Measuring and Assessing Executive Function Skills

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There are many abilities children need to develop to be happy and successful in life

...including to be

kind and compassionate,

honest and trustworthy,

to stay curious and retain

a sense of wonder

Some other important skills are:

- Being able to stay focused and pay attention
- Creative problem-solving (thinking outside the box)
- Reasoning (playing with ideas and facts in your mind, relating one to the other)
- Being able to delay gratification and stay the course
- The self-control to not put your foot in your mouth
- Being able to resist temptations & not act impulsively
- Being able to take advantage of serendipity
- Flexibility to adjust to changed demands or priorities

ALL of those skills

are

EXECUTIVE FUNCTIONS

‘Executive Functions’

refers to a family of

mental processes needed

whenever going ‘on automatic’

or relying on instinct or intuition

would **NOT** be a good idea

There are 3 core Executive Functions

1. Inhibitory Control
2. Working Memory
3. Cognitive Flexibility

Inhibitory Control

being able to resist a strong inclination to do one thing,

and instead do what is most appropriate or needed.

Inhibitory control at the level of attention:

Inhibitory control at the level of behavior:

Selective or Focused Attention

Self-Control

Focused Attention

- Screening out distractions

which enables you to be able to concen-trate and stay focused


An activity from Montessori schools, that is essentially a type of walking meditation.

Everyone (even the grown-ups) gets a bell and walks in a line or circle. The goal is for no one's bell to make a sound.

Focused Attention

Example: Singing a song as a Round

BUT, note that because we are able to selectively attend, we can miss important things because we were selectively attending to other things.

"Our notions of what *should* happen block us from seeing what actually *does* happen."

-- Bernie Glassman,
Bearing Witness

People were ask to count the number of photos in a newspaper.

Some people finished in a few seconds; others took minutes.

It was <u>not</u> that some were faster counters.

The secret lay on Page 2 where in huge block letters it said:

STOP COUNTING! THERE ARE 43 PHOTOGRAPHS IN THIS PAPER.

Many people missed that enormous headline.

They were so focused on counting the photos they hadn't notice it.

We need to balance

selective attention

with

cognitive flexibility

There's Inhibitory control at the level of <u>attention</u>:

Focused Attention

Inhibitory control at the level of <u>behavior</u>:

Self-Control

SELF-CONTROL

resisting temptations,

not acting impulsively,

thinking before you speak or act

Examples of when you need SELF-CONTROL

- wait your turn, don't hit, don't eat dessert first
- resist hurting someone just because that person hurt you (cycle of 'tit for tat')
- don't blurt out the 1st thing that comes to mind
- resist acting in the heat of the moment (don't press 'send' right away)
- resist jumping to a conclusion of what something must have meant or why it was done

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When my son, Erik, was in the first grade his teacher asked the class,

"What is the color of apples?"

Most of the children answered red. A few said green.

Erik said white.

The teacher tried to explain that apples could be red, green, or sometimes golden, but never white.

Kevin said, “Look inside.”

and

- to have the discipline and perseverance…

  to resist the many temptations to quit and not finish what you started

  to continue to work even though the reward may be a long time in coming (delaying gratification)

requires Self-Control

Need to be willing and able to <u>stop</u> persevering at something when the evidence shows it's not working

Need to balance discipline & perseverance with cognitive flexibility

Self-control saves us from putting our foot in our mouth or making a social faux pas.

Think of all the trouble you'd get in if you told your boss your real opinion of him or her,

..grabbed whatever you wanted without asking or paying, or

..did other socially inappropriate or hurtful things.

If we want to change,
if we want to mend our ways,
we need self-control.

Working Memory

Holding information in mind to work or play with it

Working memory is critical for making sense of anything that unfolds over time, for that always requires holding in mind what happened earlier and relating that to what is happening now.

- relating one idea to another
- relating what you read (or learned / heard) earlier to what you are reading (learning / hearing) now
- mental math calculations
- understanding cause and effect
- remembering multi-step instructions & executing them in the correct order

Working memory is critical for reasoning; reasoning requires holding bits of information in mind and seeing how they relate.

WORKING MEMORY is critical for being able to creatively disassemble and re-combine ideas and facts in new ways

Holding information in mind

while working on something else

requires working memory

e.g., holding a question or

comment in mind as you listen

to what is currently being said

Working memory and inhibitory control each independently predict both math & reading competence from the earliest grades thru university often better than does IQ.

(Alloway & Alloway, 2010; Bull & Scerif, 2001; Dumontheil & Klingberg, 2012; Gathercole et al., 2004; McClelland & Cameron, 2011; Nicholson, 2007; Passolunghi et al., 2007; St Clair-Thompson & Gathercole, 2006; Savage et al., 2006; Swanson, 2014)

Cognitive Flexibility

involves being able to

..see an issue from different perspectives

..think about something in a whole new way ("thinking outside the box")

..seamlessly adjust to change or unexpected situations

In what way is a carrot like a cucumber?

In what way is a carrot like

In what way is a carrot like

In what way is a carrot like

In what way is a carrot like a cucumber?

In what way is a carrot like an orange?

In what way is a carrot like

In what way is a carrot like

In what way is a carrot like a cucumber?

In what way is a carrot like an orange?

In what way is a carrot like a potato?

In what way is a carrot like

In what way is a carrot like a cucumber?

In what way is a carrot like an orange?

In what way is a carrot like a potato?

In what way is a carrot like an apple?

Cognitive Flexibility also includes having the FLEXIBILITY…

- …to take advantage of a sudden opportunity (serendipity)
- …to get to your desired goal despite unexpected obstacles seeming to block the way
- …to admit you were wrong when you get more information

An example of poor cognitive flexibility:

When one door closes, another door opens;

but we often look so long and so regretfully upon the closed door,

that we do not see the ones which open for us.

- Alexander Graham Bell

If there's a problem that we haven't been able to solve, can you 'think outside the box' to...

...conceive of the problem, frame the problem, in a new way?

... come up with a completely different way of attacking it?

If you always do

what you always did,

you'll always get

what you always got.

- Einstein

Can you creatively see the same thing from different perspectives?

For example,
What unusual uses can you think of for a TABLE?

You could hide under it.

Turned it on its side to protect you from things hurled at you (like rotten tomatoes or snowballs).

Turn it upside down to play horseshoes.

Use it as a percussion instrument.

Cut it up for firewood.

The 3 core Executive Functions are:

- Inhibitory Control
- Working Memory
- Cognitive Flexibility

Higher-order Executive Functions are:

- Problem-solving
- Reasoning
- Planning

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= Fluid Intelligence

References for our Reviews of Studies that have tried to Improve EFs

Diamond, A. & Lee, K. (2011). Interventions shown to aid Executive Function Development in Children 4-12 years old. *Science*, *333*, 959-964.

Diamond, A. & Ling, D.S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34–48.

and

Diamond, A. & Ling, D.

