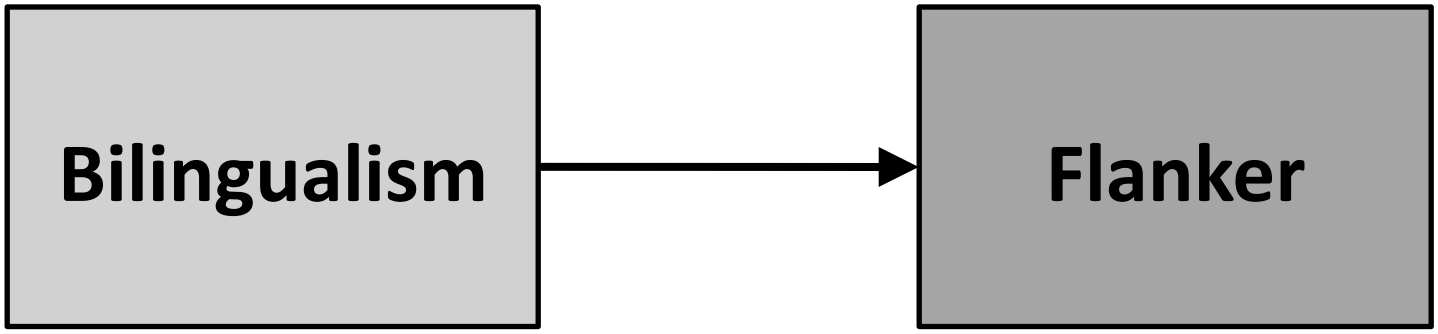
What is (are) executive function(s)?

Insights from individual differences research

Executive Functions (EFs)

- General purpose control mechanisms that enable us to regulate our own thoughts and actions
- EF tasks recruit a network of frontal, parietal, and subcortical regions
  - But PFC is considered a key player

Hypothesis



Assumptions:

