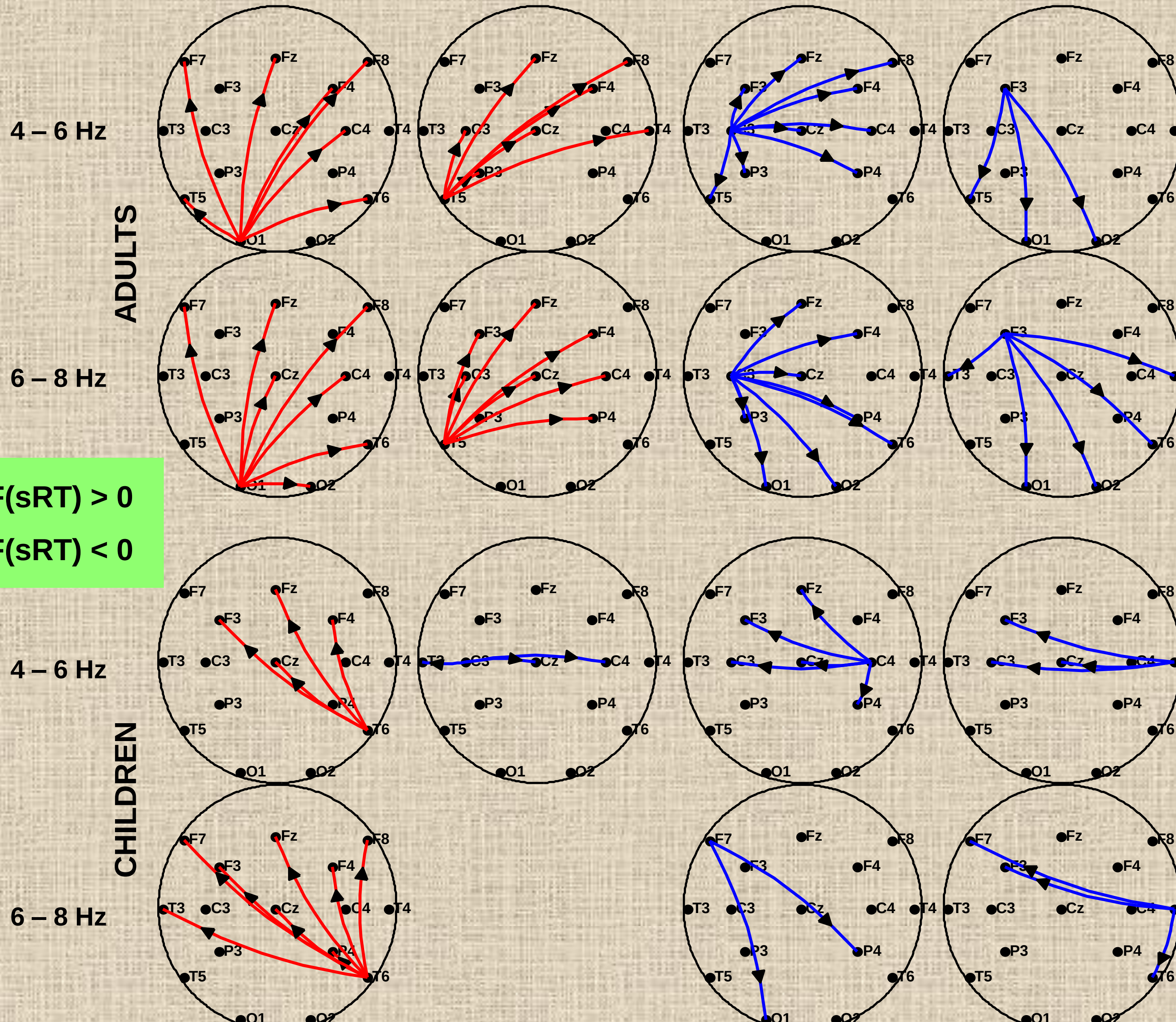


Direct + indirect O2 onto F4 influence relative to the overall influence that F4 receives from all locations (including O2 and F4 itself)

