An Investigation of Whether Assumptions Underlying the Use of fMRI can be Validly Applied to Children

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RESEARCH QUESTIONS

Might having to lie still without moving, or having to lie down rather than sit up, change the pattern of neural activity in very young children?

(1) Lying still is difficult for young children. If children are concentrating on not moving, might that change their pattern of neural activation while performing a cognitive task (perhaps creating a dual-task situation)? Might researchers, by requiring children to lie absolutely still, be altering the very thing they want to study?

(2) We normally perform cognitive tasks while upright. There is evidence that children perform cognitive tasks more poorly when lying down than when sitting up. Might a difference in body position affect patterns of neural activation?

SUMMARY OF METHODS & RESULTS

To investigate this we tested children of 5 and 8 years in a mock scanner while monitoring brain activity with 128-electrode scalp electrical recording.

In this within-subjects design, all children were tested under all 3 conditions, order counterbalanced across children:

(a) Lying absolutely still in the scanner, as required for fMRI.
(b) Lying down in the scanner, but not stone still.
(c) Sitting up on the scanner table.

Two clear findings emerged:

(1) There was no difference in neural activity when performing the same task lying down or lying down stone still.

(2) Neural activity in each lying down position differed significantly from that while sitting up, especially over frontal and parietal sites.

ERP METHOD

Data were obtained using nets of 128 Ag/AgCl or carbon electrodes embedded in sponges (Geodesic Sensor Net, EGI, Inc.) and soaked in warm electrolyte (KCl).

All impedances were kept at or below 40 kOhms.

All electrodes were referred to Cz and then re-referenced to an average of all electrodes off-line.

Filters were set to .1 – 30 Hz, sampling rate = 250 Hz.

ERP epochs included 100-ms baseline and 700 ms post-stimulus intervals. Artifact rejection was performed off-line. Data from 2 participants were excluded due too many trials rejected for artifacts (eye blinks) and too many bad channels (>10%).

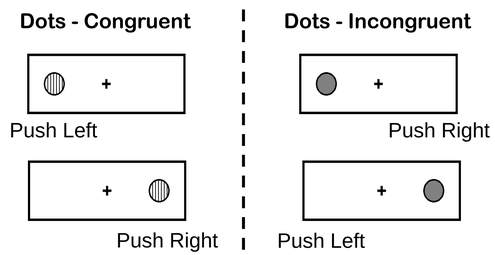
PARTICIPANTS

- 7 children (3 female) of 5 years (5.42 yrs [+/- 0.32 s.d.])
- 14 children (9 female) of 8 years (8.31 ys [+/- 0.34 s.d.])

All were right-handed (Laterality Quotient of .97 [+/- 0.08 s.d.] and .91 [+/- 0.22 s.d.], respectively), healthy, typically developing, & born full-term.

BEHAVIORAL TASK

Directional Stroop Task: Dots Condition



Diamond, O'Craven, & Savoy, 1998 a, b.
O'Craven, Savoy, & Diamond, 1998.
Diamond, O'Craven, Davidson, Cruess, Bergida, & Savoy, 1999.

In CONGRUENT blocks (30 trials), the rule was to "press the response button on the same side as the stimulus."

In INCONGRUENT blocks (30 trials), the rule was to "press on the side opposite the stimulus."

In MIXED blocks (60 trials), Congruent and Incongruent trials were randomly intermixed. This requires working memory (holding 2 rules in mind), inhibition (resisting the tendency to always respond on the same side as the stimulus [Simon Effect]), and set-switching.

Every trial began with a central fixation point presented for 1000 ms, followed by a single stimulus presented for 2000 ms to the left or right of fixation.

The inter-trial interval varied randomly between 1800 and 2800 ms to prevent habituation.

Trial blocks were separated by a 20-sec break during which the instructions were repeated.

Prior to the experiment, the children practiced responding to each type of trials until a criterion of 80% correct responses was reached.

During the recording one experimenter monitored the child while the other experimenter monitored the equipment. If the child became agitated during testing (noisy recording for two stimuli presentations in a row), the experimenter paused the recording until EEG activity was again optimal for recording.