- Language control requires domain-general EFs
  - We know what those EFs are and can measure them
- Everyday use trains EFs, and that training transfers to other tasks

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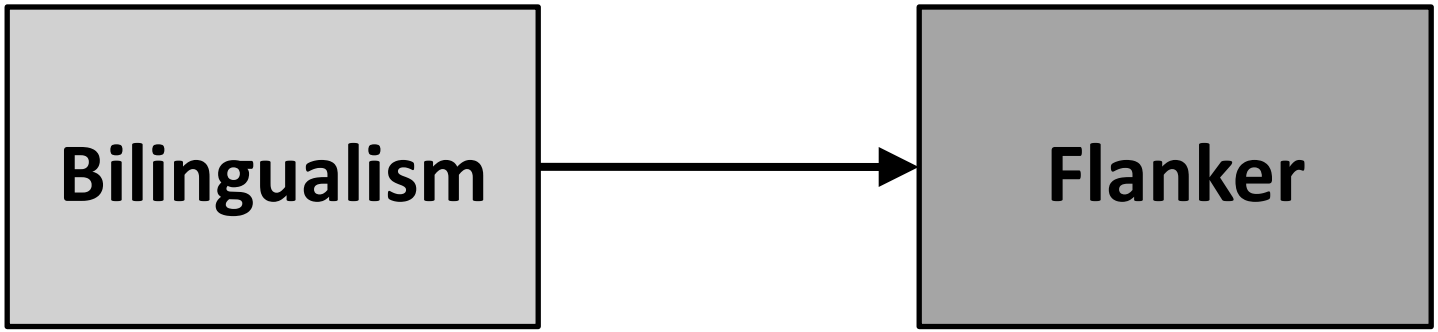

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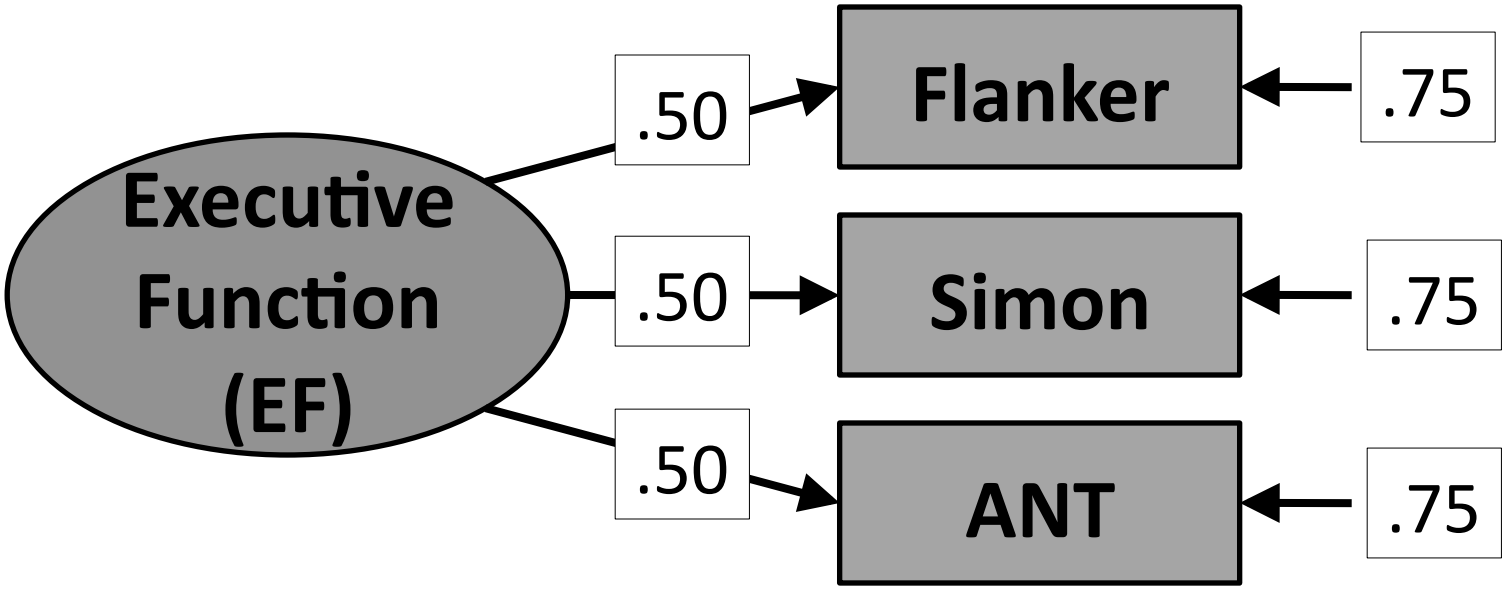
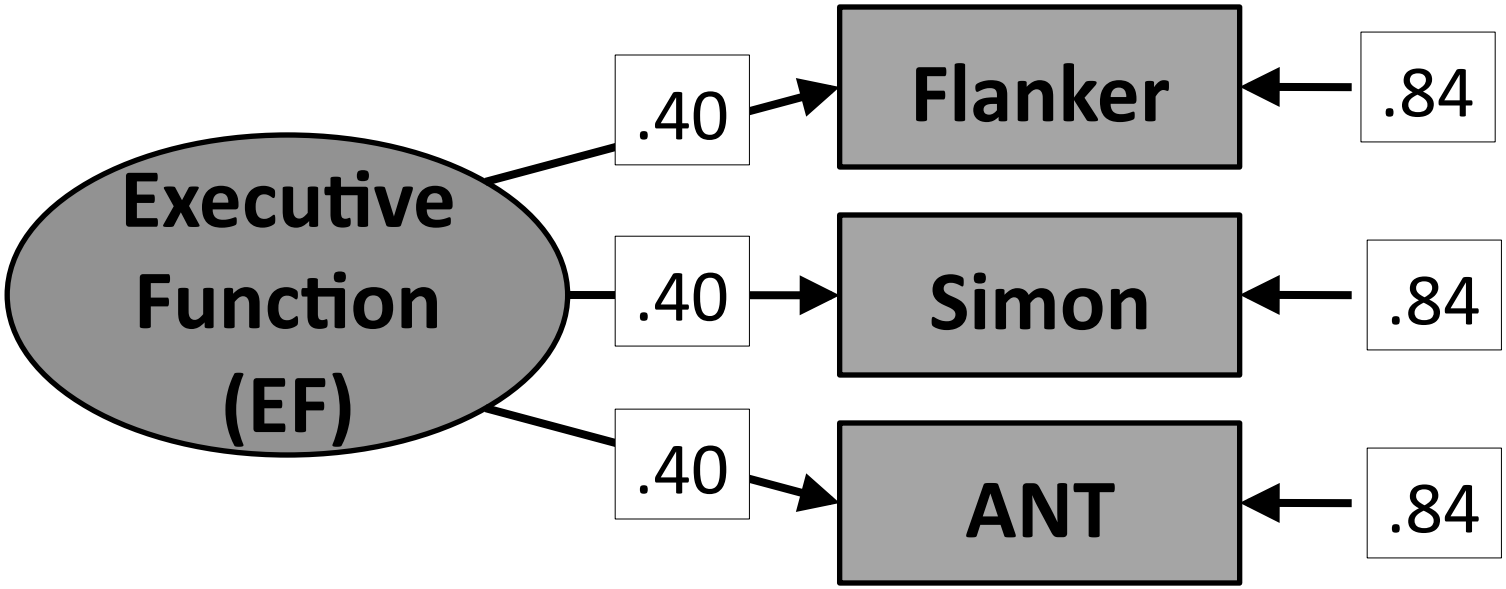
Overview