SQR vs. sRT: DTF in THETA band

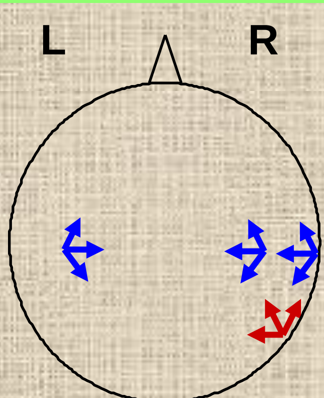
pairwise comparisons $p < 0.05$





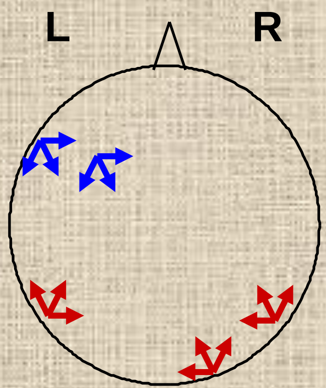
■ DTF(SQR) – DTF(sRT) > 0

■ DTF(SQR) – DTF(sRT) < 0



SQR vs. sRT: DTF in ALPHA & low BETA bands

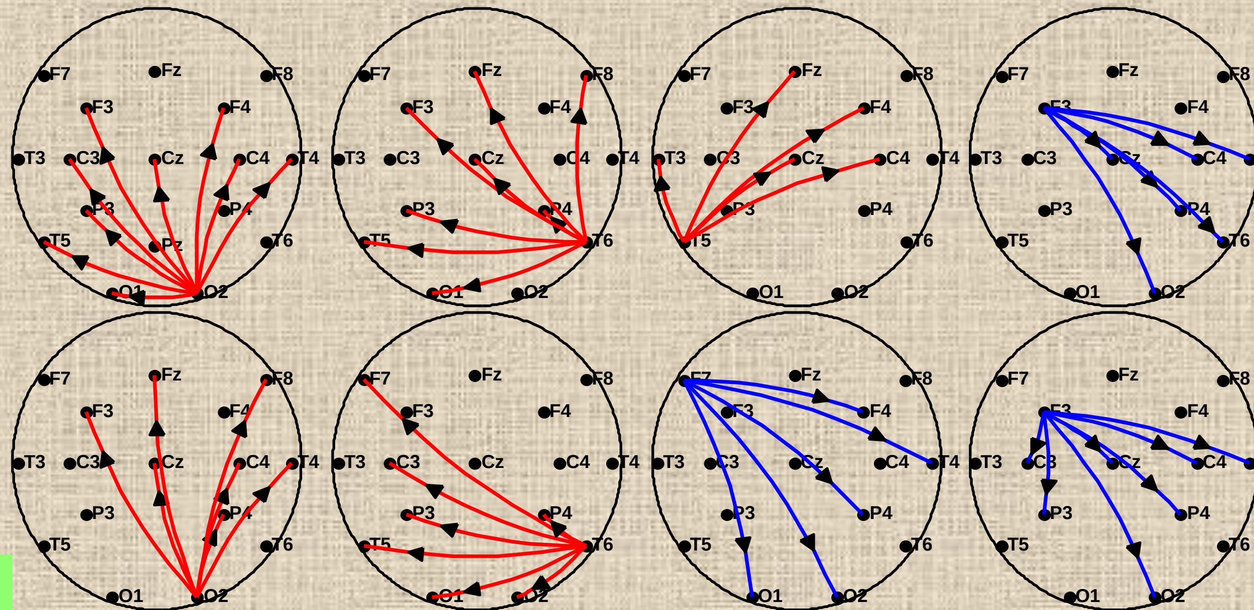
pairwise comparisons $p < 0.05$



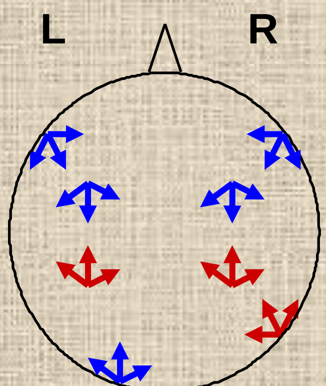
8 – 13 Hz

ADULTS

15 – 20 Hz



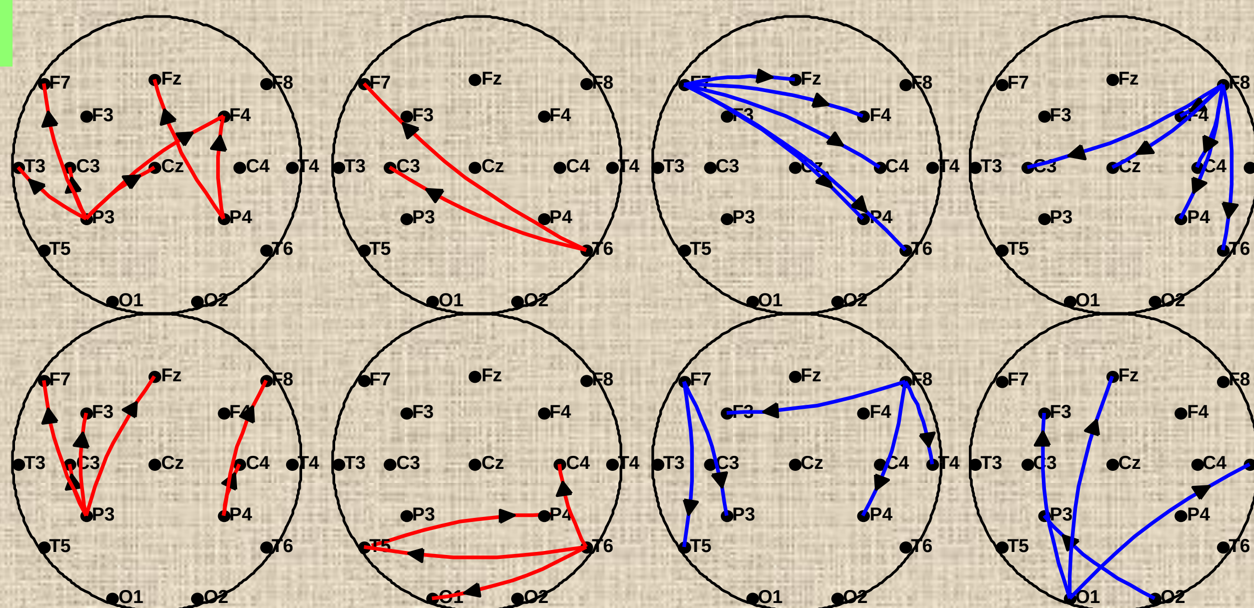
(red)	DTF(SQR) – DTF(sRT) > 0
(blue)	DTF(SQR) – DTF(sRT) < 0