(forthcoming)

"Fundamental Questions Surrounding Efforts to Improve Executive Functions"

The **first** review to look at **all** the different methods (e.g., cog. training, phys. exercise, etc.) and at **all** ages (children thru elderly).

in an Oxford UP book edited by Bunting et al.

An Integrative Approach to Cognitive & Working Memory Training

There's been a lot of interest in computerized cognitive training.

But, it's fair to conclude that while computerized WM training improves working memory,

the results have generally been disappointing with narrow benefits that fade away in several months time.

Contrary to influential reviews on the benefits of aerobic exercise….

Nature Reviews Neuroscience (January 2008)

"Be Smart, Exercise Your Heart:
Exercise Effects on Brain and Cognition"

Charles Hillman, Kirk Erickson & Art Kramer

In particular, the frontal lobe & executive functions
that depend on it show the largest benefit
from improved fitness.

‘Mindless’ Aerobic Exercise or Weight Training (e.g., riding a stationary bike) does not improve executive functions.

Of 12 aerobics studies in children, only 1/3 found better EFs than controls.

A meta-analysis of 12 other aerobics studies in adults found <u>no</u> EF benefits.

BUT

People who are more physically active and have better aerobic fitness have better EFs.

That's true for kids: Scudder et al., 2014

Hillman, Castelli, & Buck 2005

and for older adults: Boucard et al., 2012

Voelcker-Rehage, Godde, & Staudinger, 2010

How can you reconcile that with:

Aerobic interventions (even ones that last a year) do little to improve EFs or memory ??

It could be that the correlation between better physical and cognitive fitness is due to one or more <u>other variables</u> and <u>not to better fitness</u> per se.

Perhaps people who are more physically fit have the good sense to eat better or get more sleep.

Or, maybe causality goes in the opposite direction since one probably needs good EFs, especially good inhibitory control and discipline, to maintain a regular exercise regimen.

Many people who maintain better fitness do so by participating in physical activities that involve cognitive challenges and complex motor skills (such as ultimate Frisbee, rock climbing, beach volleyball, social dance or martial arts).

Results for interventions w/ more emphasis on motor skills and cognitive demands

(more components of sports activities)

have been only slightly better than for 'mindless' aerobic exercise,

but people have only started to look at this in the last few years so this is early days,

& most have looked at 'disembodied' skills abstracted from the sport they are used in.

An all-too-common finding in EF intervention studies is that, despite random assignment, the experimental grp often starts out performing worse on the pre-test than controls.

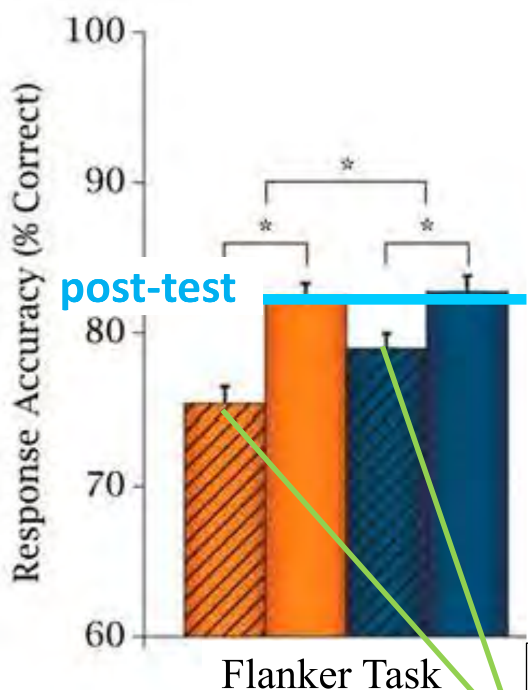
At post-test the 2 grps perform comparably.

The researchers are correct that the exp. grp improved more. But what happened is that they simply caught up to controls.

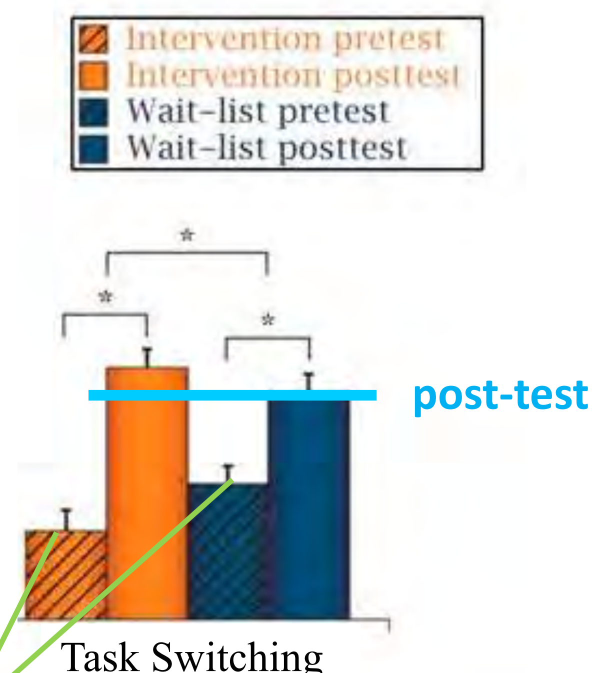
Hillman et al. (2014)

Effects of the FITKids randomized controlled trial on executive control and brain function.

