



# NIH Toolbox

Assessment of Neurological and Behavioral Function

## Validation of the NIH Toolbox: Executive Function, Working Memory, Sustained Attention

Philip David Zelazo  
Jacob E. Anderson  
Jennifer Richler

SRCD, Montréal, 31 March, 2011

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For more information, please visit  
[www.nihtoolbox.org](http://www.nihtoolbox.org)  
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# Toolbox Objective



**Develop measures of  
*cognitive, emotional, sensory, & motor* health & function:**

**Brief yet comprehensive**

**Standardized, reliable, and validated**

**Freely available and inexpensive to use**

**English & Spanish**

**Appropriate for longitudinal or intervention research**

***Suitable for participants ages 3-85 years***



# NIH Toolbox

Assessment of Neurological and Behavioral Function

## Steering Committee

Richard Gershon (PI)  
Cindy Nowinski (co-PI)

Thomas Bleck  
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## Cognition Team: Senior Scientists + Developers

**Sandy Weintraub,**  
Cognitive Domain Leader

**Patricia Bauer**  
**Sureyya Dikmen**  
**Nathan Fox**  
**Robert Heaton**  
**Jennifer Manly**  
**Dan Mungas**  
**David Tulsy**  
**Phil Zelazo**

## Junior Scientists

**Jacob Anderson**  
**Beth Borosh**  
**Noelle Carlozzi**  
**Nancy Chiaravalloti**  
**Joanne Deocampo**  
**Jennifer Richler**

## Process/Organization

**David Blitz**  
**Jerry Slotkin**  
**Dick Havlik**

# Identify Subdomains



Request for Information (RFI) and Expert Interviews:

Online-surveys ( $N = 147$ ) and subsequent in-depth interviews ( $N = 45$ ) of NIH-funded experts

**Average years of research experience = 25 ( $SD = 8$ )**

**Experience conducting clinical research/trials = 86%**

**Experience conducting longitudinal/epidemiologic research = 87%**

# RFI & In-depth Interviews



**Rankings of subdomains identified by the RFI and fine-tuning of categories:**

- 1) Executive Function**
- 2) Processing Speed**
- 3) Learning and Memory**
- 4) Language**
- 5) Attention**
- 6) Working Memory**

# Subdomains



## Executive Function:

Conscious, goal-directed control of attention and behavior  
Processes related to, but different from, knowledge/IQ  
Use of knowledge in the service of goal-directed behavior

## Processing Speed:

Speed (simple) cognitive operations can be performed:  
Amount of info processed within a certain unit of time

## Attention (sustained):

Ability to sustain focus of attention

## Working Memory:

Maintaining & manipulating info in a short-term buffer

# Interest in Development of EF

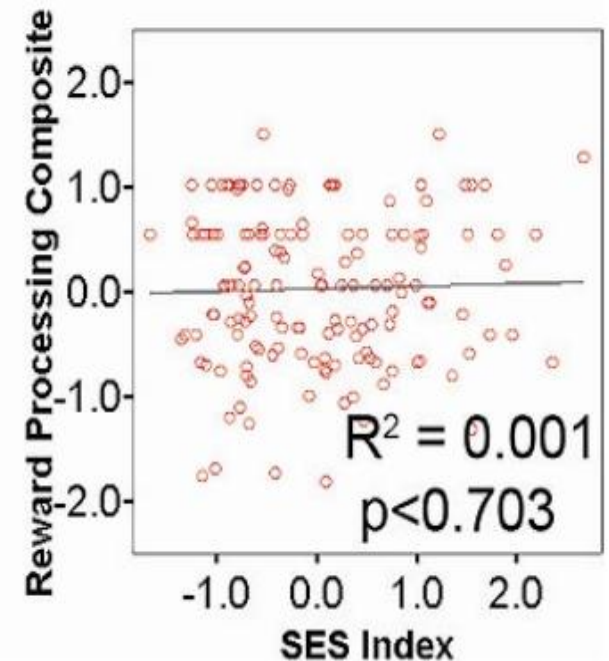
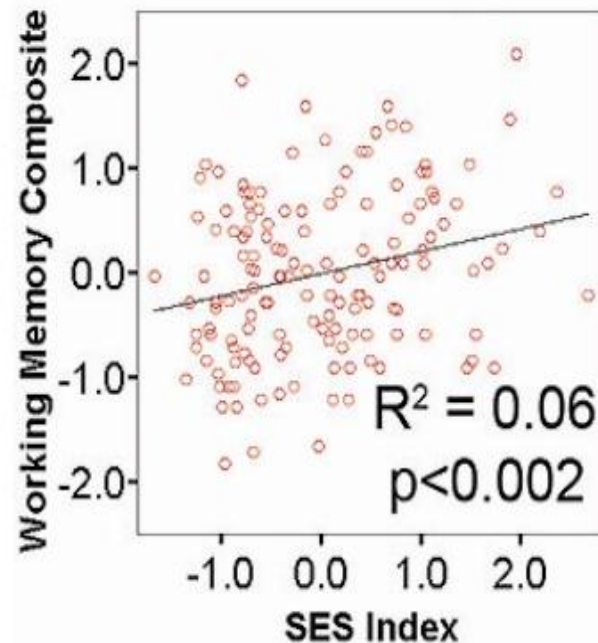
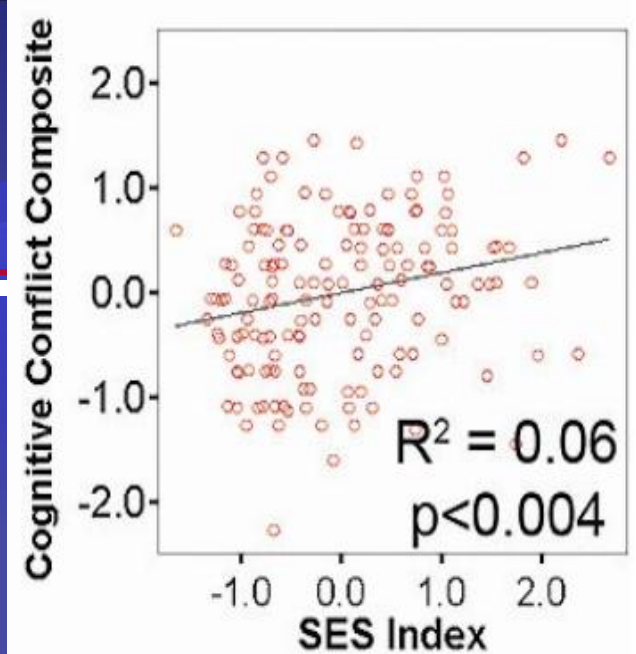