- Measuring EFs
- Multiple EFs
  - Possible mechanisms
- Genetic influences
  - Implications for bilingual advantage hypothesis
- Conclusions and considerations

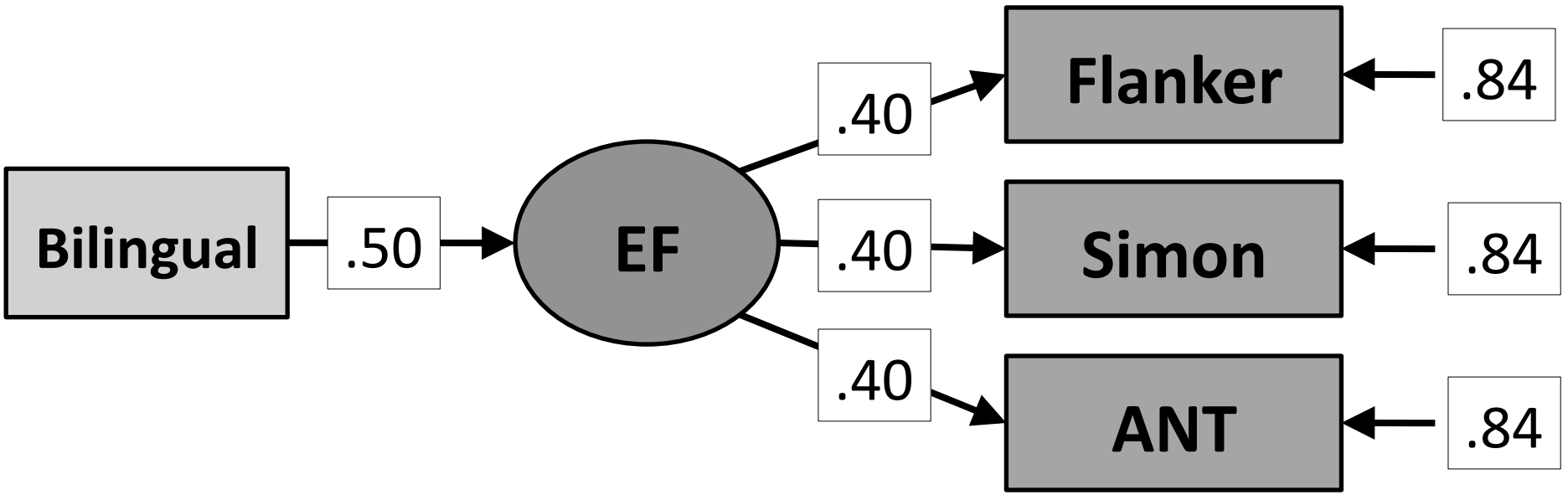
Measuring EF



Measuring EF

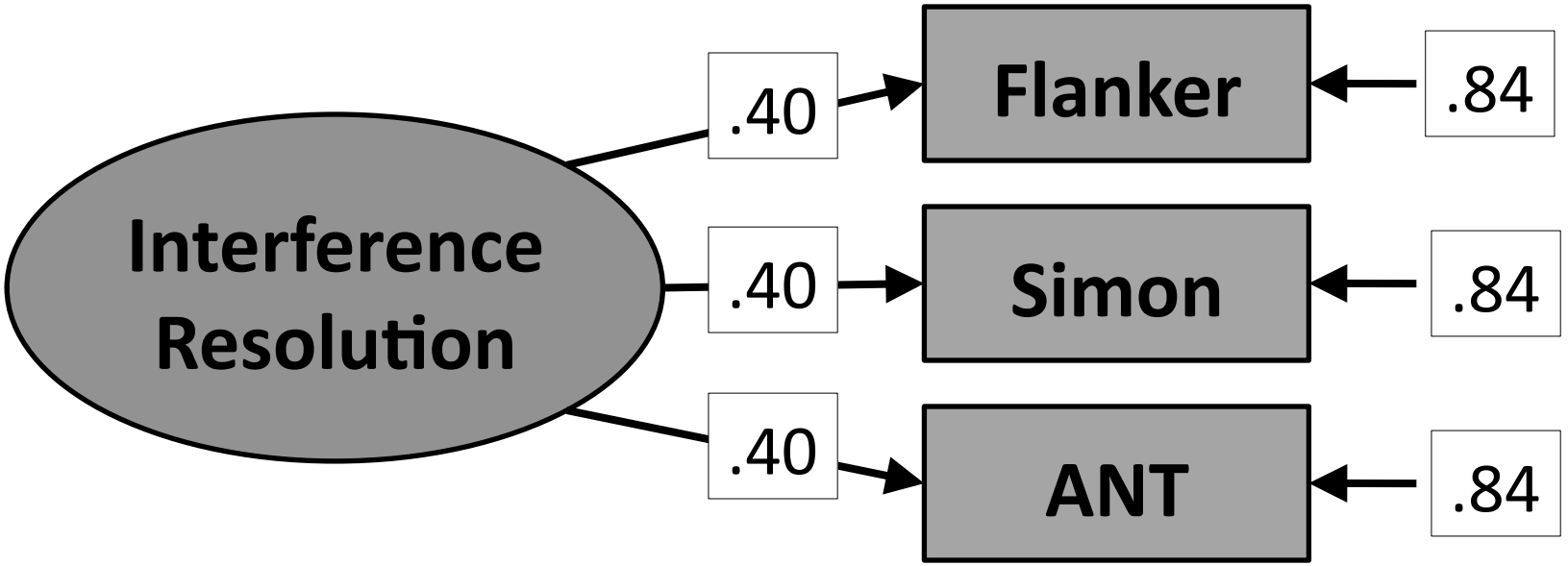


Implication



Predicted effect on individual task:
.50*.40 = .20

Other EFs?



- Stroop, Go/NoGo, Stop-Signal
- *N*-back, working memory tasks
- Task-switching (e.g., Color-Shape)
- Verbal fluency, dual tasking, problem solving, reasoning, planning

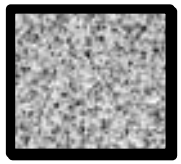
Multi-Component Structure

- EF is not a single ability, but a family of functions
  - Normal young adults
    - Friedman et al. (2006); Ito et al. (2015); Miyake et al. (2000)
  - Older adults
    - Fisk & Sharp (2004); Hedden & Sharp (2006)
  - Children
    - Huizinga et al. (2006); Lehto et al. (2004); van der Sluis et al. (2007)
  - Neuroimaging studies
    - Collette et al. (2005); Sylvester et al. (2003)

Three EFs

- Inhibition
  - Stopping prepotent (dominant or automatic) responses
  - Example: Antisaccade

Inhibiting: Antisaccade task



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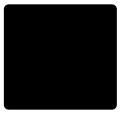


Three EFs

- Updating
  - Monitoring and rapid addition/deletion of working memory contents
  - Example: Keeptrack