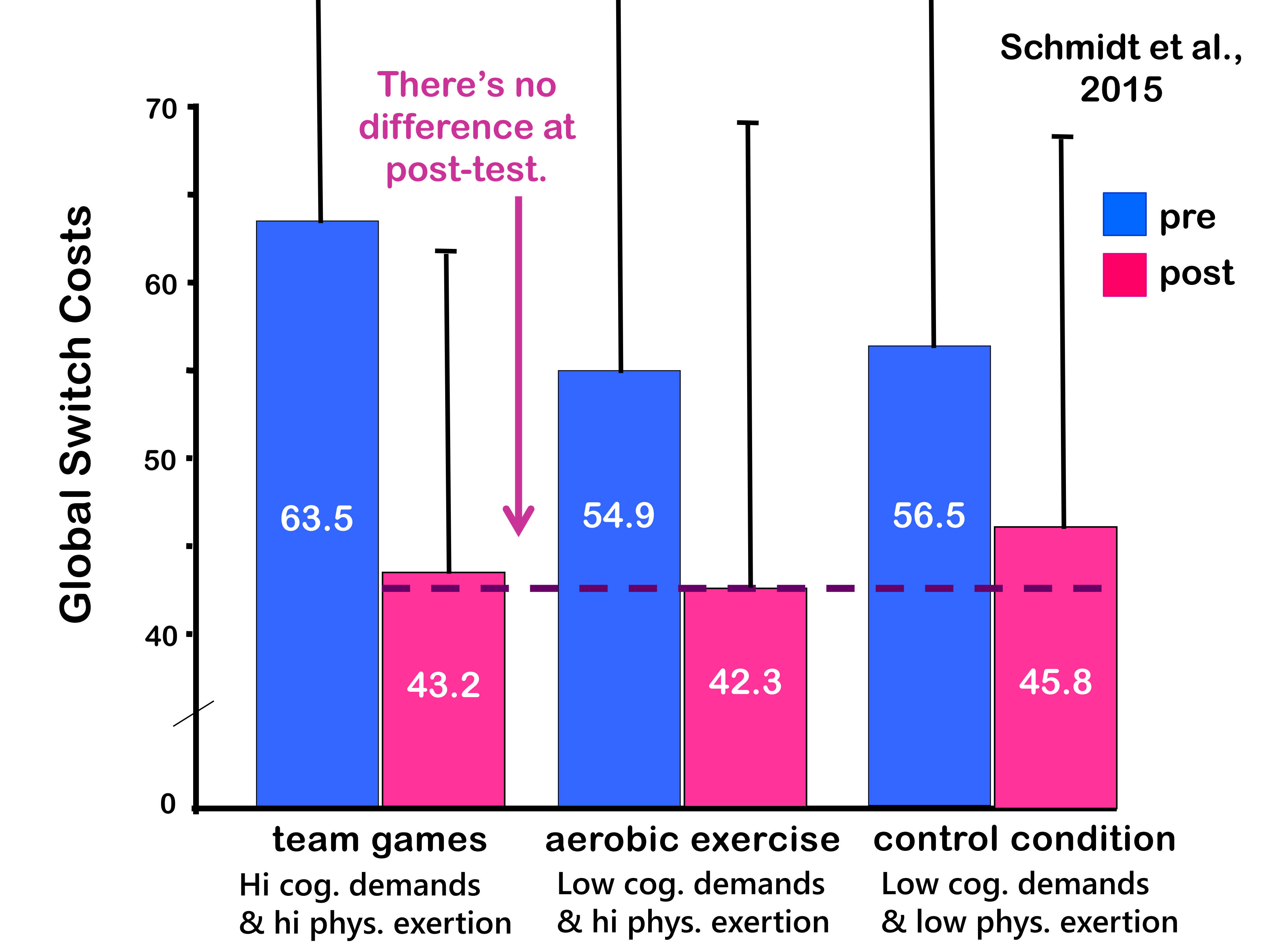
Pediatrics, 134, e1063-1071.

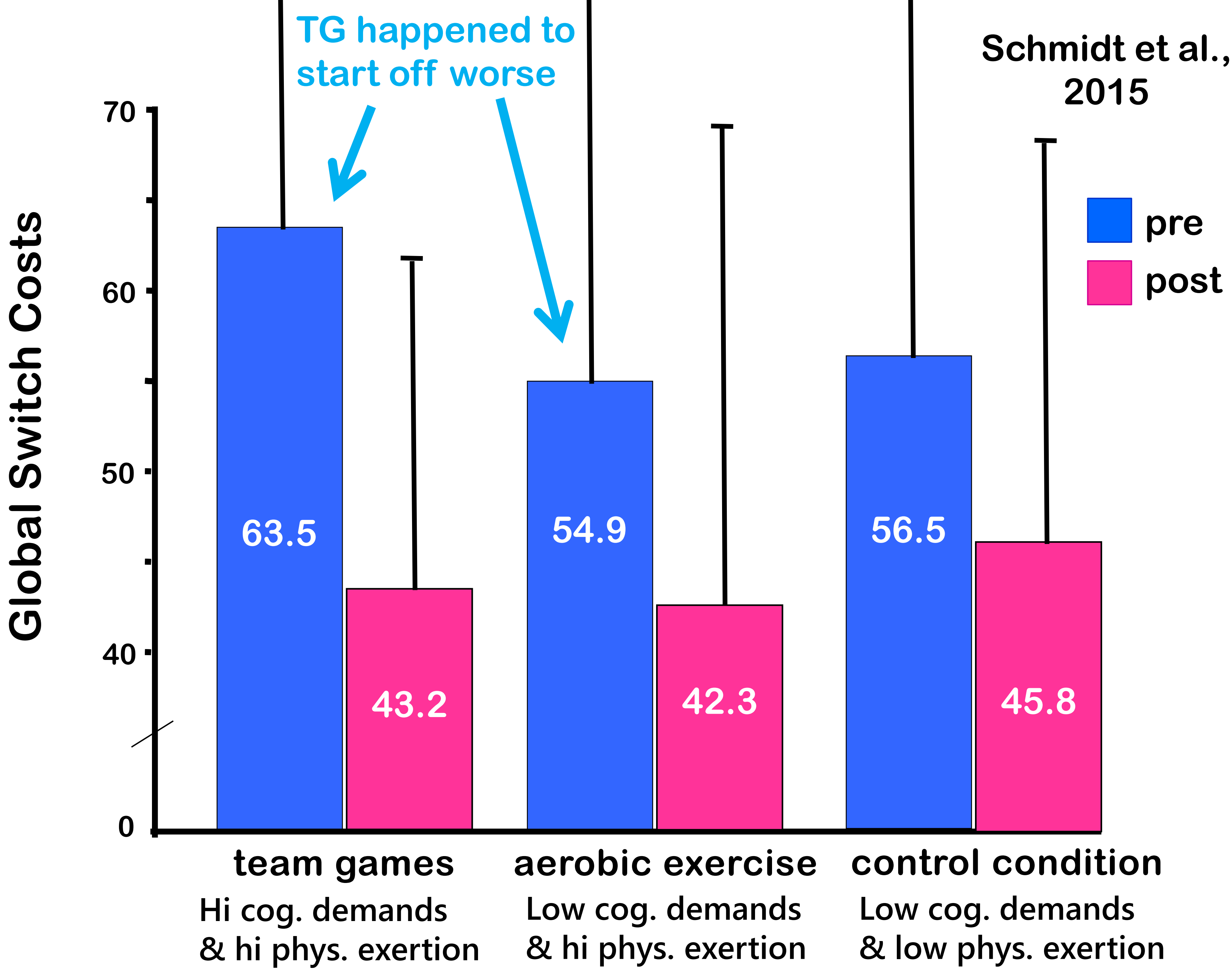


The wait-list group started out better & the intervention group caught up. There are no sign. differences in post-test levels.



Wait-list group started out better


Schmidt et al., 2015
There's no difference at post-test.
Global Switch Costs
70
60
50
40
0
pre
post
63.5
43.2
54.9
42.3
56.5
45.8
team games
Hi cog. demands & hi phys. exertion
aerobic exercise
Low cog. demands & hi phys. exertion
control condition
Low cog. demands & low phys. exertion


TG happened to start off worse
Schmidt et al., 2015
Global Switch Costs
70
60
50
40
0
pre
post
63.5
43.2
54.9
42.3
56.5
45.8
team games
Hi cog. demands & hi phys. exertion
aerobic exercise
Low cog. demands & hi phys. exertion
control condition
Low cog. demands & low phys. exertion

I want to see BOTH sign.ly better improvement & sign.ly better post-test scores.

