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Sandra A. Wiebe
University of Nebraska Lincoln, swiebe@unlnotes.unl.edu

Daniel J. Carroll
University of Sheffield

Megan Herrington
University of Nebraska Lincoln

Sari Raber
University of Nebraska Lincoln

Kimberly A. Espy
University of Nebraska, kespy2@unl.edu

Changing the Rules at the Drop of a Hat: An ERP Study of Preschoolers' Set-Shifting Ability

Sandra A. Wiebe, Ph.D.[1], Daniel J. Carroll, Ph.D.[2], Megan Herrington[1], Sari Raber[1], & Kimberly Andrews Espy, Ph.D.[1]

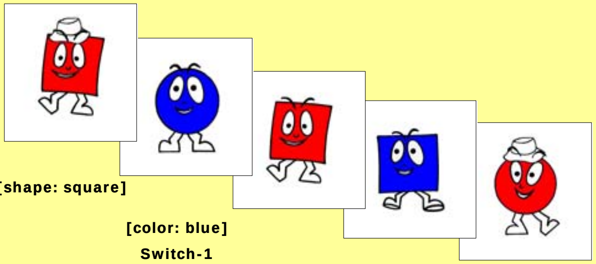
1. Developmental Cognitive Neuroscience Lab, University of Nebraska-Lincoln
2. Department of Psychology, University of Sheffield

Introduction

- Preschool children are increasingly expected to modulate their behavior adaptively in different contexts (e.g., home, school, grocery store)
- The ability to flexibly shift between response modes can be assessed using tasks that require *set-shifting*, a component of executive control (Miyake et al., 2000)
- Executive control is strongly identified with prefrontal function:
  - *The PFC is important when 'top-down' processing is needed; that is, when behavior must be guided by internal states or intentions. The PFC is critical in situations when the mappings between sensory inputs, thoughts, and actions either are weakly established relative to other existing ones or are rapidly changing* (Miller & Cohen, 2001)
- In the present study, a preschool set-shifting behavioral task previously used to examine advances in set-shifting, the Shape School (Espy et al., 2006), was adapted for use with event-related potentials (ERPs), a neuroimaging technique appropriate for use with children (Nelson & Monk, 2001), and notable for its fine-grained temporal sensitivity
- We examined the neural correlates of set-shifting in 5-year-old children, and examined whether the ease of switching was affected by varying the number of non-switch trials preceding a switch

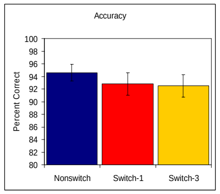
Method

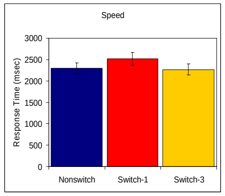
- The sample included 19 preschool children (10 girls, 9 boys) who ranged in age from 5.29 to 6.00 years (mean 5.6 years)
- Children first completed the training phase of the Shape School task (including a color and shape block in counterbalanced order, and a switch block)
  - For trials where the cartoon stimulus was wearing a hat, the correct response was the stimulus shape
  - For trials where the stimulus was hatless, the correct response was the color
- Then, they were fitted with a 128-channel EGI Hydrocel Geodesic Sensor Net
- Finally, children completed 132 Shape School test trials where the rule switched unpredictably after 1 or 3 trials, yielding 3 switching conditions (Switch-1, Switch-3, Non-switch)



Behavioral Performance

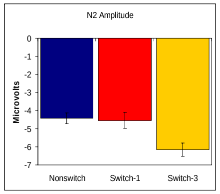
- Analyses were conducting using SAS *proc mixed*, specifying an unstructured covariance structure for the effect of Condition
- Accuracy varied by Condition: $F(2, 17) = 3.70$, $p < .05$
  - However, no conditions differed significantly from each other when Tukey tests were examined
  - A planned contrast comparing the Non-switch against the 2 Switch conditions was significant, $F(1, 18) = 7.04$, $p < .02$)
- Response time also varied by Condition: $F(2, 17) = 11.82$, $p < .001$
  - Response time was slowest for the Switch-1 condition, and differed from both the Non-switch and Switch-3 conditions