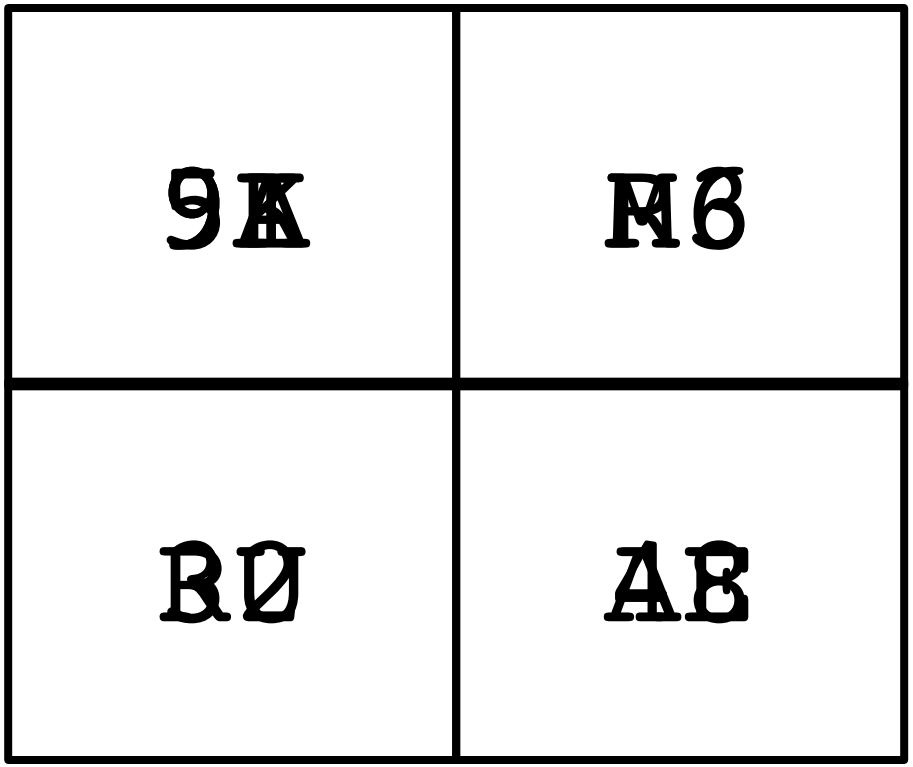
Updating: Keeptrack Task

RELATIVES METALS

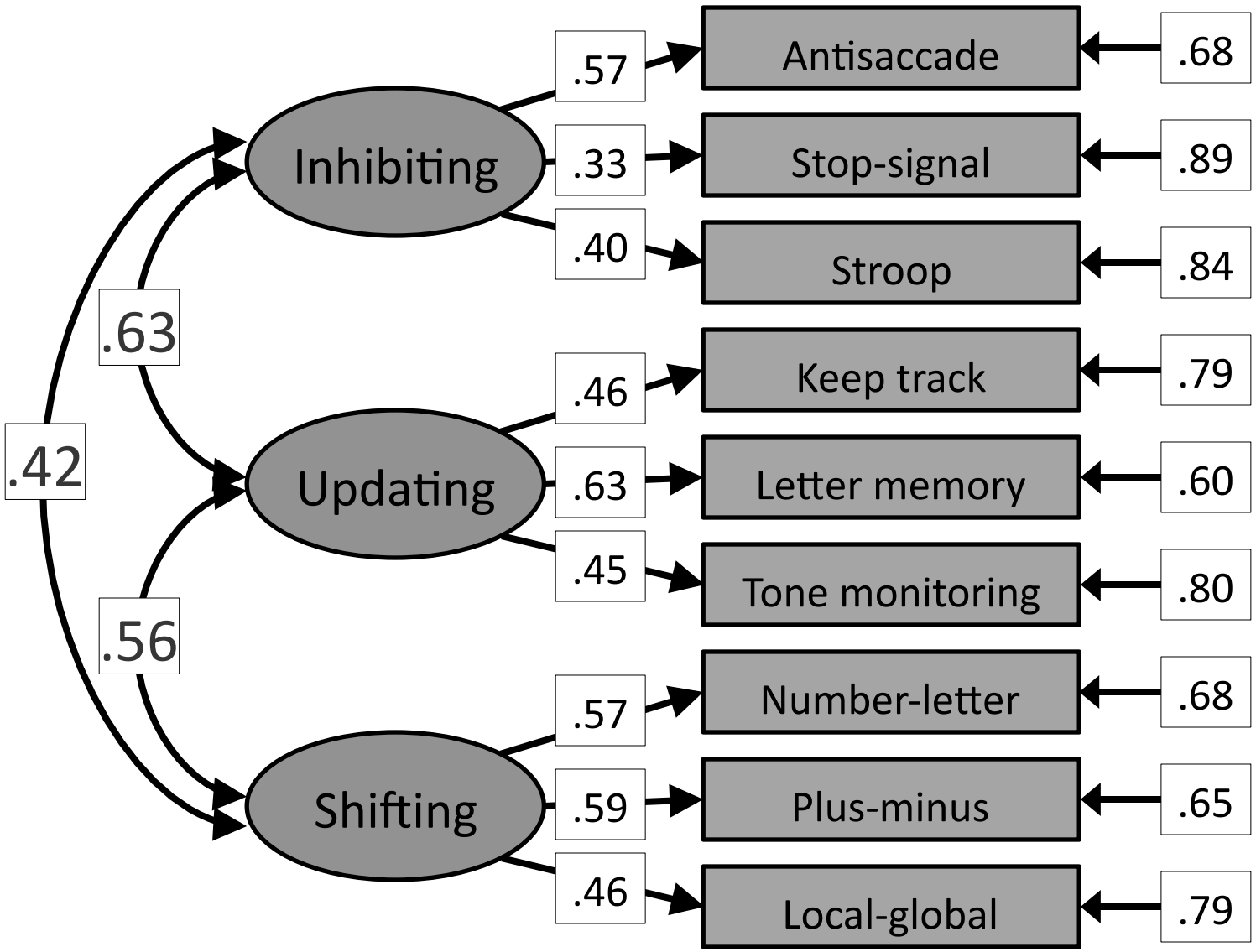
Three EFs

- Shifting
  - Switching flexibly between tasks or mental sets (switch costs)
  - Example: Number-Letter