Otherwise, did an intervention really help or are we seeing regression to the mean or normal differences in developmental timetables?

E.g., controls might have experienced a spurt in EFs before the study started (hence better at pre-test) and exp. grp might have experienced a spurt in EFs during the study independent of the intervention.

If children in one grp but not another were walking at 9 mos, and then

by 15 mos children in both groups were comparable in walking,

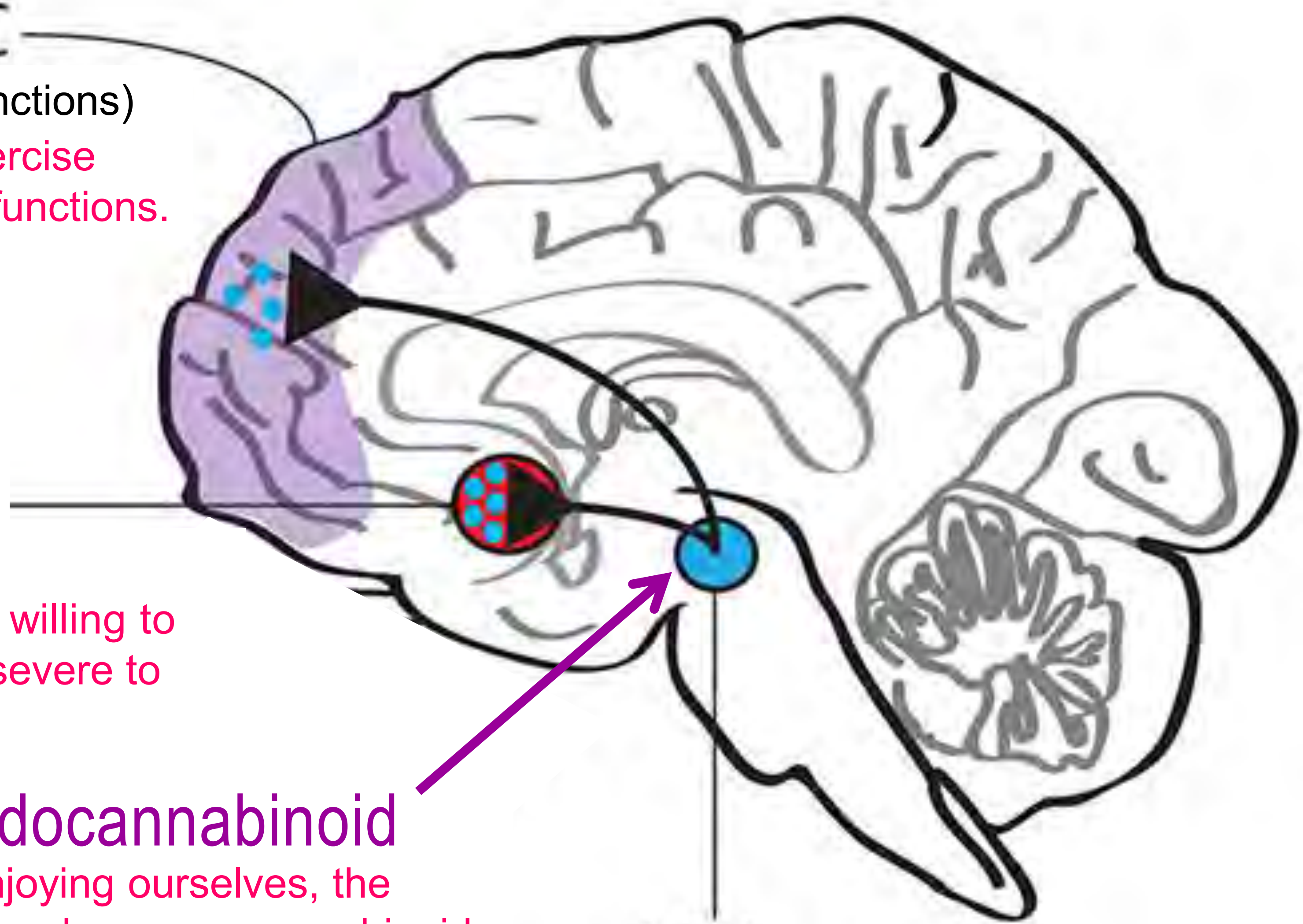
that could easily be due to normal developmental processes rather than any program improving those who had not been walking at 9 months.

People who freely choose to do physical activities probably enjoy them more than people who are randomly assigned to them.

There's evidence that any benefit of physical activity for cognition may be proportional to how much joy the physical activity brings

(Hill et al., 2010; Raichlen, Foster, Gerdeman, Seillier, & Giuffrida, 2012; Heyman et al., 2012; Wolf et al., 2010) .

Boring exercise is particularly unlikely to yield cognitive benefits.


3a. PFC
(Executive Functions)
We're able to exercise better executive functions.
3b. Nucleus Accumbens
(Reward Center)
We're happier and willing to work harder & persevere to achieve a goal
1. Endocannabinoid
When we're enjoying ourselves, the brain releases endogenous cannabinoids
They activate dopamine (DA) neurons in the VTA:
2. VTA
(Produces Dopamine)
The VTA is the source of the DA projection to PFC & to the nucleus accumbens

Many people who maintain better fitness do so by participating in activities that engage their hearts & minds –

many are passionate about these activities and deeply committed to them

the activities may be an important part of their lives and an important source of pride and personal identity.

Most EF interventions EFs have focused only on training EFs (or only improving aerobic fitness to improve EFs) ignoring powerful emotional factors.

Yet, if you're passionate about an activity, you'll devote lots of time & effort to it, & it's the hours practicing, pushing yourself to improve that drives the benefit.

I propose that whether someone is emotionally <u>invested</u> in an activity that trains EFs is key to how much that activity will improve EFs and that how much joy a person derives from an activity that challenges EFs will predict how much EFs improve.

Individuals are more invested in training if they have a real-world use for what is being trained. We learn something when we need it for something we want to do. We enjoy the training more if it is meaningful / related to real life.

I predict that training Ss on a sport or dance will be more enjoyable to them and successful in improving EFs than training Ss on isolated skills abstracted from a sport or dance/ decontextualized.

Individuals are more invested in an activity if they have a say in what's done during that activity.

I predict, for ex., that youths who have a say in shaping EF-demanding aerobic workouts will enjoy the workouts more, thus show greater benefits to mood & EFs and hence to academic performance & health, than those who do the same EF-demanding aerobic exercises but without a say.

Along similar lines, and combining something that could address both helping students to be better, more caring persons AND improving EFs – could be having them plan and execute a service activity / an activity to help their community or people elsewhere.

Students can get totally into this and be very motivated – it is meaningful to them and it's theirs (they have a say, they own it) -- and it requires EFS: planning, problem-solving, cognitive flexibility, creativity, perseverance, and discipline.

