The Development of Conscious Control: How it Depends on Self-Regulation, Reflection, and Keeping Things in Mind

Stuart Marcovitch
Department of Psychology
University of North Carolina at Greensboro

Department of Psychology, Wake Forest University
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Collaborators

A. Nayena Blankson
Janet Bosevski
Susan Calkins
Mike Kane
Robin Knapp
Esther Leerkes
Janet Leigh
Jennifer McVay
Stephanie Miller

Marion O’Brien
Mark Schmuckler
Philip D. Zelazo

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Conscious Control

• In child research, typically defined as Executive Function
  • processes involved in goal-directed problem solving—processes such as working memory, inhibitory control, and error correction
  • Conspicuous in its absence
EF Tasks in Children: Day/Night Stroop

- Gerstadt, Hong, & Diamond (1994)

- 3.5-year-olds much slower than 4.5-year-olds
EF Tasks in Children: Dimensional Change Card Sort


- 3-year-olds fail the post-switch; 5-year-olds pass
EF and Self-Regulation

• Cardiac measures of self-regulation include:
  – Vagal Tone
    • Measured by respiratory sinus arrhythmia (RSA)
    • Indicator of level of arousal → attention
  – Vagal Withdrawal
    • Measured by RSA decrease
    • Indicator of reorientation of attention when faced with a challenge
Experiment 1

- Baseline RSA (i.e., vagal tone) should be related to performance on EF tasks.

- Amount of vagal withdrawal during EF tasks should be related to EF performance; too little or too much may be a problem

- Both vagal tone and withdrawal have been linked to emotion regulation, but not to cognitive task performance
Exp. 1

- 220 3.5-year-old children
  - Socio-economically diverse (controlled for poverty level)

- Baseline RSA
  - Measured during non-stress inducing video
  - Average of scores recorded across 30 second epochs

- RSA during EF tasks
  - Day/night Stroop and Number Recall Task
  - Average of scores recorded across 15 second epochs
Exp. 1

linear relation  
\[ F(2,212) = 4.4, \ p = .01 \]

quadratic relation  
\[ F(2,212) = 3.6, \ p = .03 \]
EF and Reflection

• Inspired by research in infancy and toddlerhood
  – Reflection is defined as the ability to represent a representation (see Rosenthal, 1997; Zelazo, 2006)

• A-not-B task taps working memory and executive function skills
  – Inhibiting, shifting, updating (Miyake et al., 2000)
Hierarchical Competing Systems Model (HCSM)

Marcovitch & Zelazo (2009; Developmental Science)
HCSM

reflection

Rep

stimulus

Habit

behavior
Relationship between # of A Trials and B Trial Performance

• No relation
  – “a single A trial is just as likely to elicit perseveration as several A trials” (Harris, 1989, p. 119; Wellman, Cross, & Bartsch, 1986)

• Positive relation
  – Increases in habit makes it difficult to switch (e.g., Diamond et al., 1994; Marcovitch & Zelazo, 1999)
Experience on A trials increases habit strength and the likelihood of reflection.
Experiments 2, 3, and 4

- **Exp 2:** A-not-B task (Marcovitch, Zelazo, & Schmuckler, 2002; *Infancy*)
  - 84 9-month-olds
  - 1, 6, or 11 A trials

- **Exp 3:** Multistep multilocation search task
  - 71 2-year-olds
  - 1, 6, or 11 A trials

- **Exp 4:** Sandbox task (Marcovitch & Zelazo, 2006; *Journal of Cognition and Development*)
  - 64 2-year-olds
  - 3, 7, 11, or 15 A trials
Exps. 2, 3, 4

\[ \chi^2 (2, N = 84) = 7.51, p < 0.05 \]

Quadratic: 
\[ Wald = 5.05, p < .05 \]

Quadratic trend: 
\[ F(1, 43) = 7.22, p < .05 \]
Experiment 5

• Representational capability (and likelihood of reflection) should vary with working memory capacity (WMC)