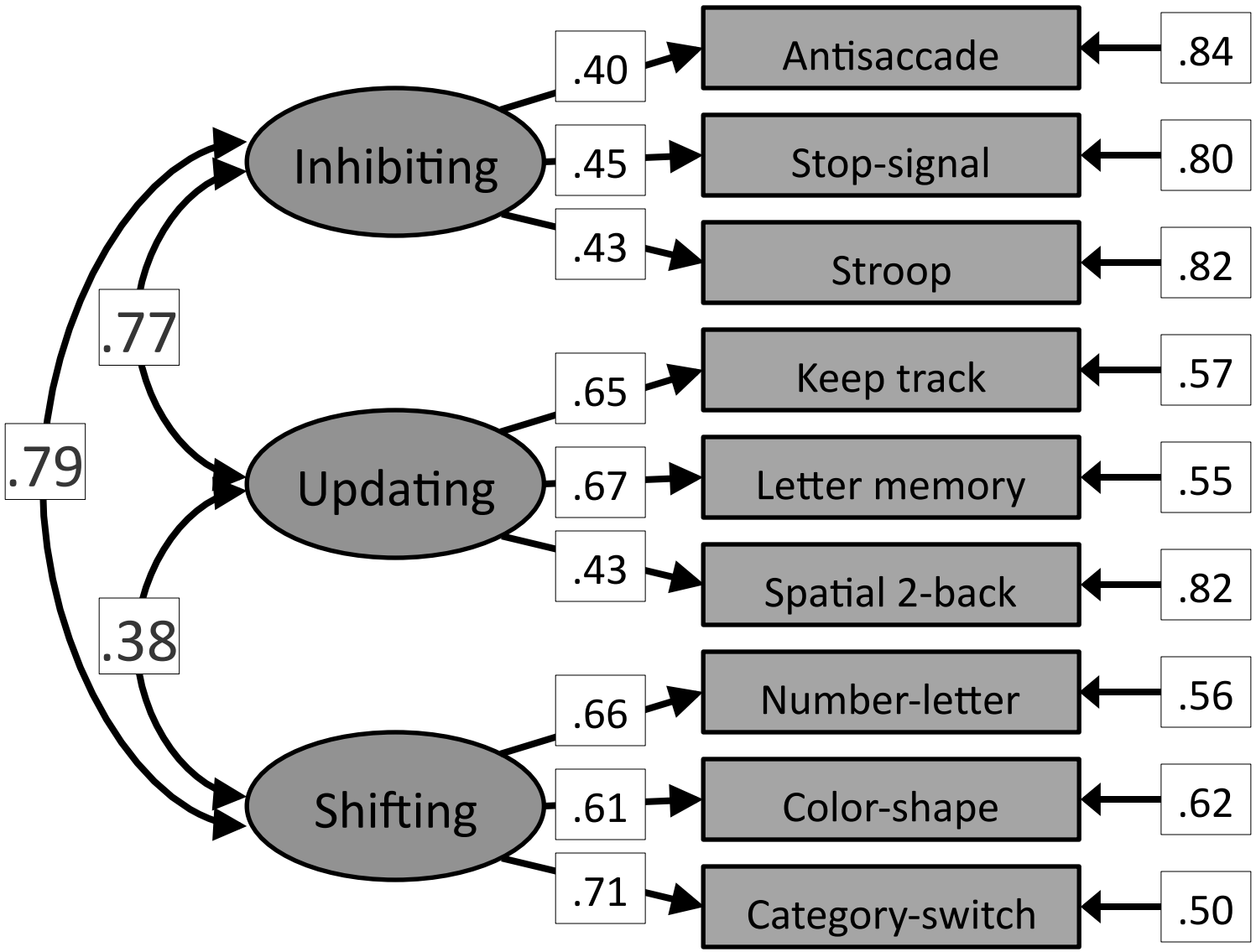
Shifting: Number-Letter Task



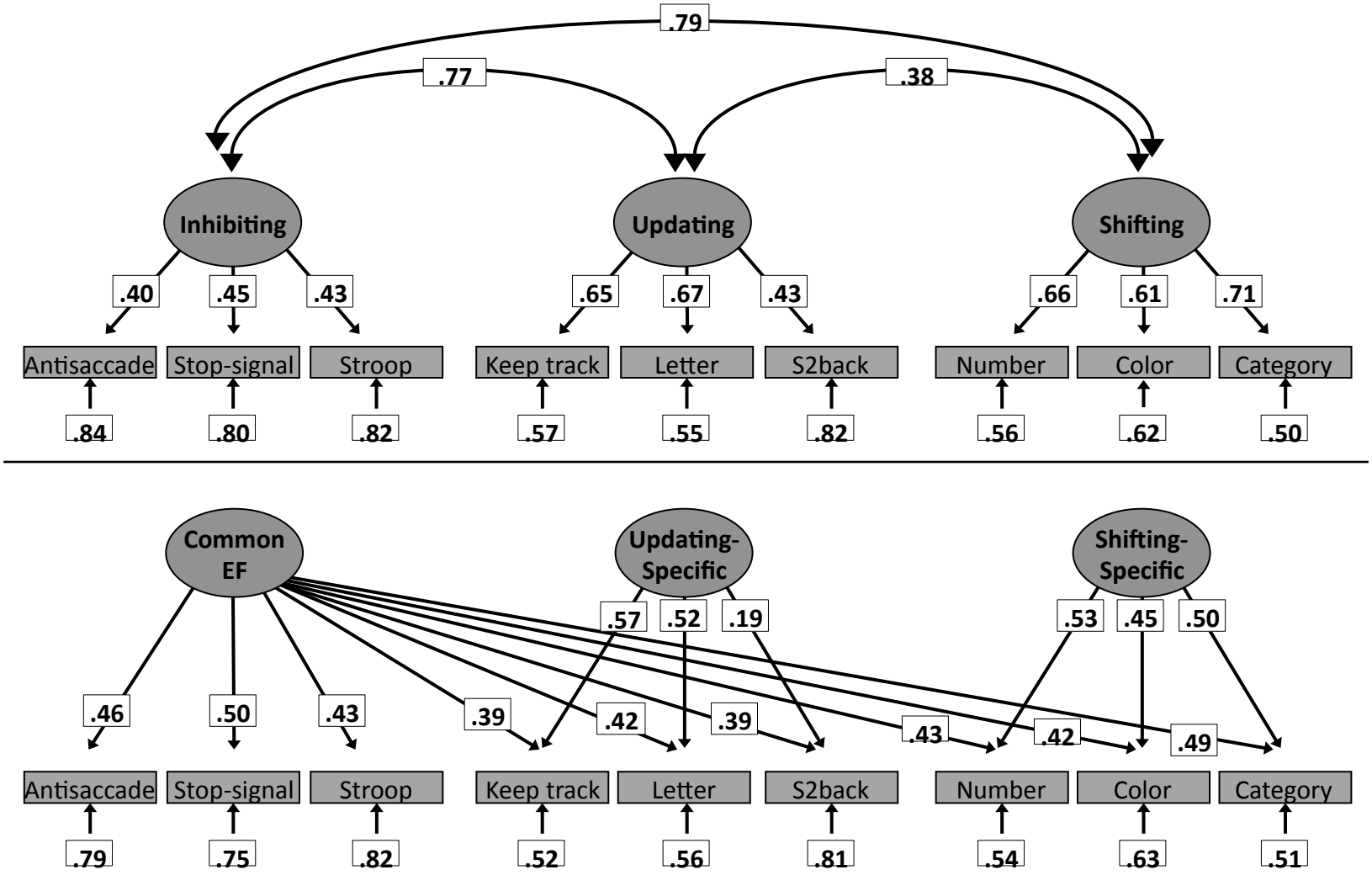
Miyake et al. (2000)



Friedman et al. (2008; 2011)