Working Memory & just holding information in mind (Short-Term Memory) are different.

Forward Digit Span

assesses short-term memory

After you see all the numbers, say them back in the order in which they appeared.

6

2

11

9

1

Say them back in the order they had appeared.

Now try to visualize the next set of digits as a 4-digit number

4

7

3

1

Backward Digit Span

Say the numbers back beginning with the last number first (in the order opposite to how they were presented)

1, 3, 7, 4

Re-ordering the Digits

assesses working memory

Say the numbers back in numerical order (smallest to largest)

5

2

7

12

3

Say them back in order of size

(smallest to largest)

2, 3, 5, 7, 11

We don’t allow

3 consecutive #s

3 ″ even or odd #s

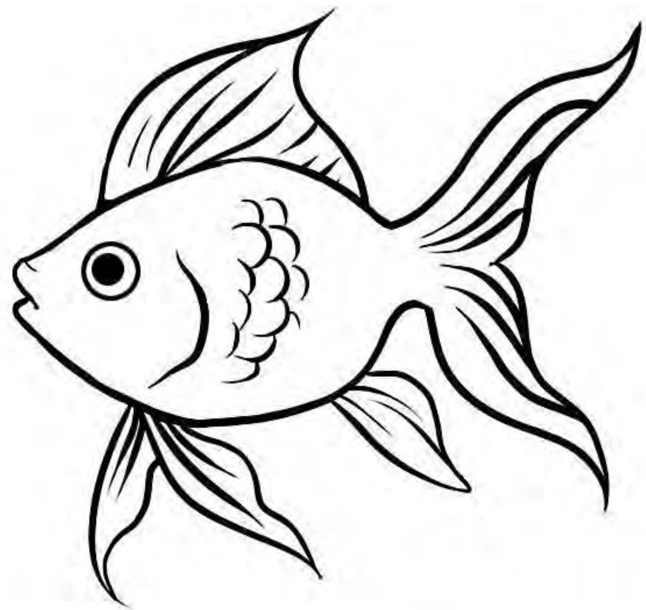
or 3, 6, 9

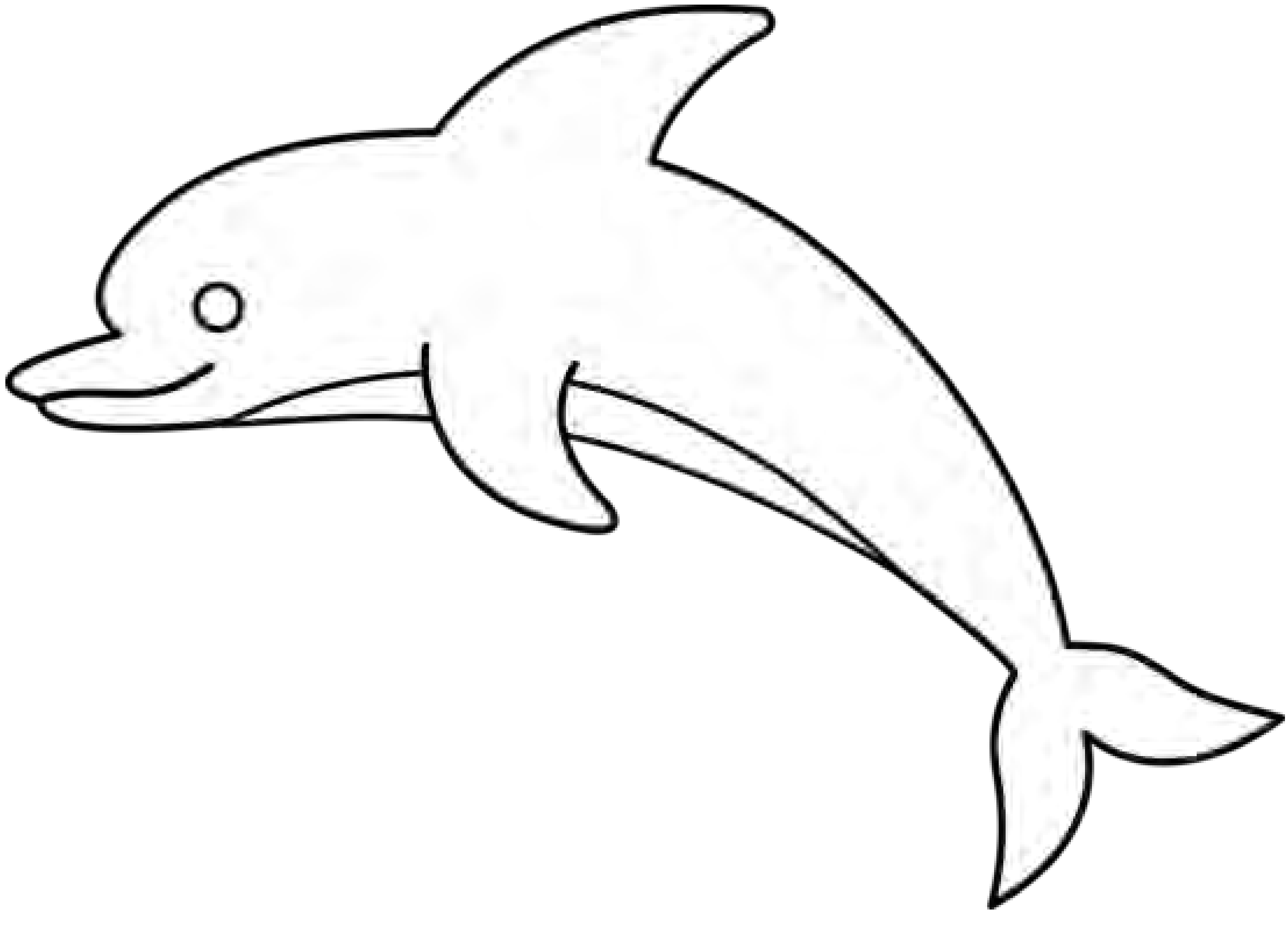
We also include 10,11, & 12

As far as I know no one else does this. Random generation of sequences can then result in some very easy sequences.