EF in childhood tied to wide range of dev'l outcomes:

- ♦ Self and social understanding (ToM)
  - ♦ e.g., Carlson et al., 2004
- ♦ Psychiatric disorders w/ child onset (ADHD, CD, autism)
  - ♦ e.g., Willcutt et al., 2005
- ♦ School readiness (early math and reading ability)
  - ♦ e.g., Blair & Razza, 2007
- ♦ And it has a predictive utility that extends from preschool to young adulthood (e.g., Eigsti et al., 2006)

- ◆ Also related to SES
  - ◆ Noble et al., 2005, 2007

- ◆ Perhaps particularly **certain aspects** of EF, cool/ EF (also related to SES)

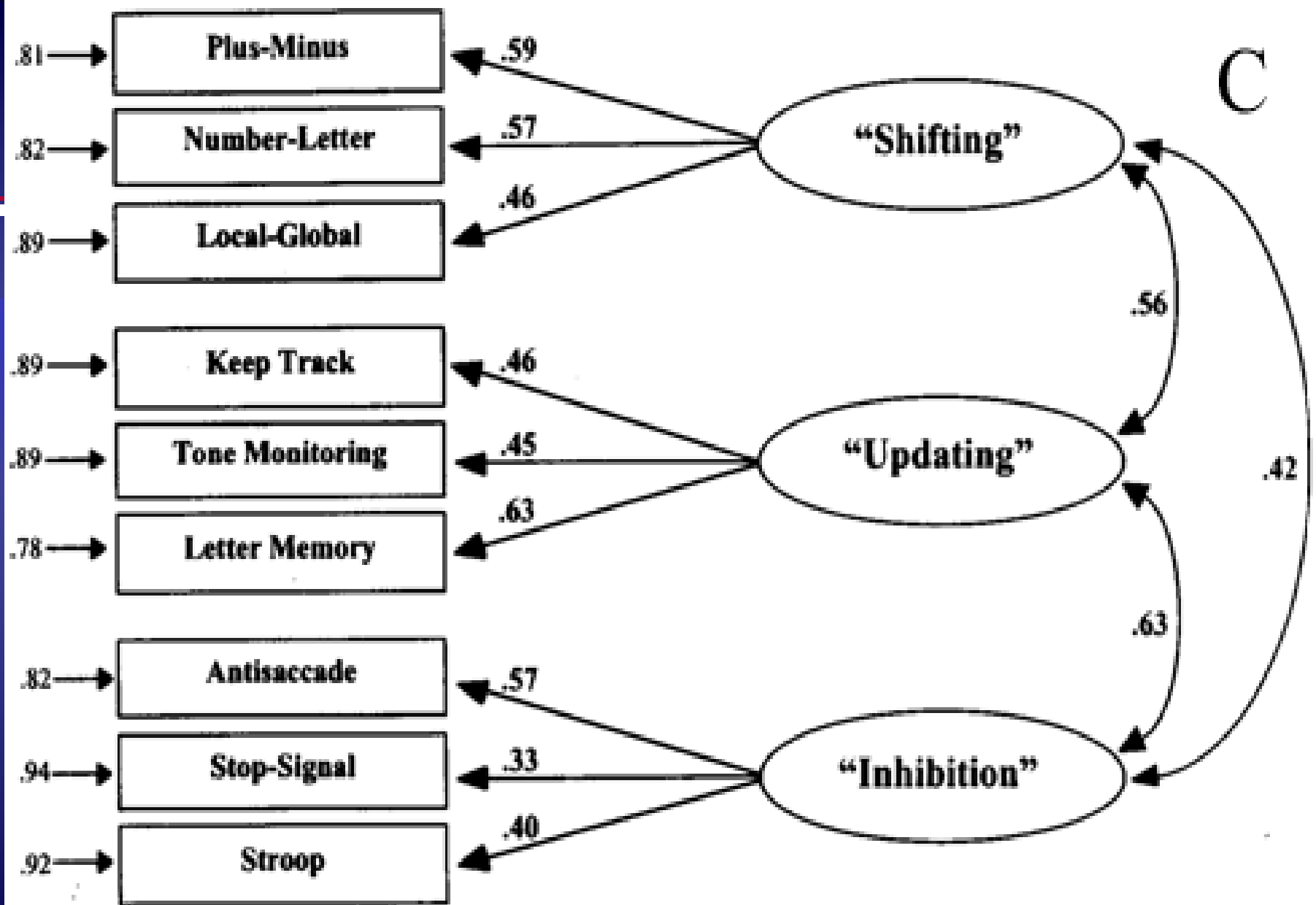


Data from Noble et al.  
(2007), *Dev Sci*



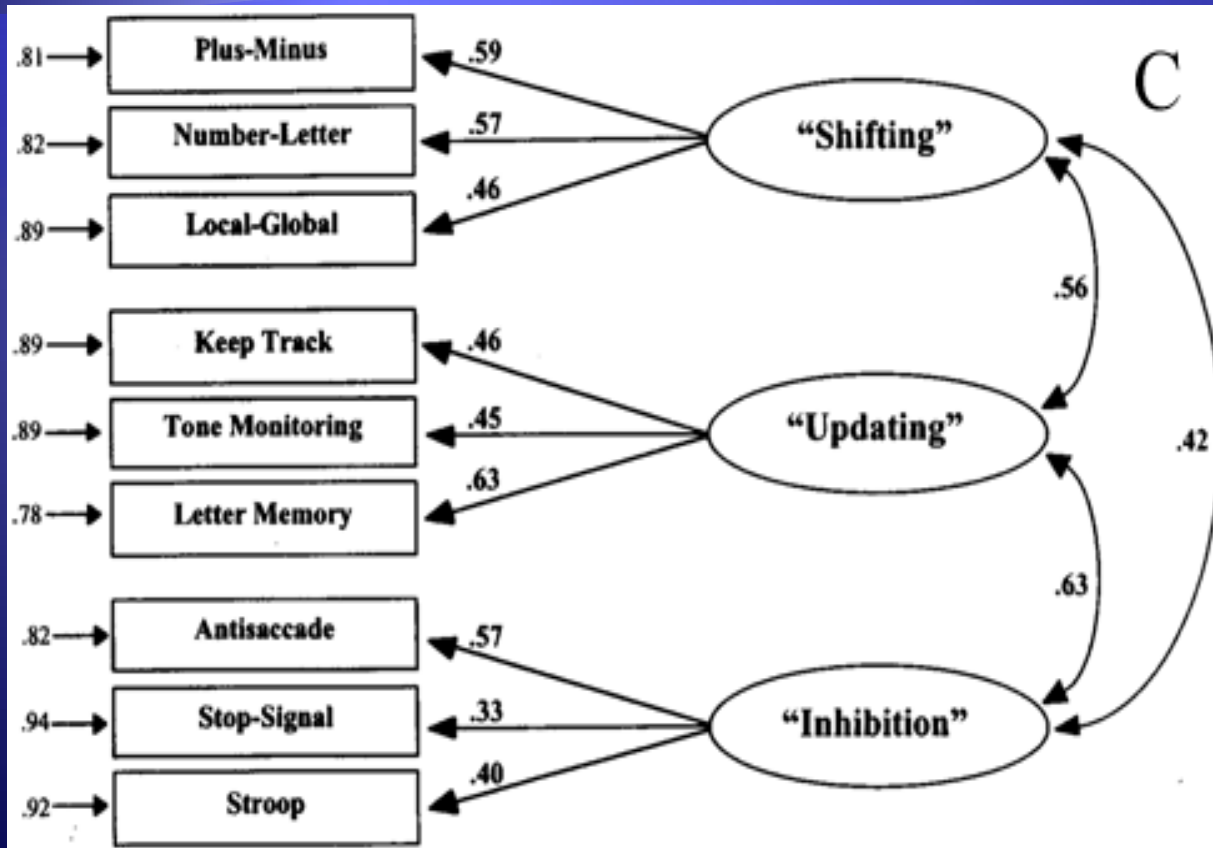
- ◆ EF heterogeneous construct

- ◆ Miyake et al. (2000) attempted to characterize the processes underlying cool EF using CFA
- ◆  $N = 137$  adults, tested the hypothesis that divisible into
  - ◆ Shifting
  - ◆ WM/updating
  - ◆ Inhibition



Miyake et al. (2000), *Cog Psychol*

# Executive Function



3 Measures

DCCS

List Sorting