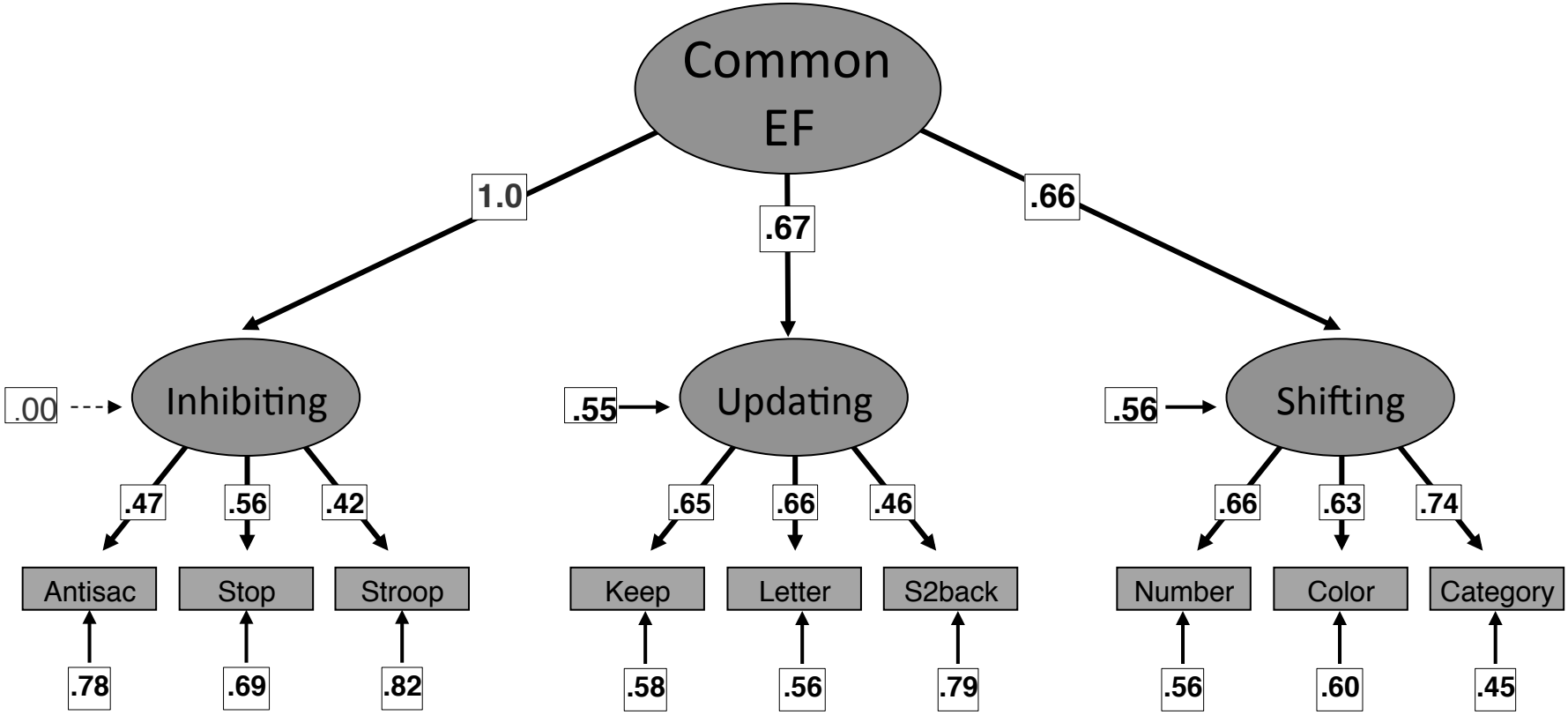


Unity/Diversity Framework



Friedman et al., *JEP: General*, 2008; Friedman et al., *Dev. Psych.*, 2011

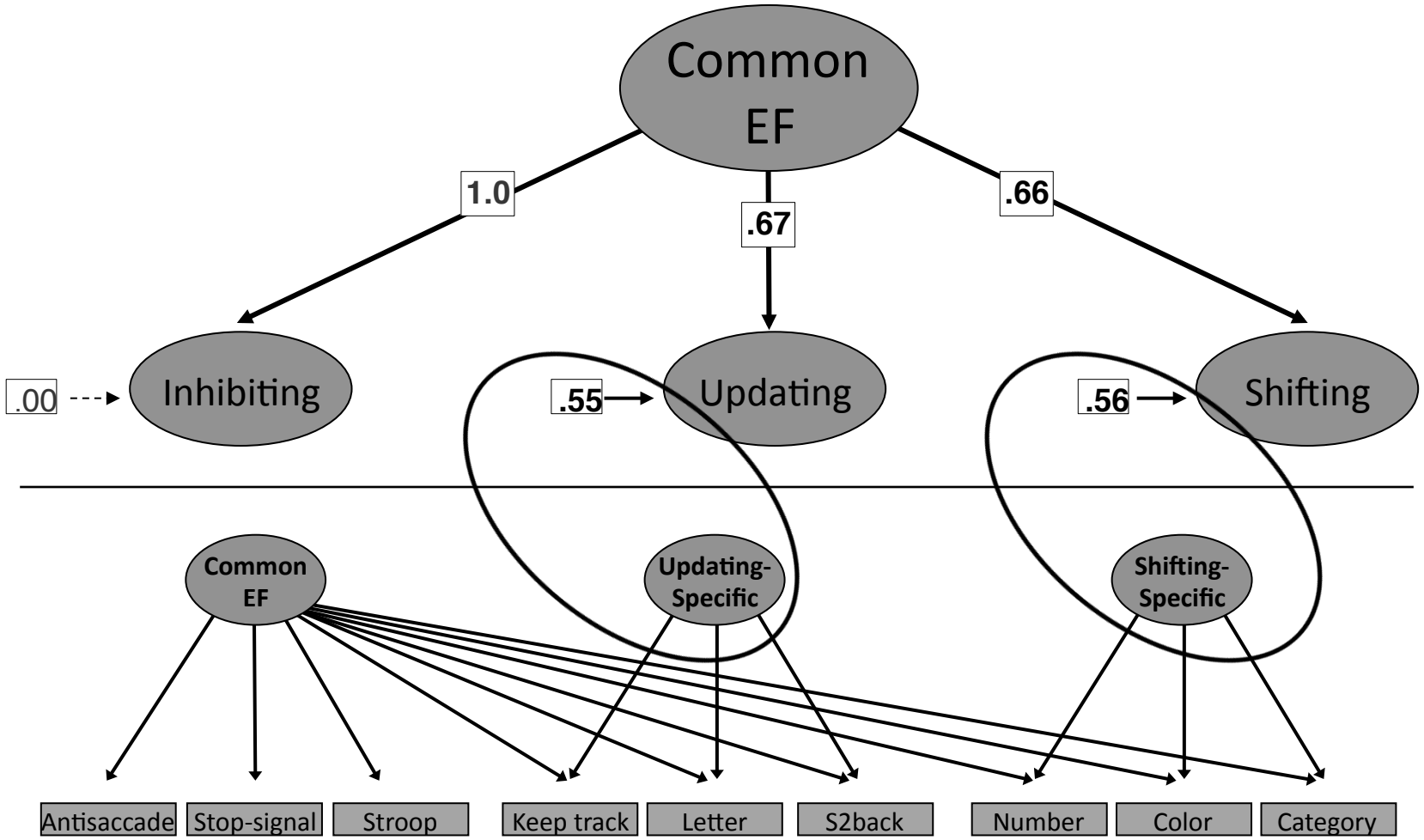
No Inhibiting-Specific Factor



Friedman et al., *JEP: General*, 2008

- Replicated in 3 additional independent datasets

Specific Components Like Residuals



Mechanisms

- Common EF: active maintenance of goals (in working memory) and the use of these goals to bias ongoing processing
- Shifting-Specific: speed of replacing goals in working memory
  - Flexibility-stability tradeoff
- Updating-Specific: effective gating of information, controlled retrieval from long-term memory

Common EF = Inhibition?

- Is the term “inhibition” more informative about the underlying mechanism than goal-related processes?
- Whether there is a common inhibitory function (attributed to right inferior frontal cortex) across diverse tasks, and whether it determines performance, is still debated
  - E.g., Banich & Depue, 2015; Munakata et al., 2011

Relations to Other Frameworks

- Controlled or executive attention (Engle, Kane, et al.)

"Our view is that WM capacity, the construct measured by WM span tasks, reflects the general capability to maintain information, such as task goals, in a highly active state."