Very young children have difficulty with numbers

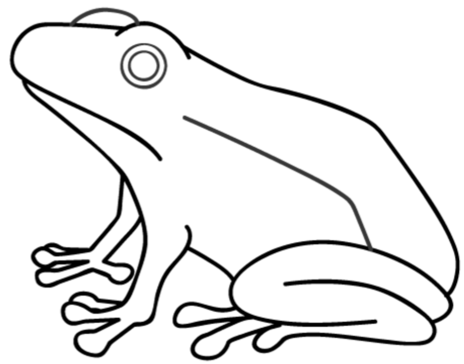
Re-order
by size here

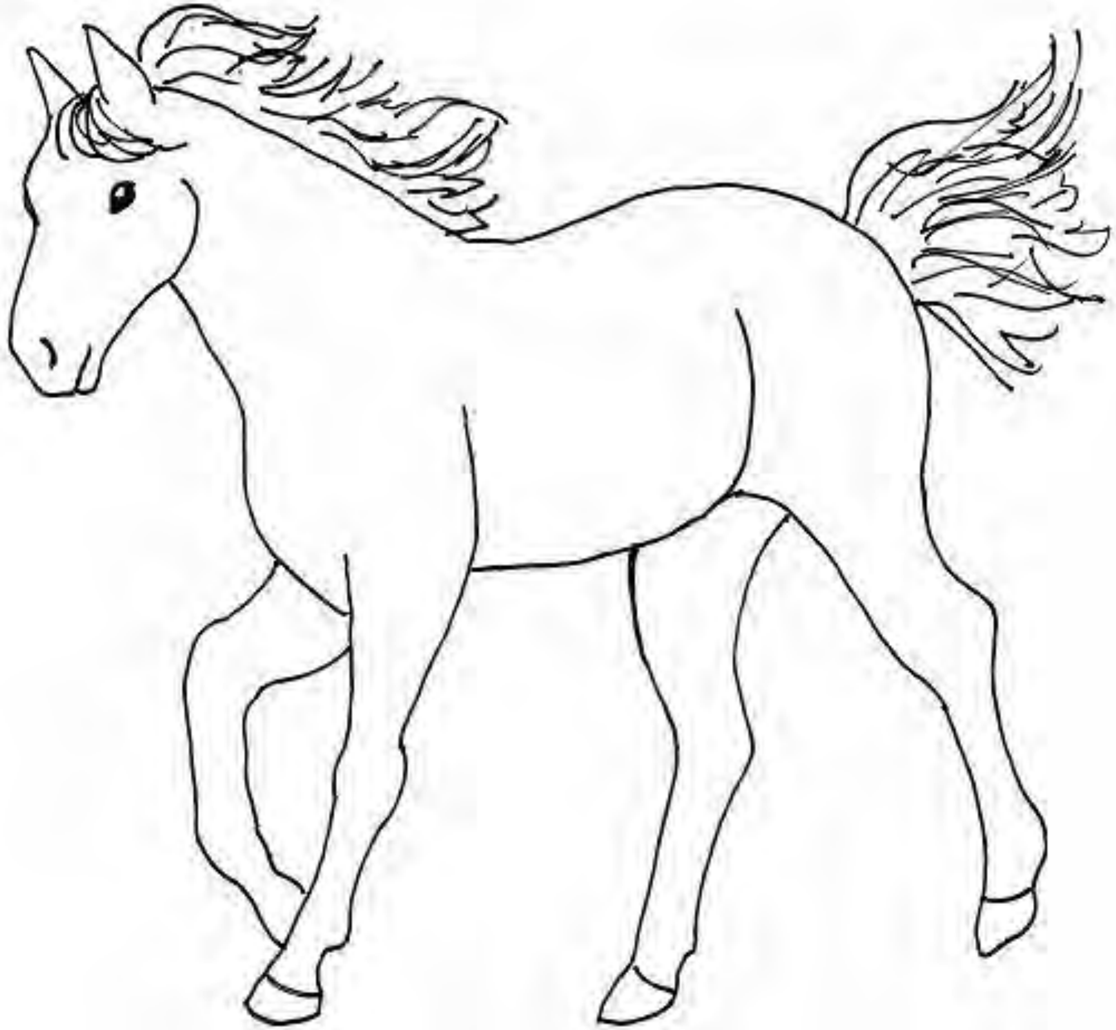


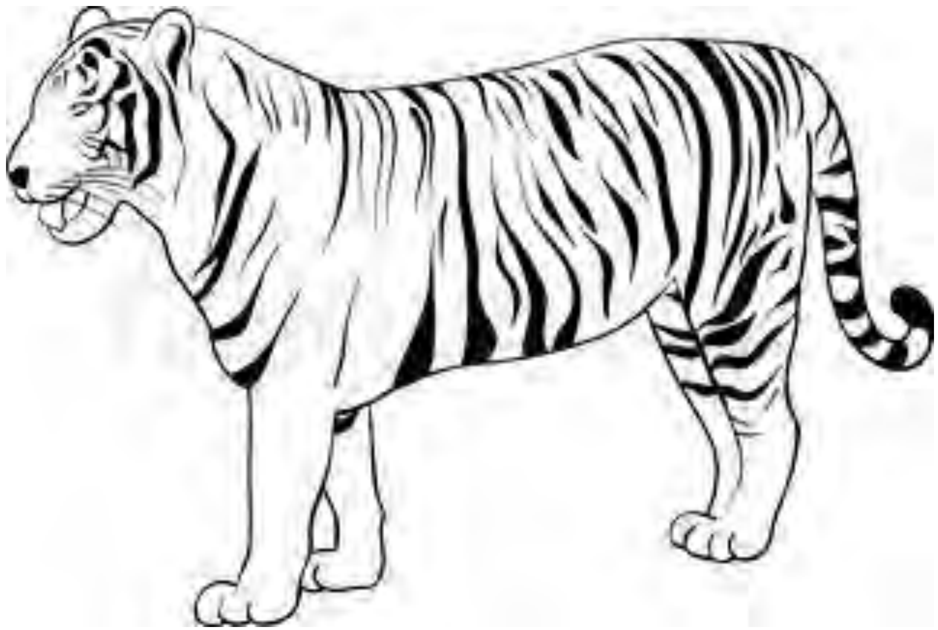


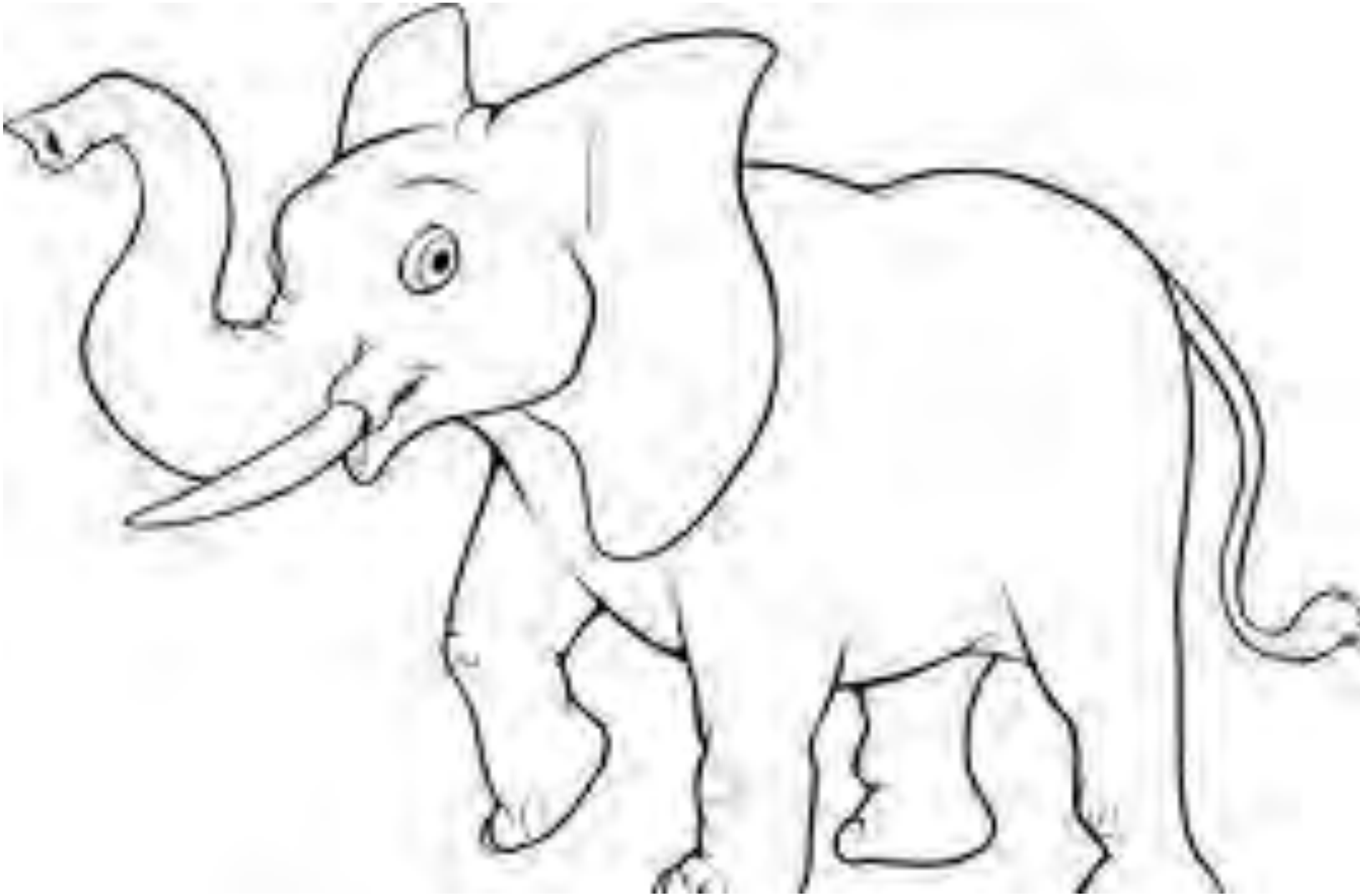
Say them back in order of size (smallest to largest)

Again, re-order by size here









Say them back in order of size (smallest to largest)

Mouse

Frog

Dog

Tiger

Horse

Elephant

Many working-memory researchers use the term 'working memory' so broadly that it becomes synonymous with executive functions.

COMPLEX SPAN TASKS

Messy (require several executive function abilities) but excellent measures of the integrity of PFC functioning