Flanker

# Instrument Development Iterative Process



## SUBDOMAIN

## Toolbox Measures

## Validation Measures

**EF**

**Flanker (inhibition)**  
**DCCS (shifting)**

**WPPSI-III Block Design (3- 6 yrs)**  
**D-KEFS Color-Word Inhibition (8-15)**

**PROCESSING SPEED**

**Pattern Comparison**

**WAIS-III Processing Speed Index**

**WM**

**List Sorting**

**NEPSY Sentence-Rep (3-7 yrs)**  
**Letter-Number Seq'ing (8-15)**

**Sustained Attn**

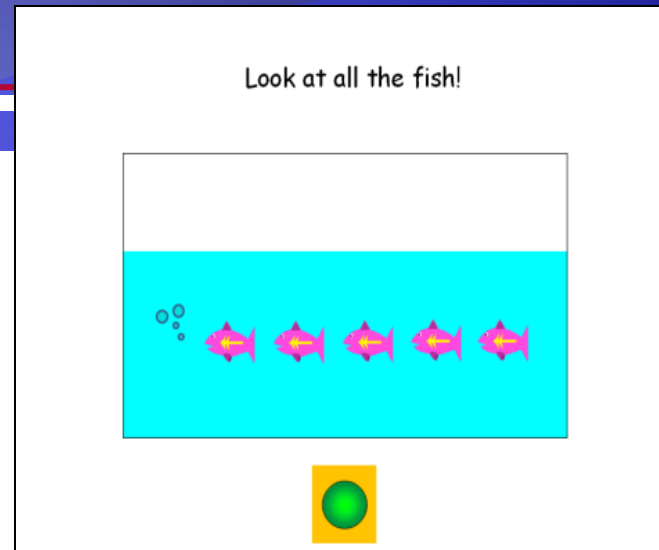
**Flanker (congruent trials)**

**Coding and Symbol Search raw scores from WPPSI-III (5-6 yrs), and from WISC-IV (8-15 yrs)**  
**CBQ Attention Focusing (3-6 yrs)**

# EF: Inhibition/Attention



## Flanker (< 5 min) Choice RT



- ◆ Rueda et al. (2004)
- ◆ Indicate orientation of middle stimulus
- ◆ (1) Stim , flankers *congruent*: Choice-RT/Attn
- ◆ (2) *Incongruent*: Inhibitory control/selective attn



# EF: Inhibition/Attention



- ◆ 20 Fish (12:8), 20 Arrows (12:8)



- ◆ Acc, RT (new algorithm that integrates them)

