What Predicts Education Relevant (Implicit) Task-Switching Flexibility?

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Overview
Cognitive flexibility is the ability to modify representations or plans based on changing information in the environment.

Cognitive flexibility is usually measured using explicit task-switching cues. However, in learning environments like classrooms, task-switching cues are often implicit or implied.

We tested children ages 4-6 in computerized variants of a binary rule-switch task. Task-implicit cue conditions stated the exact rule on each trial. Task-implicit cue conditions only indicated whether to switch or stay on task.

Several other questions were addressed:
- Does stimulus matching speed, a low-level factor, predict flexibility? Does practicing low-level matching improve flexibility?
- Does task-switching improve with practice? Facilitation from one task-switching test to another, a week later, was tested.
- Do inhibition and processing speed predict task-switching flexibility?

Background: Cognitive Flexibility
There are large age group (4-6) and individual differences in cognitive flexibility.

- Differences predict early reading and math skills (Bull & Searf, 2001; Carwright 2008).
- Cognitive flexibility is often assumed to be a product of separate cognitive functions:
  a) Inhibition of prepotent responses (Diamond et al, 2005)
  b) Processing Speed (Cepeda et. al, 2001)
- Differences might be due to speed of using cues to select appropriate responses from working memory (Logan and Schneider, 2003)
  a) Perseverative children respond slower to a single rule (Cepeda and Munakata, 2007).
  b) Arbitrary rules are harder to access in working memory (Chevalier and Blaye, 2009)

Methods
- **Participants:** N = 110
  4-year-olds (n = 38, mean age = 53.4 months, 19 girls)
  5-year-olds (n = 38, mean age = 64.4 months, 14 girls)
  6-year-olds (n = 31, mean age = 78.8 months, 15 girls)

- **Procedures:**
  a) **Screening Tests:** PPVT III-A, Digit Span
  b) **Tests of General Cognitive Functions**
    a) Inhibition: Go-No-Go tests; Luria Tapping-test
    b) Processing speed: Box Completion (W-J); Button-press (to targets at varying times)
  c) **Unidimensional Matching** [SEE FIGURES]
    a) Speed to match color-only or shape-only stimuli after an implicit or explicit cue
    b) Cues and stimulus values were same as in Task-Switching tests
  d) **Task-Switching** [SEE FIGURES]
    a) Tasks: Match by color or shape.
    b) Explicit cues: “Play the [Color/Animal] game”
    c) Implicit cues: “Play the [Same/Other] game”
    d) Two stimulus sets: Test A (brown/blue cat/duck) and Test B (green/grey pig/bear)
    e) The other switching and matching tests (set A or B) were given one week later

Results: Task-Switching
- **Switching:** Switch trials slower than stay trials (F = 24.0, p < .001, n² = .20)
  a) Cue x Switch x Congruency interaction:
    - When Cue is Explicit (“Animal/Color”): Switch costs only on conflict (incongruent) trials
    - When Cue is Implicit (“Same/Other”): Switch costs only on non-conflict (congruent) trials
  b) Cues: Responses to Task-implicit cues were slower than Task-explicit cues (F = 78.7, p < .001, n² = .45).
  c) Practice: Responses were faster to second test one week later (F = 4.8, p < .03, n² = .05).
  d) Congruency: No-conflict stimuli faster than conflict (incongruent) (F = 40.1, p < .001, n² = .29)

Results: Predictors
- **Unidimensional Matching Speed**
  a) Explicit cues faster than Implicit cues (F = 78.7, p < .001, n² = .45).
  b) Color task trials faster than animal task trials, regardless of cue (F = 78.71, p < .001, n² = .45).

- With age partialled out, switch costs predicted by unidimensional match speed:
  a) Unidimensional speed with either implicit or explicit cues predicted significant unique variance.
    - Task-Switch w/ Explicit Cues: Predictors are...
      1. Unidimensional Speed w/ Explicit cues: β = .362, R² = .24 (p < .001)
      2. Unidimensional Speed w/ Implicit cues: β = .508, R² change = .10, p < .001
      3. Processing speed: R² change = .06, p < .001
  b) Task-switching w/ Implicit cues: Predictor is...
     1. Unidimensional Speed w/ Explicit Cues: β = .51, R² change = .19, p < .001
     b) Inhibition does not predict significant additional unique variance

- **Unidimensional speed (Explicit Cue) predicted learning (i.e., faster switching one week later):**
  a) β = -.842, R² change = .17, p < .001, with Task-explicit cues
  b) No other test predicted repeat performance in task-switching with Task-implicit cues (little improvement)

Conclusions
- Cognitive flexibility depends on how well children understand and use cues.
  a) Educational relevance: Higher-order or implicit cues are harder
  b) Cue effect more pronounced than switch effects when both stimuli and cue are difficult (switch not > stay in conflict conditions with implicit cue)
  c) Even with no-conflict stimuli and no switching demands, faster to follow explicit than implicit cues
- Efficient switching was predicted by how quickly children could match simple stimuli (i.e., activate a low-level response)
  a) General processing speed, but not inhibitory speed, predicted additional variance.
- Improved flexibility in a second task-switch test, one week later, was predicted by low-level (unidimensional) stimulus matching.
  a) Correlation was strongest in condition with greatest improvement (i.e., task-explicit cue condition)