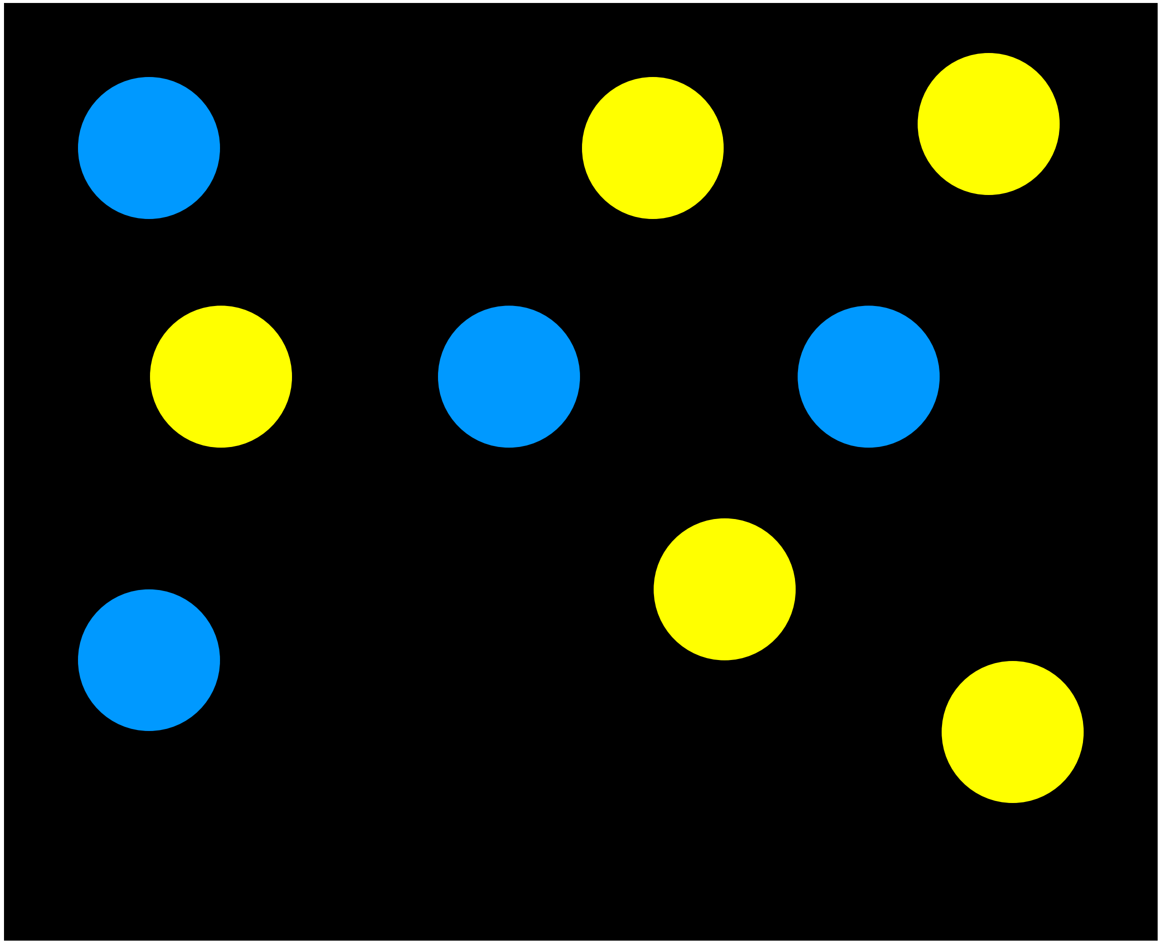
Example of a Complex Span Task

Counting Span Task

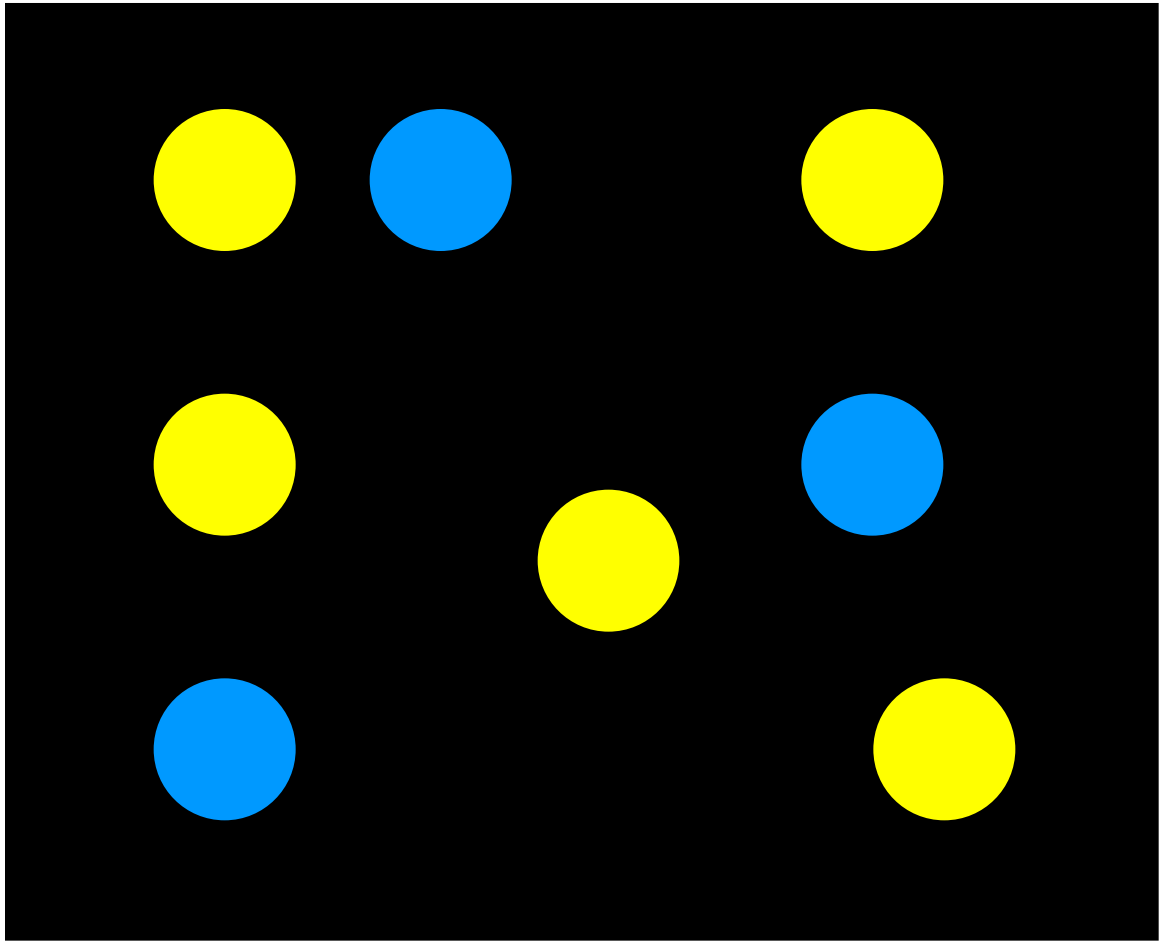
(Robbie Case *et al.*, 1982)

Count the number of blue dots (ignore the yellow dots), touching each blue dot as you count out loud.