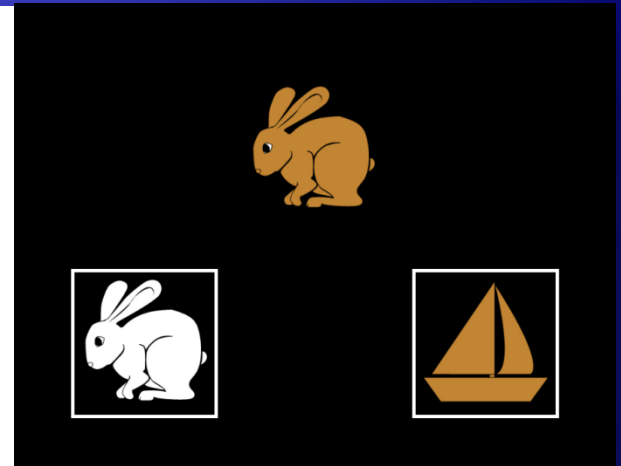
# EF: Cognitive Flexibility



## Dimensional Change Card Sort (DCCS)

(< 6 min)

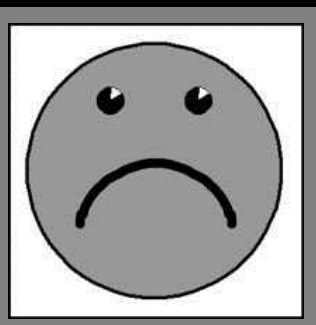
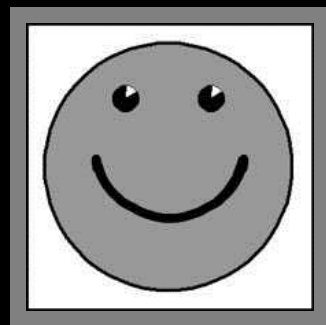
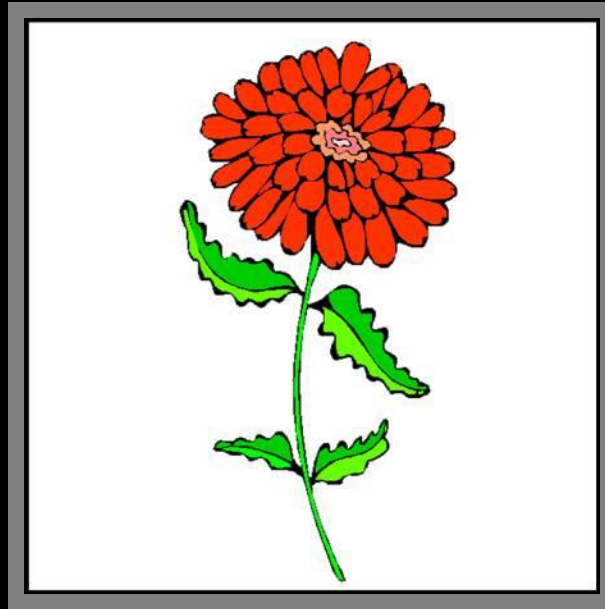
- ◆ Zelazo (2006, *Nature Protocols*)
- ◆ Match by shape (5) then color (5)
- ◆ If pass post-switch then mixed version: relevant dimension switches randomly (23:7)
- ◆ Acc, RT

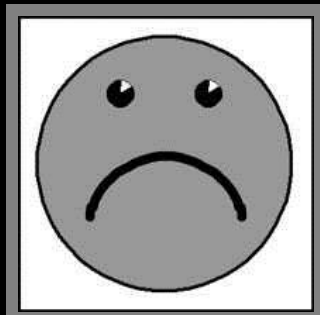
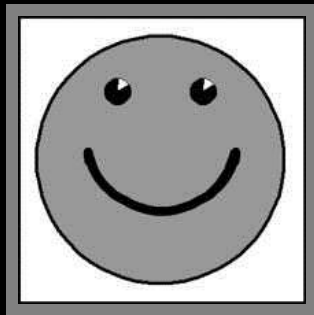
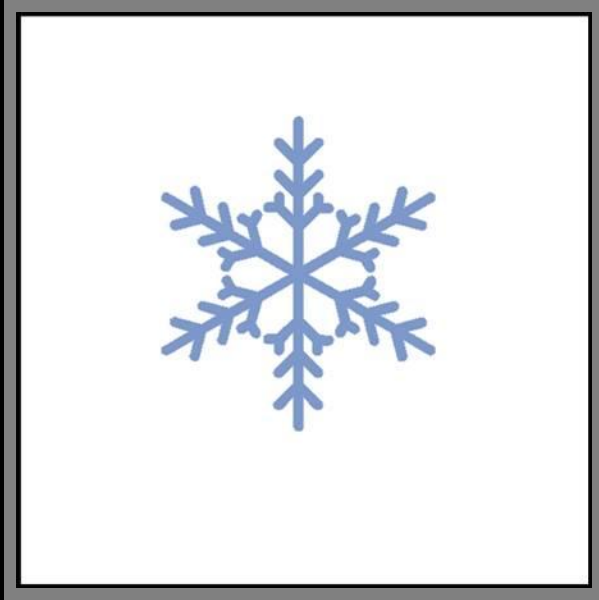
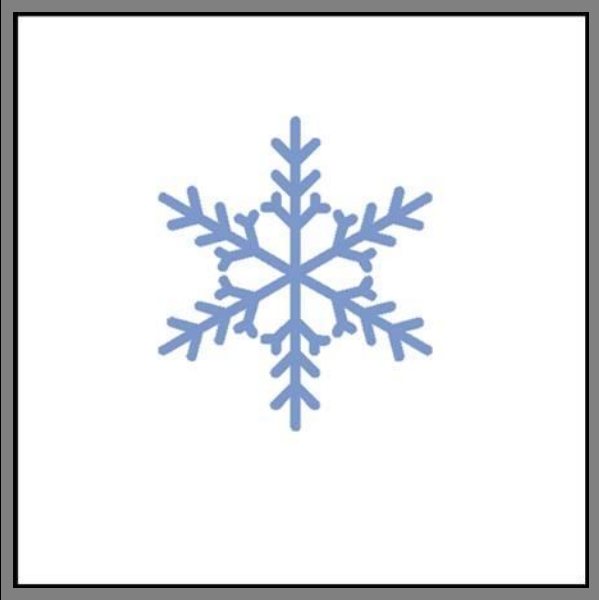


# Processing Speed



- ◆ **Pattern Comparison: Developed after Salthouse**
- ◆ **(<5 min)**
- ◆ **Identify whether patterns are same/ different**
- ◆ **How many in 90 s?**