SITTING CONDITION

LYING DOWN CONDITIONS

ELECTROPHYSIOLOGICAL RESULTS: 8-YEAR-OLDS

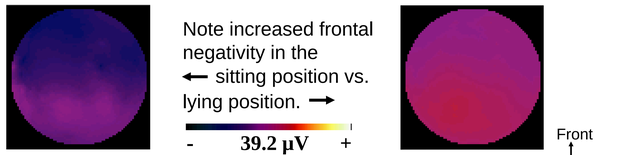
ERPs differences were noted between electrodes as a function of the child's body position in 2 time intervals after stimulus onset (Position x Electrode: $F_{(8,104)} = 2.899$, $p<.006$ & $F_{(8,104)} = 5.309$, $p<.001$, respectively).

ERPs were significantly different in each of the 2 lying down conditions versus the sitting position over frontal ($t(13) = -2.911$, $p < .012$; $t(13) = -3.218$, $p < .007$) and parietal regions ($t(13) = 2.353$, $p <. 035$; $t(13) = 3.594$, $p < .003$) .

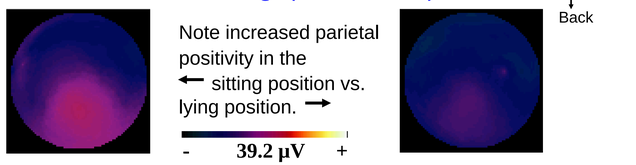
No significant differences found between simply lying & lying very still.

Topographic Maps of Brain Activity for Incongruent Trials in Mixed Blocks

88 - 200 ms range (max = 136 ms)



256 - 608 ms range (max = 424 ms)

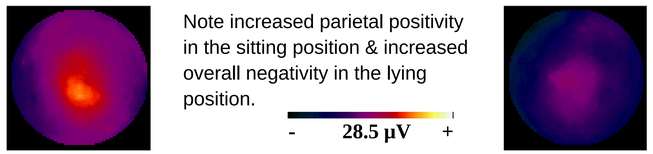


ELECTROPHYSIOLOGICAL RESULTS: 5-YEAR-OLDS

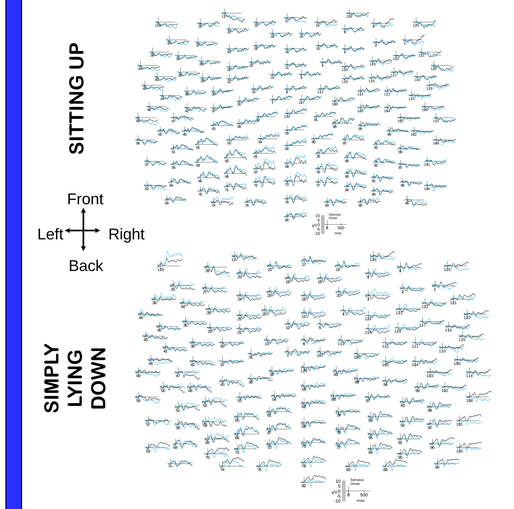
ERPs differences were noted between hemispheres as a function of the child's body position (Position x Hemisphere: $F_{(2,12)} = 5.044$, $p<.026$) in the 376-700 ms range (peak latency = 624 ms). The left hemisphere generated larger ERPs in the simply lying down vs. sitting up positions ($t(6) = 2.73$, $p<.034$) and in the lying very still vs. sitting up positions ($t(6)=4.62$, $p<.004$).

Again, no difference was found between the two lying down positions.

Presented below are topographic maps representing brain activity for Incongruent Trials in Mixed Blocks (as appears above for 8-year-olds).



Waveform Plots for 128 channels for Incongruent Trial Blocks (black) and Incongruent Trials within Mixed Blocks (blue)



These plots demonstrate changes in amplitudes and latencies of ERPs across two body positions. Data quality was comparable in all conditions.

BEHAVIORAL RESULTS

There were no significant differences in reaction time or accuracy across the different body positions for either age group. Many precedents exist for no behavioral differences yet differences in neural activity patterns (e.g., Molfese et al., 1975; Bookheimer *et al.*, 2000).

CONCLUSIONS

1. Body position affected brain activity during performance of this cognitive task. Recorded brainwaves differed within the same child when the child was sitting up versus lying down.
2. Body position resulted in different changes in brain activity across the two age groups:
   A. For 5-year-olds, differences in body position resulted in hemispheric differences.
   B. For 8-year-olds, different body positions were associated with differential responses from frontal and parietal electrodes.
3. Lying down perfectly still did not result in different patterns of neural activity from simply lying down.