  - Kane et al. (2001, p. 170)

Relations to Other Frameworks

- Proactive vs. reactive control (Braver)

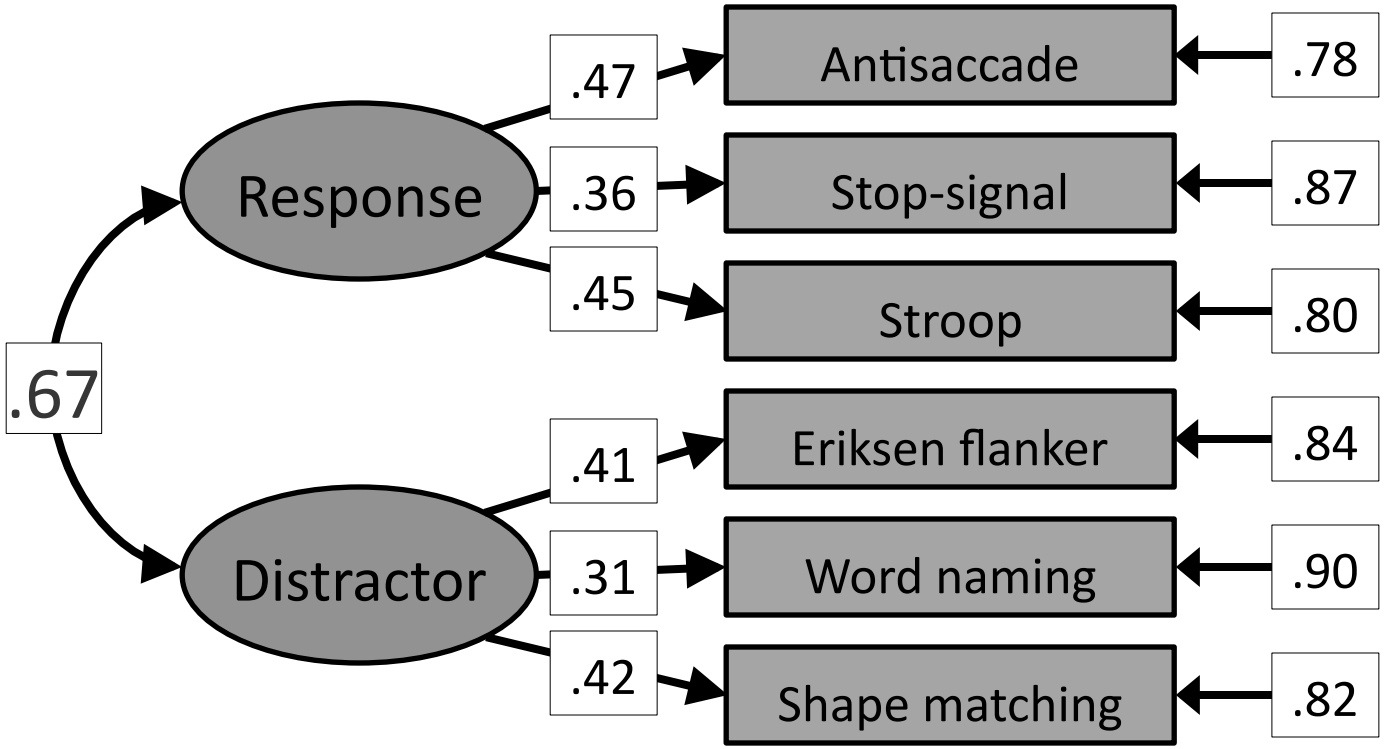
"The proactive control mode can be conceptualized as a form of 'early selection' in which goal-relevant information is actively maintained in a sustained manner, before the occurrence of cognitively demanding events, to optimally bias attention, perception and action systems in a goal-driven manner. By contrast, in reactive control, attention is recruited as a 'late correction' mechanism that is mobilized only as needed, in a just-in-time manner, such as after a high interference event is detected."

  - Braver (2012, p. 106)

Other EFs?

- Selective attention or resistance to distractor interference
  - e.g., Flanker task

Friedman & Miyake (2004)



Other EFs?

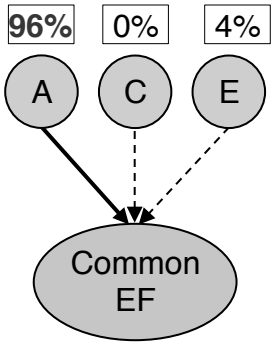
- Mixing costs
  - In switch tasks, RT in mixed-block repeat trials > in single task blocks
  - Used as measure of monitoring (e.g., Paap et al., 2014)
- May also be related to Common EF
  - Preliminary analysis: switch task mixing cost latent variable related to Common EF (*r* = –.59)
  - Not related to Updating-Specific or Shifting-Specific (rs = –.11)

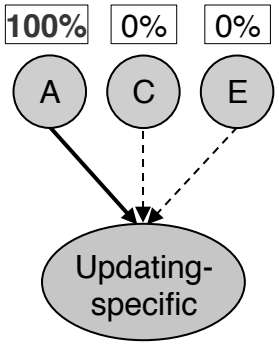
Etiology of Unity and Diversity

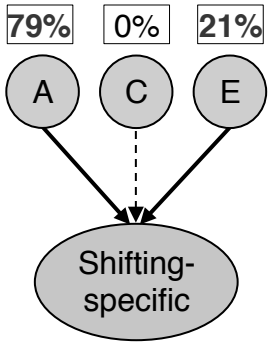
- Why do EFs show unity and diversity?
  - Common genetic factor?
  - Unique genetic influences?
- Twin Studies
  - Decompose covariances in MZ and DZ twins to estimate
    - A: Additive genetic variance
    - C: Shared environmental variance
    - E: Nonshared environmental variance

Longitudinal Twin Study

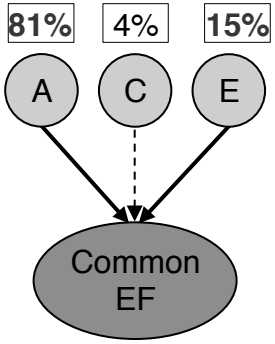
Age 17

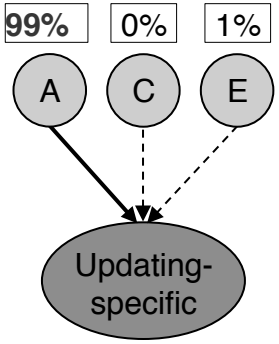


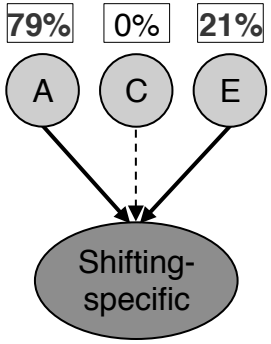




Age 23



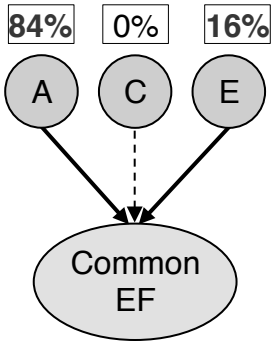


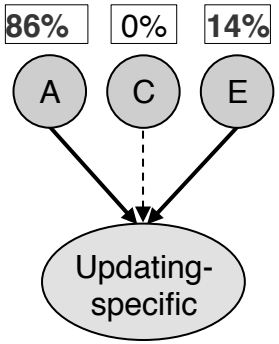


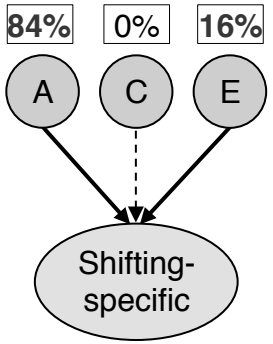
Friedman et al., 2008; 2011; *under review*