# Working Memory



- ◆ List Sorting, after Mungas' Spanish & English Neuropsychological Assessment Scales (SENAS) WM task
- ◆ (<9 min)
- ◆ Sequence 2-15 orally presented stimuli by increasing size
- ◆ 2 conditions:
  - ◆ 1-list condition and 2-list condition: Sequence stimuli first from one category then from a second

# Working Memory



**TEST ITEMS  
(one list)**



B



**PUMPKIN**



**LEMON**



**Answer: LEMON, PUMPKIN**

# Validation

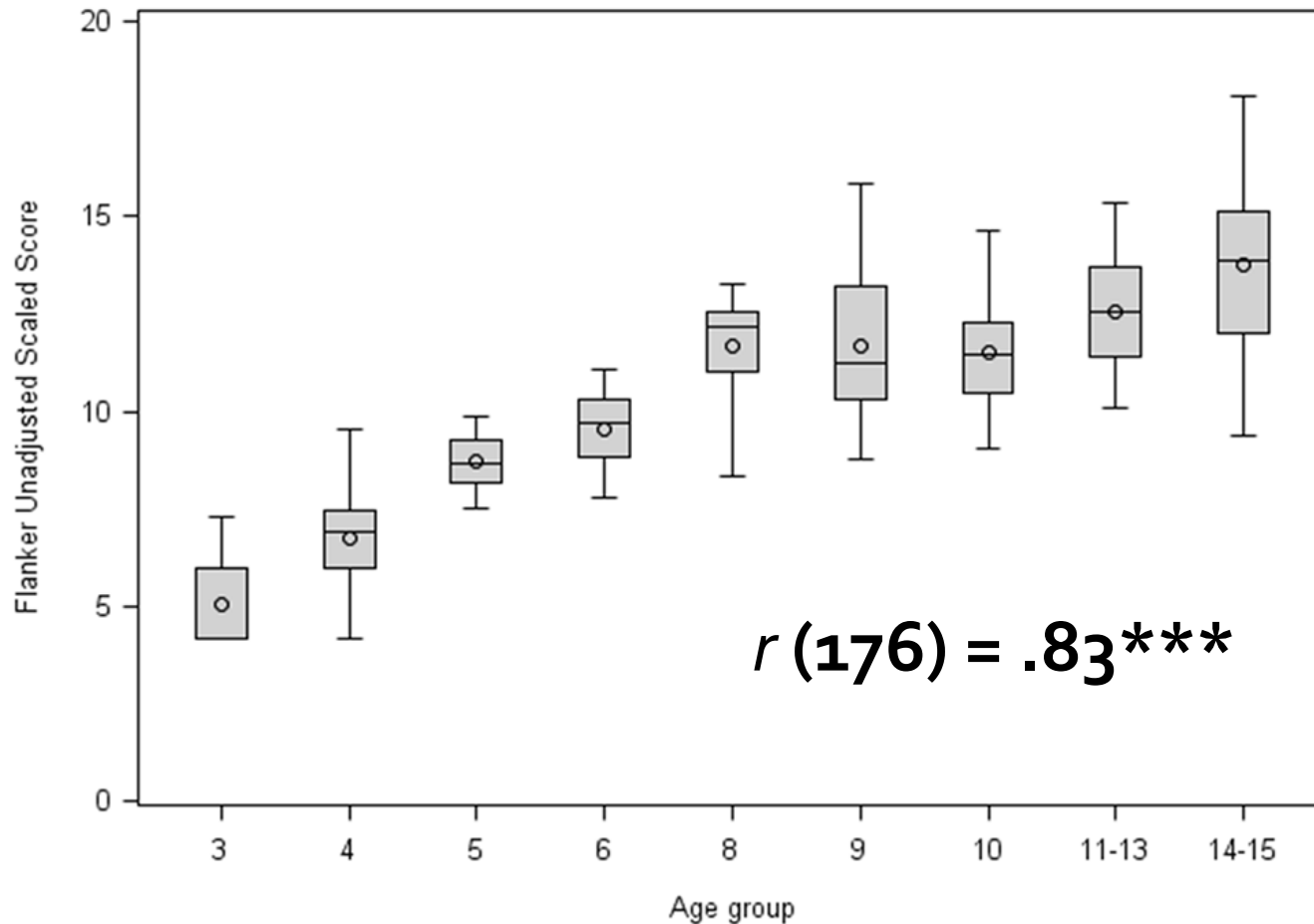


- ◆ Spring '09 ~ 4 months
- ◆ 475 individuals (154 re-tested after 2-7 days)
  - ◆ Test-retest
  - ◆ Cf. new tests and “gold standard measures” used in clinical practice (challenge for 3-6 yrs, diff measures X ages)
- ◆ Focus on 3-15 years ( $n \sim 190$  for most measures)
- ◆  $*p < .05$ ,  $*p < .01$ ,  $***p < .001$