8 – 13 Hz

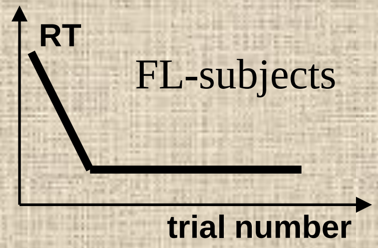
CHILDREN

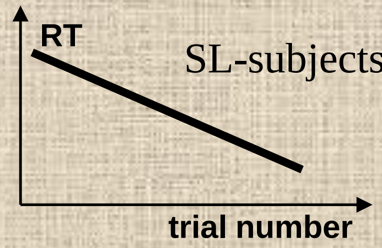
15 – 20 Hz



DTF in FL- vs. SL-SUBJECTS

Comparing Fast-learning subjects against Slow-learning subjects



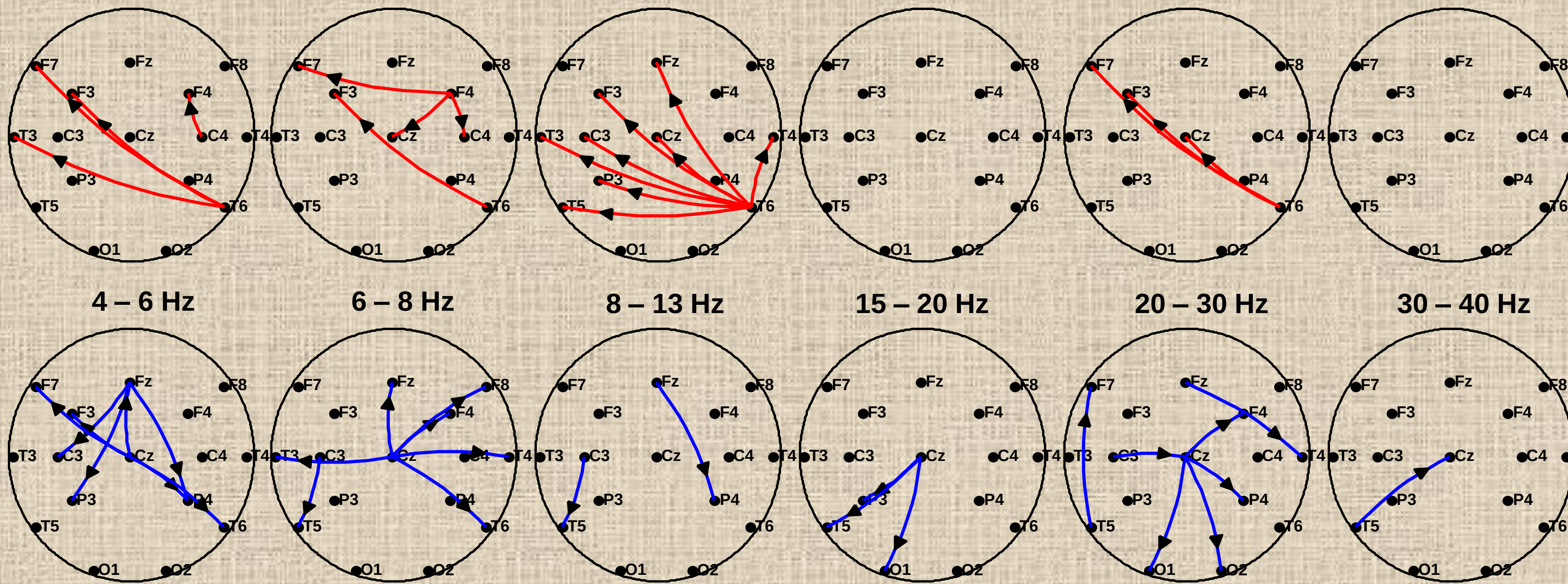


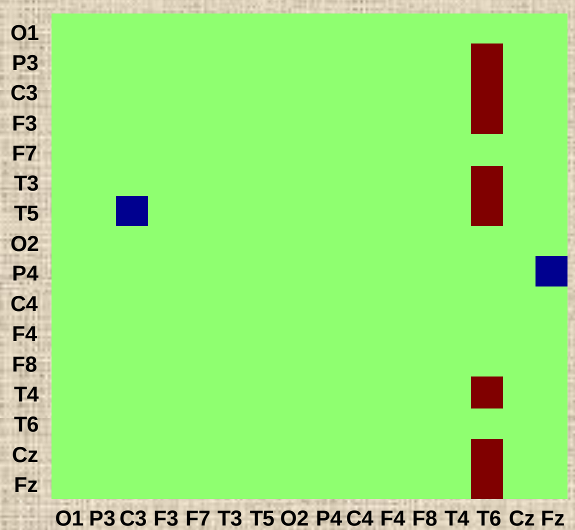
DTF in FL- vs. SL-ADULTS

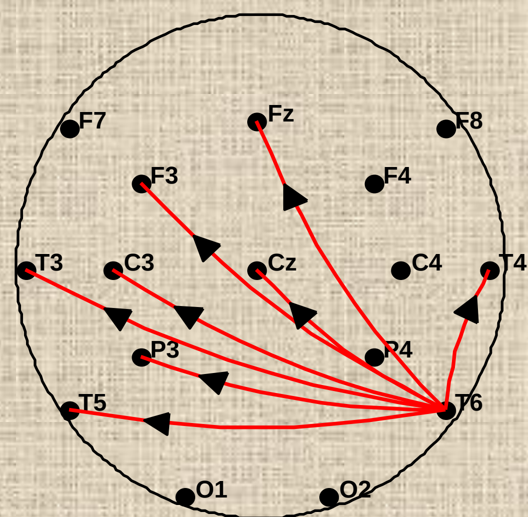
pairwise comparisons $p < 0.05$

DTF(FAST) – DTF(SLOW) > 0

DTF(FAST) – DTF(SLOW) < 0