Community Twin Study

Age 21







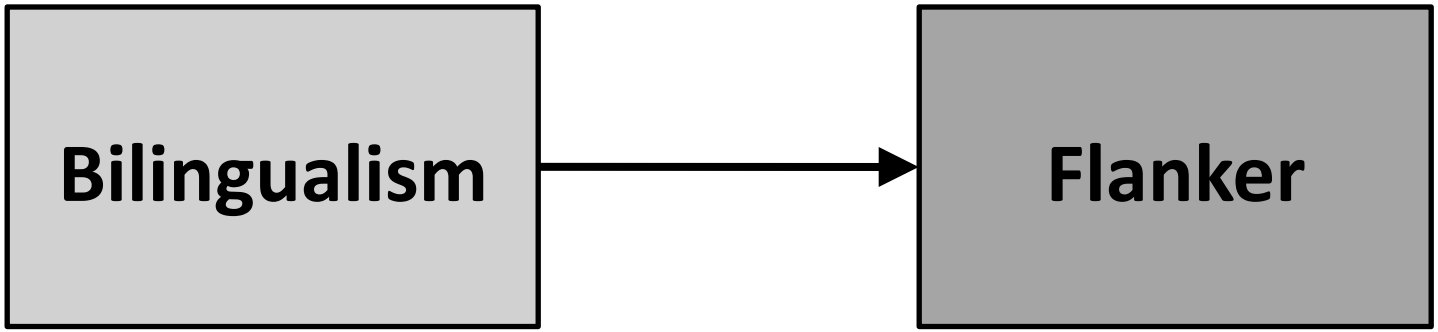
Implications of Heritability

- Where would bilingualism be?
  - C or E? Not A?
  - A estimate can include gene-environment correlations
  - Relevant to training (e.g., music); not relevant to bilingualism?
- Estimates are specific to a trait, population, and time
  - Sample includes bilinguals?

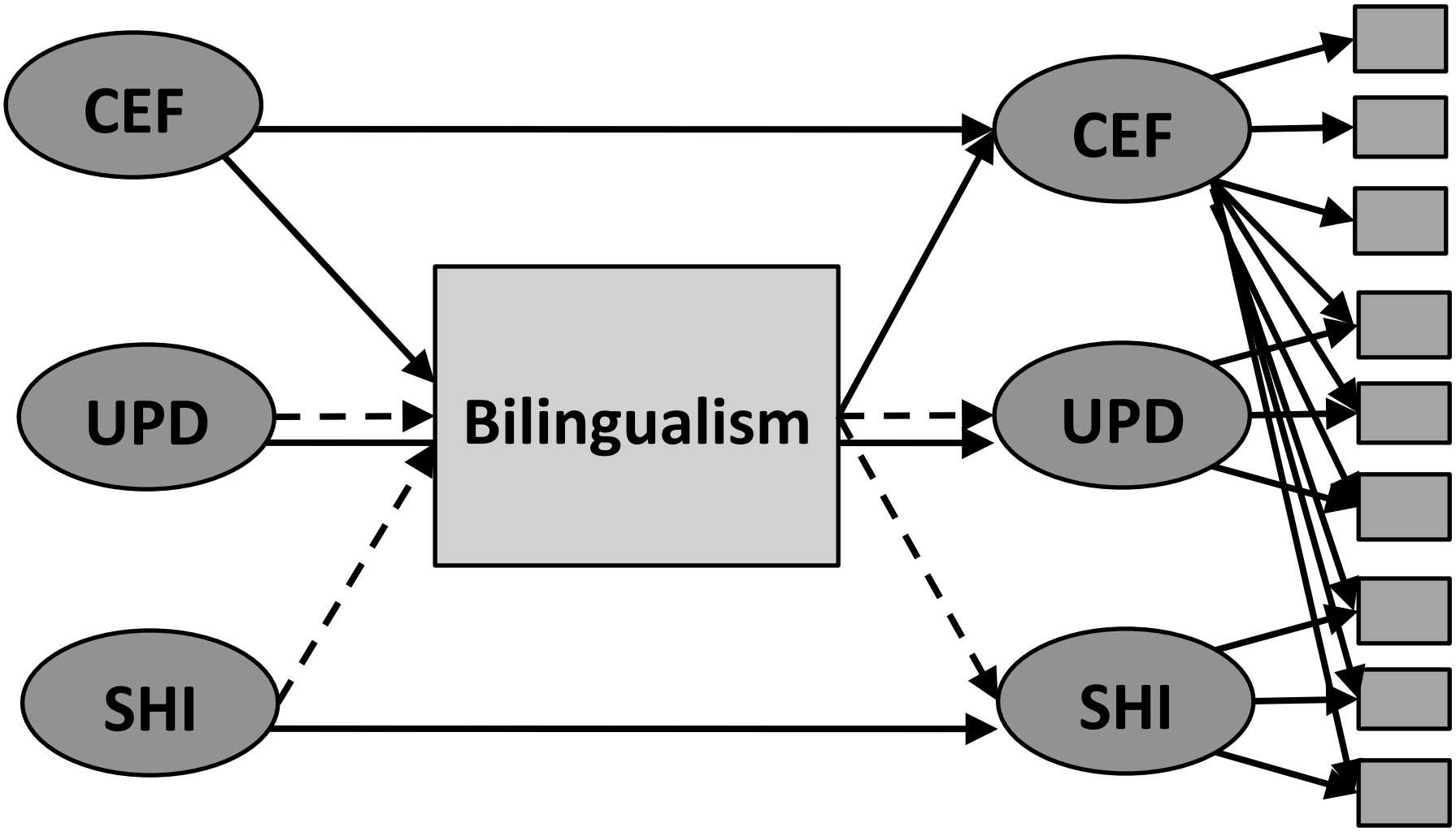
Conclusions

- EF tasks are impure
  - Attenuates effects, and makes it important to use multiple tasks
- EFs show unity and diversity
  - Which EFs are thought to be involved in bilingual language control?
- EFs are highly heritable at the level of latent variables
  - But this should not be interpreted as evidence against training effects

Original Model



More Explicit Model



Considerations

- Does bilingualism require the same EFs that we are measuring?
  - Novelty?
  - If so, which EFs, given multi-component structure?
- Does using those EFs actually train them?
  - And does that training transfer?
- Do those benefits persist throughout the lifespan?