# Flanker x Age



Distribution of Flanker Scores by Age Group



# Flanker: Test-Retest ICC



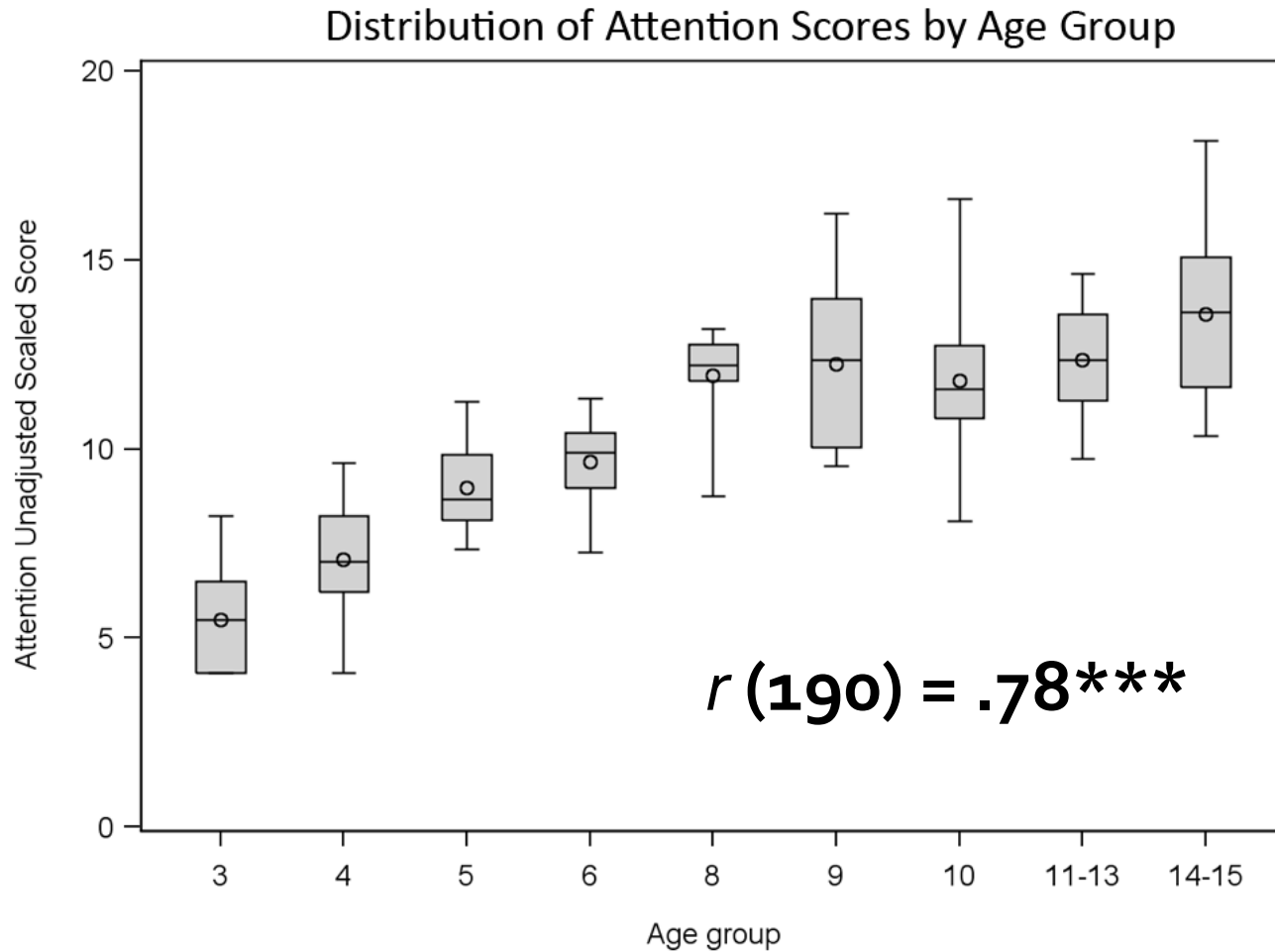
Age	ICC
3-15 years	.91***
3-6 years	.73***
8-15 years	.78***