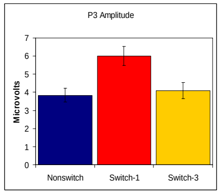


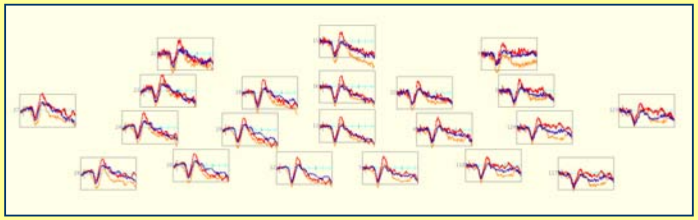


ERP Results

- ERP waveform parameters were examined across the anterior leads (shown below), because previous work with children and adults have identified components at these locations that were related to executive control processes
- Analyses were conducted using SAS *proc mixed*, specifying an unstructured covariance structure for the effect of Condition and an autoregessive covariance structure for the effect of Lead
- For the N2 (defined as the minimum peak between 150 and 350 msec from stimulus onset), there was a significant effect of condition: $F(2, 92.8) = 9.51$, $p < .0005$
  - The largest N2 was observed for the Switch-3 condition, and differed from both the Non-switch and Switch-1 conditions
- N2 amplitude also varied by Lead ($F(20, 361) = 2.65$, $p < .0005$), but there was no significant Condition x Lead interaction
- There were no significant effects for N2 latency
- For the P3 (defined as the maximum peak between 200 and 500 msec), there was a significant effect of condition: $F(2, 86.9) = 8.81$, $p < .0005$)
  - The largest P3 was observed for the Switch-1 condition, and differed from both the Non-switch and Switch-3 conditions
- P3 amplitude also varied by Lead ($F(20, 364) = 3.01$, $p < .0001$), but there was no significant Condition x Lead interaction
- P3 latency varied by Lead only, $F(20, 345) = 1.84$, $p < .02$







Conclusions

- Consistent with previous research, requiring children to shift set resulted in decreases in accuracy, and under some circumstances increased response times
- ERP indices of underlying neural processes revealed differences at anterior leads that were related to set-shifting demands
- *When children were required to shift set* ***immediately*** *after another switch trial (Switch-1 condition):*
  - Longer response time
  - ERP waveform difference from Non-switch condition not apparent until later in processing (i.e., at P3 component)
- *When children were required to shift set after 3 non-switch trials (Switch-3 condition)*
  - RT equivalent to Non-switch trial (suggesting that these Switch-1 trials are less difficult than Switch-3 trials)
  - ERP waveform difference from Non-switch condition apparent earlier in processing (in the N2 component)
- The number of consecutive trials completed utilizing a particular rule appears to result in dynamic changes in the ease of "switching gears", observed in response time and ERP waveforms but not at the level of performance accuracy
- ERP differences were observed shortly after stimulus onset and therefore likely involve mechanisms engaged early in the process of set-shifting (e.g., recognizing the presence of a cue—the presence or absence of a hat—that signals the necessity of shifting set) rather than mechanisms related to selecting the relevant rule or preparing the correct response
- Interestingly, the topography and timing of effects are similar to differences observed in children performing the Go/No-Go, an executive control task with stronger inhibitory demands (e.g., Lewis et al., 2006; Wiebe et al., 2007)—consistent with recent behavioral findings that preschool executive control draws on a common underlying mechanism (Wiebe, Espy, & Charak, 2008)
- Future work will build on these findings by parametrically varying aspects of the task to further parse the processes involved in preschool set-shifting (e.g., by varying the amount of conflict present in a trial, separating the cue from the response, etc.)

Acknowledgments

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