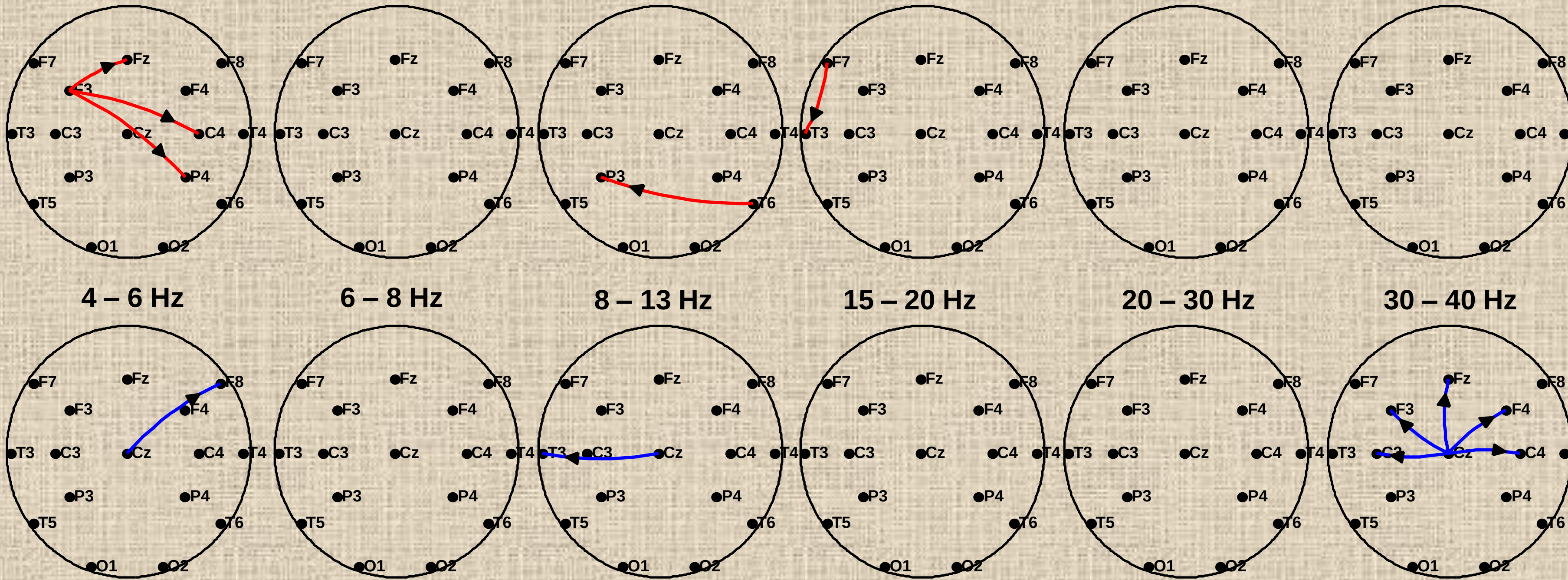


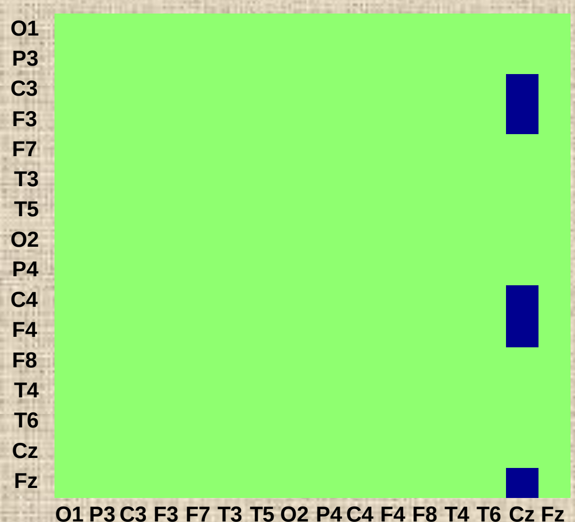


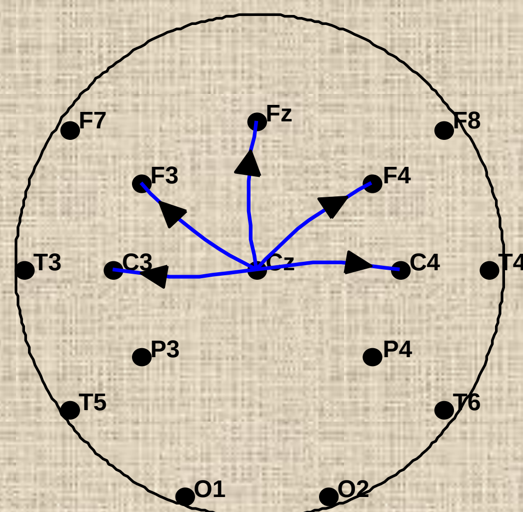
DTF in FL- vs. SL-CHILDREN

pairwise comparisons $p < 0.05$

- DTF(FAST) – DTF(SLOW) > 0
- DTF(FAST) – DTF(SLOW) < 0







CONCLUSIONS

- Both adults and younger schoolchildren aged 7-8 show similar serial learning capabilities as assessed with the sequence reproduction task, the major difference between two age groups being the higher absolute value of reaction time in children than in adults

- In spite of similarity in learning curves in adults and children the functional connectivity patterns in the course of serial learning seem to be different in these two age groups

- The functional connectivity patterns are different in the fast-learning subjects and the slow-learning subjects, both in adults and in children, suggesting a difference in the underlying brain mechanisms in the two groups of learners

СПАСИБО

THANK YOU