# Flanker: Validity



Age	DCCS	WPPSI BD/ DKEFS-Inhib
3-6 years	.63***	.63***
8-15 years	.57***	.36***

# Sustained Attention x Age



# Attn: Test-Retest ICCs



Age	ICC
3-15 years	.93***
3-6 years	.78***
8-15 years	.79***

# Attn: Validity

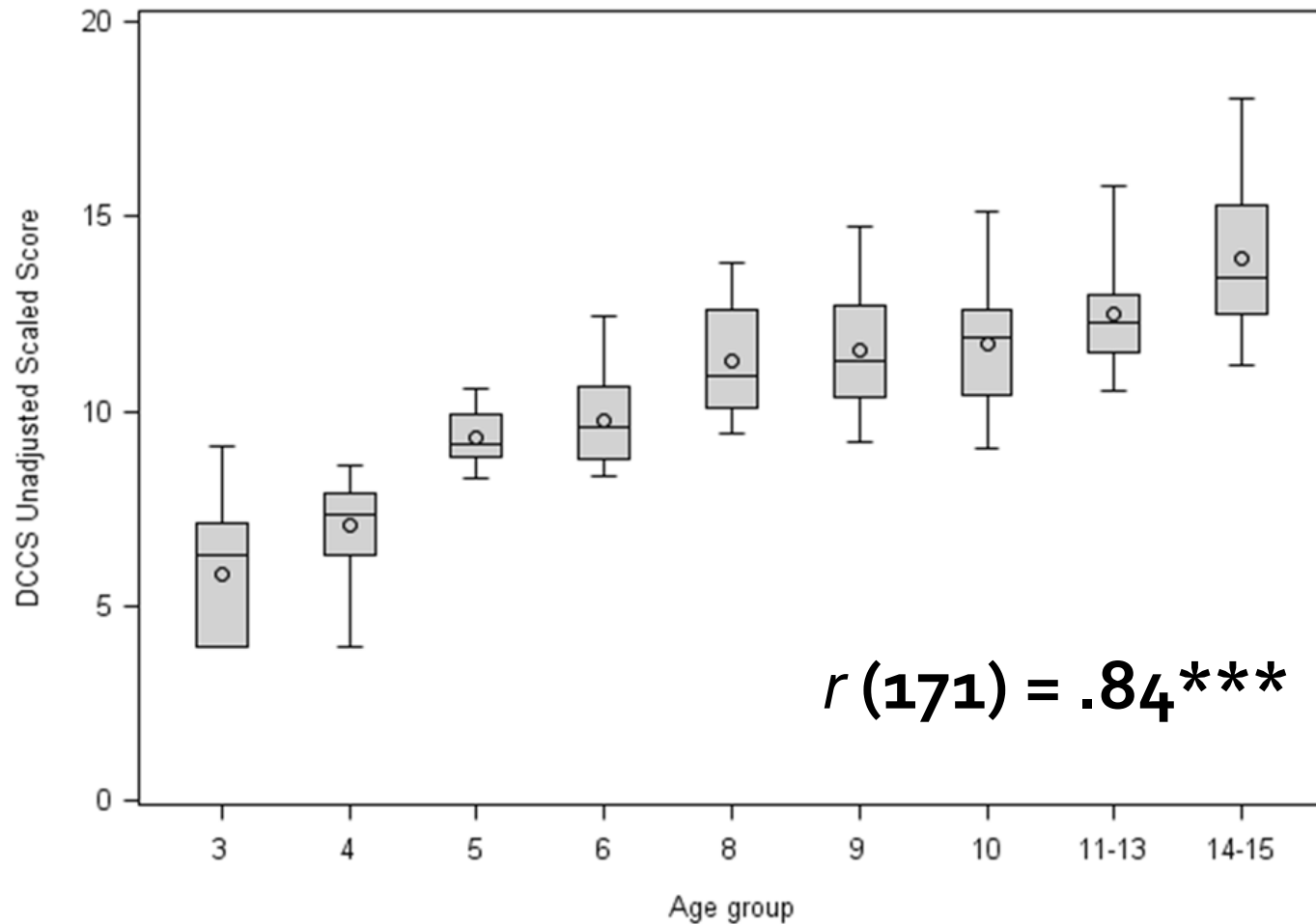


Age	CBQ AF/ Coding & SymSearch
3-6 years	.19 (parent rated), ns
5-6 years	.34*
8-15 years	.29**

# DCCS x Age



Distribution of DCCS Scores by Age Group



# DCCS: Test-Retest ICC



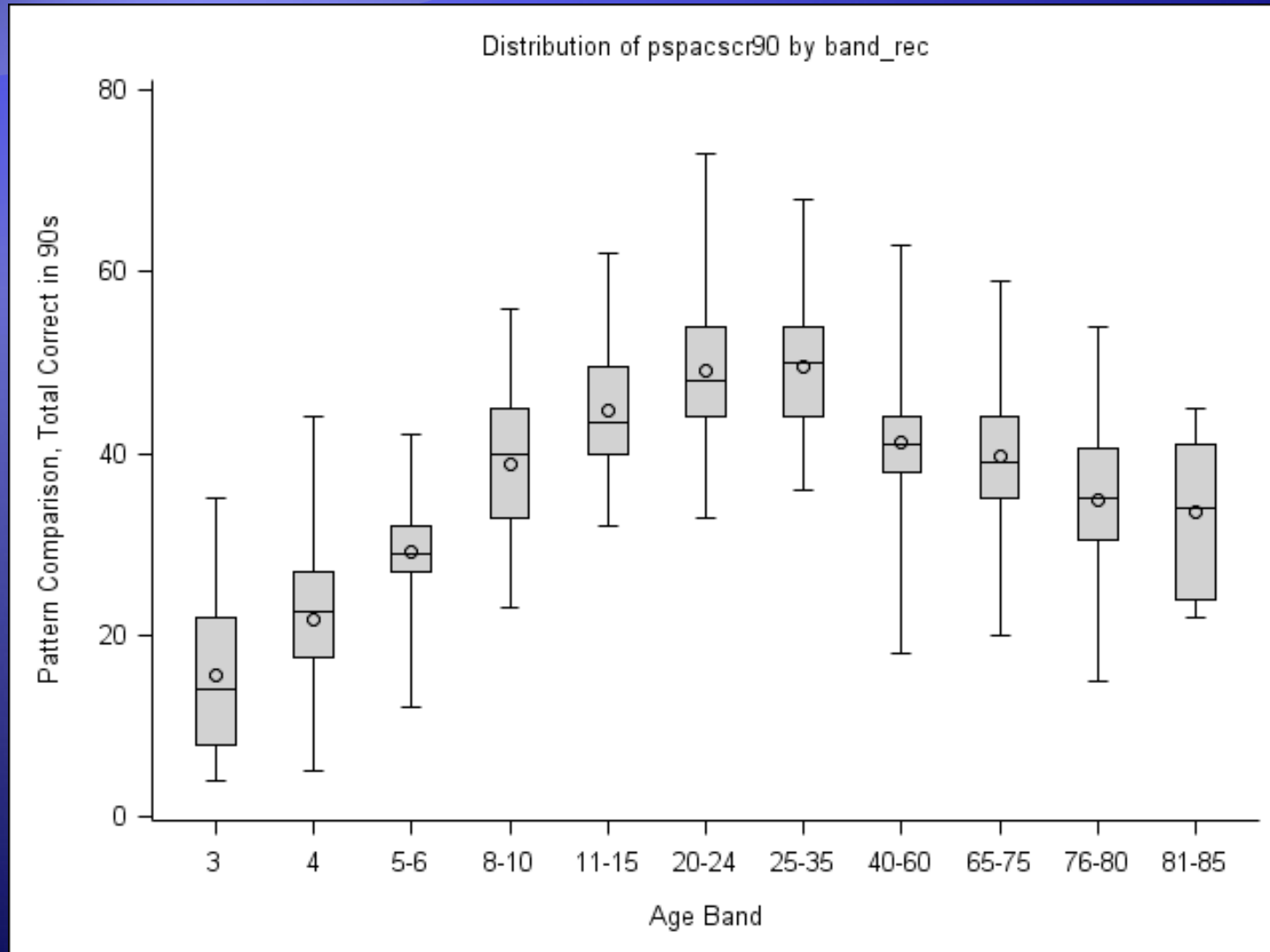
Age	ICC
3-15 years	.92***
3-6 years	.87***
8-15 years	.76***

# DCCS: Validity



Age	Flanker	WPPSI BD/ DKEFS-Inhib
3-6 years	.63***	.68***
8-15 years	.57***	.61***