• 46 High WMC students (upper quartile)  
  – Expected to perform at ceiling

• 36 Low WMC students (lower quartile)  
  – Expected to show U-shaped relation

Marcovitch, Boseovski, McVay, & Kane (in progress)
Exp. 5

• List 1
  – 8 semantically related word pairs (that will interfere with the eventual test pairs)
    • knee – bone
  – 2 pairs presented 1 times, 2 pairs presented 6 times, 2 pairs presented 11 times, 2 pairs presented 16 times

• List 2
  – 8 eventual test pairs
    • knee – bend
  – Participants asked to read words aloud and that these word pairs (not the pairs from the first list) will be tested
Exp. 5

• Test: 8 fragment completions

  knee – b _ n _

bone    bend
Exp. 5

Low WMC Quadratic trend: $F(1, 35) = 18.8, p < .01$
Experiment 6

- Representational capability (and likelihood of reflection) should vary with increases in labeling complexity

- Computerized multistep multilocation search task

- 6 A trials; 10 sec. delay

- 153 older 2-year-olds
Exp. 6

(a) No Picture Condition ("The star is hiding in this box")

(b) No Verbal Label Condition ("The star is hiding in this box")

(c) Experimenter Verbal Label Condition ("The star is hiding in flower box")

(d) Child Verbal Label Condition ("Which box is the star hiding in?")
Exp. 6

Mantel-Haenszel $\chi^2(1) = 4.71, p < .05.$
EF and Keeping Things in Mind

• *Goal neglect* refers to the disregard of task requirements despite understanding and being able to recall them (Duncan, Emslie, Williams, Johnson, & Freer, 1996)

• *Goal maintenance* is the complementary process of keeping requirements in mind in the face of obstacles
Experiments 7 and 8

Goal Neglect DCCS
Test cards are a mixture of conflict cards and redundant cards

• Pre-switch: *Identical to standard DCCS*
  – 5 trials
  – Rule repeated on every trial
  – All conflict cards

• Post-switch
  – 30 trials
  – Rule ONLY before 1\textsuperscript{st} trial (Exp. 7; 16 4- and 16 5-year-olds) or before EVERY trial (Exp. 8; 16 4- and 16 5-year-olds)
  – 2 card sorts
    • Mostly redundant (24 redundant and 6 conflict cards)
    • Mostly conflict (24 conflict and 6 redundant cards)
Exps. 7 and 8

AGE: $F(1,30) = 3.41, p = .07$

CONDITION: $F(1,30) = 8.88, p = .01$

CONDITION: $F(1,30) = 12.0, p < .01$
• According to Engle and Kane (2004), there are 2 factors of executive control that can be measured by working memory capacity (WMC)

• Mostly Redundant sort may assess “the maintenance of the task goals in active memory” (Factor 1)

• Mostly Conflict sort may assess “the resolution of response competition or conflict, particularly when prepotent or habitual behaviors conflict with behaviors appropriate to the current task goal” (Factor 2)
Exp. 9

- WMC is composite of 3 age-appropriate WM tasks
  - Visual counting span
  - Visual backward word span
  - Auditory backward digit span

- 37 4-year-olds and 28 6-year-olds

- Both 4- and 6-year-olds expected to show WMC \(\rightarrow\) Mostly Redundant

- Only 4-year-olds expected to show WMC \(\rightarrow\) Mostly Conflict
  - Low WMC children will have difficulty maintaining rule
Exp. 9

4-year-olds: WMC $\rightarrow$ Mostly Redundant; $t(35) = 1.7, p < .10$
WMC $\rightarrow$ Mostly Conflict; $t(35) = 2.8, p < .01$

6-year-olds: WMC $\rightarrow$ Mostly Redundant; $t(26) = 2.1, p < .05$
BUT NOT Mostly Conflict; , $t < 1$
Conclusions

- The development of EF and conscious control can be studied across a wide age range and from multiple perspectives.

- The role of reflection, whether studied directly or indirectly, is a promising candidate to guide the study of the development of EF
  - Physiological self-regulation needed to focus attention appropriately
  - Keeping goals in mind may be prerequisite for reflective processes
“By three methods we may learn wisdom: first, by reflection, which is noblest; second, by imitation, which is easiest; and third, by experience, which is the most bitter.”

- Confucius
THE END

If you're happy and you know it, clap your hands...

Sammy was actually happy, he just didn't know it.