# Processing Speed x Age



# PS : Test-Retest ICC



Age	ICC
3-15 years	.84***
3-6 years	.87***
8-15 years	.76***

# PS: Validity

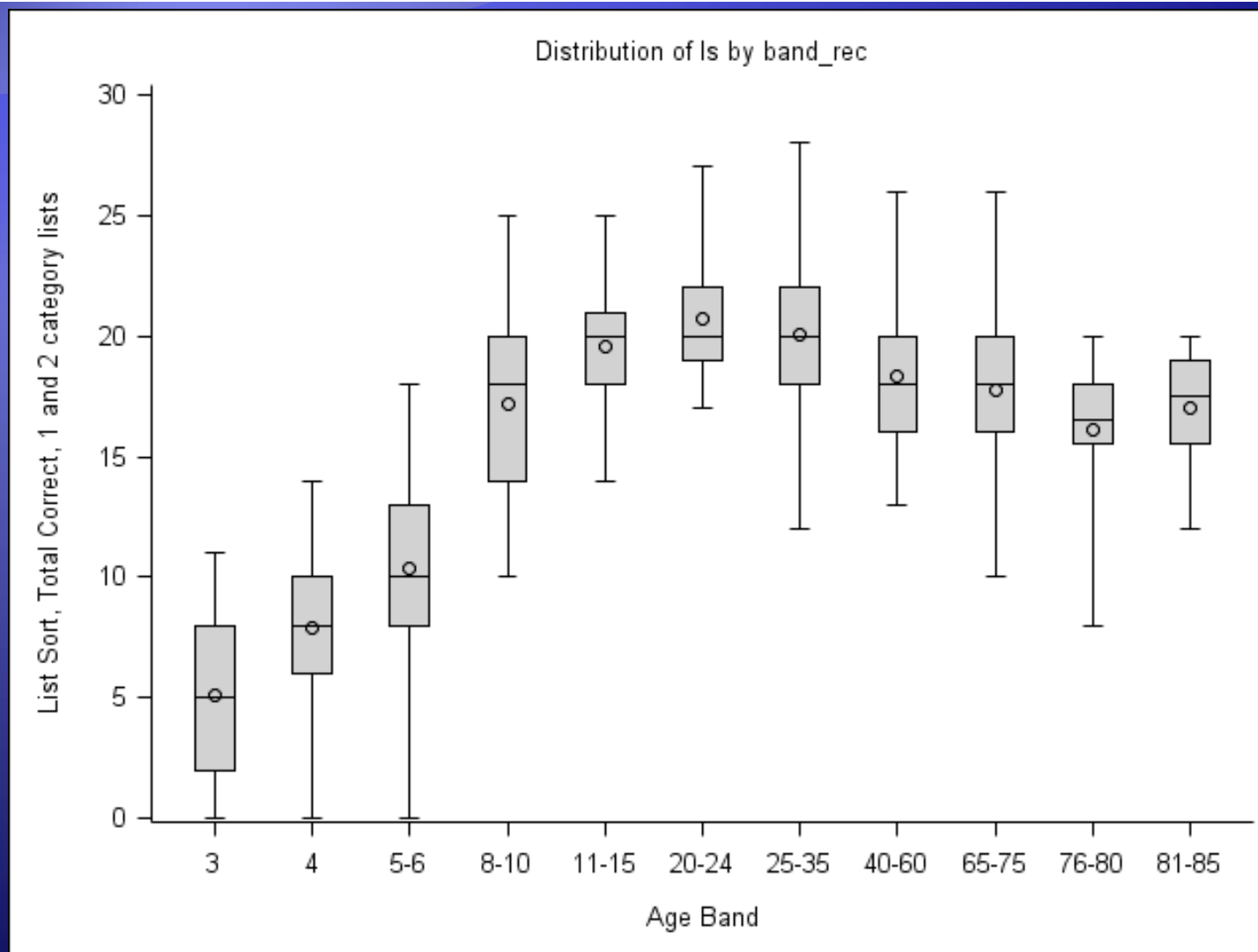


Age	<u>Wech: Coding</u>	<u>Wech:SymSearch</u>
3-6 years	.42	.31
8-15 years	.36	.37

Significant, but working on deriving a measure of processing speed that also includes RT from EF measures

Composite has better convergent validity

# List Sorting x Age



# List Sorting: Test-Retest ICC



Age	ICC
3-15 years	.82***
3-6 years	.82***
8-15 years	.81***

# List Sorting: Validity



Age	NEPSY Sent Rep/ Wech: Letter-Num
3-6 years	.54***
8-15 years	.57***

# Factor Analyses



Mungas: with full sample (including adults)

6-factor solution is best

Clear EF factor (DCCS & Flanker plus DKEFS Inhibition)  
distinct from:

Processing Speed, Attn, and WM

# Convergent / Divergent Validation x Age

## Divergent Increases

	Age 3-7				Age 8-85			
	Convergent Validity		Divergent Validity		Convergent Validity		Divergent Validity	
	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>	<i>n</i>	<i>r</i>
Flanker	85	<b>.63***</b>	38	<b>.60***</b>	312	<b>.48***</b>	319	<b>.11*</b>
DCCS	81	<b>.68***</b>	39	<b>.58***</b>	311	<b>.51***</b>	318	<b>.12*</b>

\* $p < .05$ , \*\*\* $p < .001$

Flanker 3-7 convergent = WPPSI-III block design; divergent = NEPSY speeded naming; DCCS 3-7 convergent = WPPSI-III block design; divergent = NEPSY speeded naming; Flanker 8-85 convergent = D-KEFS Inhibition; divergent = vocabulary; DCCS 8-85 convergent = D-KEFS Inhibition; divergent = vocabulary;

# SUMMARY



- ◆ Cognition instruments are being accepted by the intended populations, including pediatric, young adult, older adult
- ◆ Results very encouraging → Norming ( $N = 4,500$ )
  - ◆ Timing, floor/ceiling, reliability, validity
  - ◆ Quick, standardized measures across lifespan

# SUMMARY



- ◆ EF can be distinguished from processing speed
- ◆ Cognitive flexibility and selective attention/inhibition from WM, even in children
- ◆ With age, Increasing differentiation of EF from performance on other measures
  - ◆ EF is essential for performing well in structured situations (paying attention, following rules, etc.)
  - ◆ Experience-dependent specialization of neurocognitive skills (cf. Johnson, 2010)



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## Statistics

***Jennifer Beaumont***