Then announce the total for the current display, AND the totals for all previous displays in chronological order.



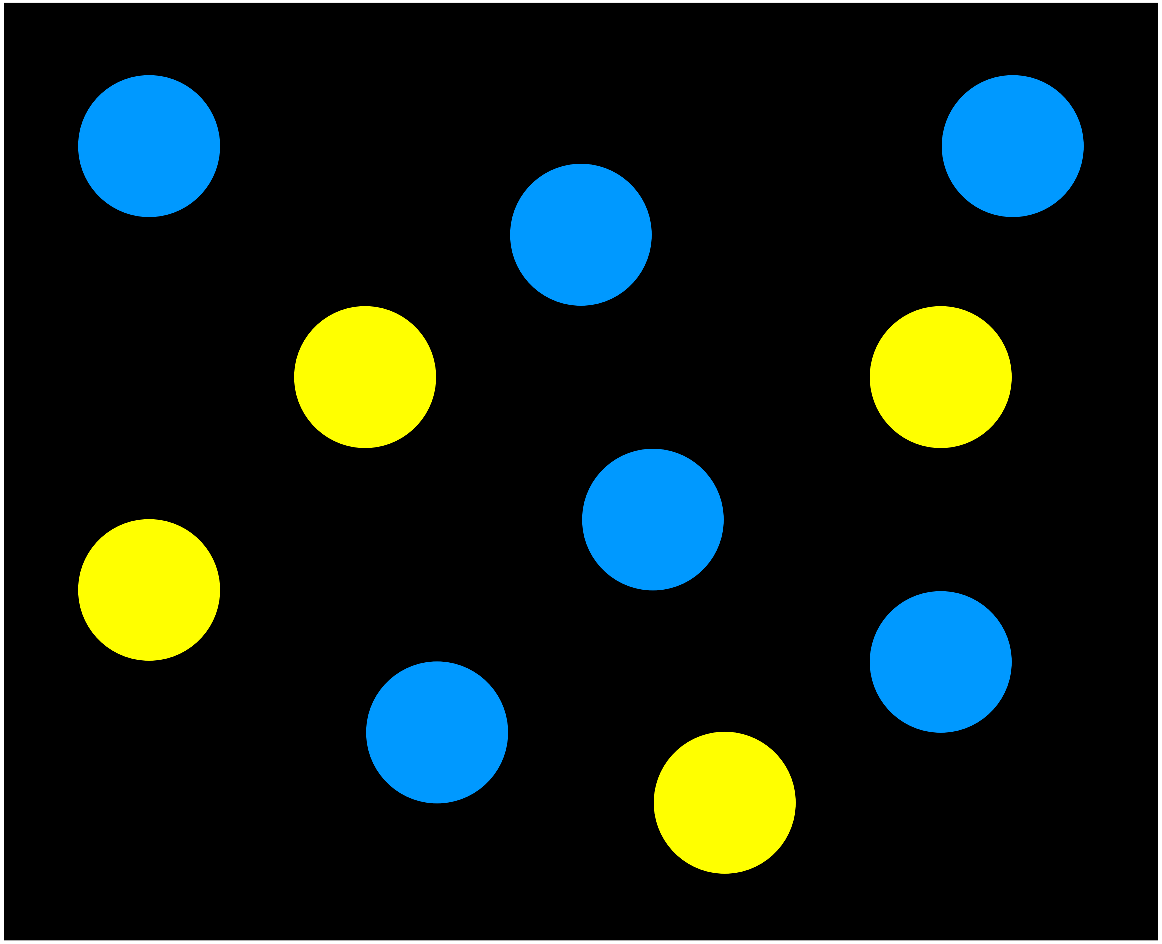
Count the number of blue dots. Touch each blue dot as you count out loud. The total is?



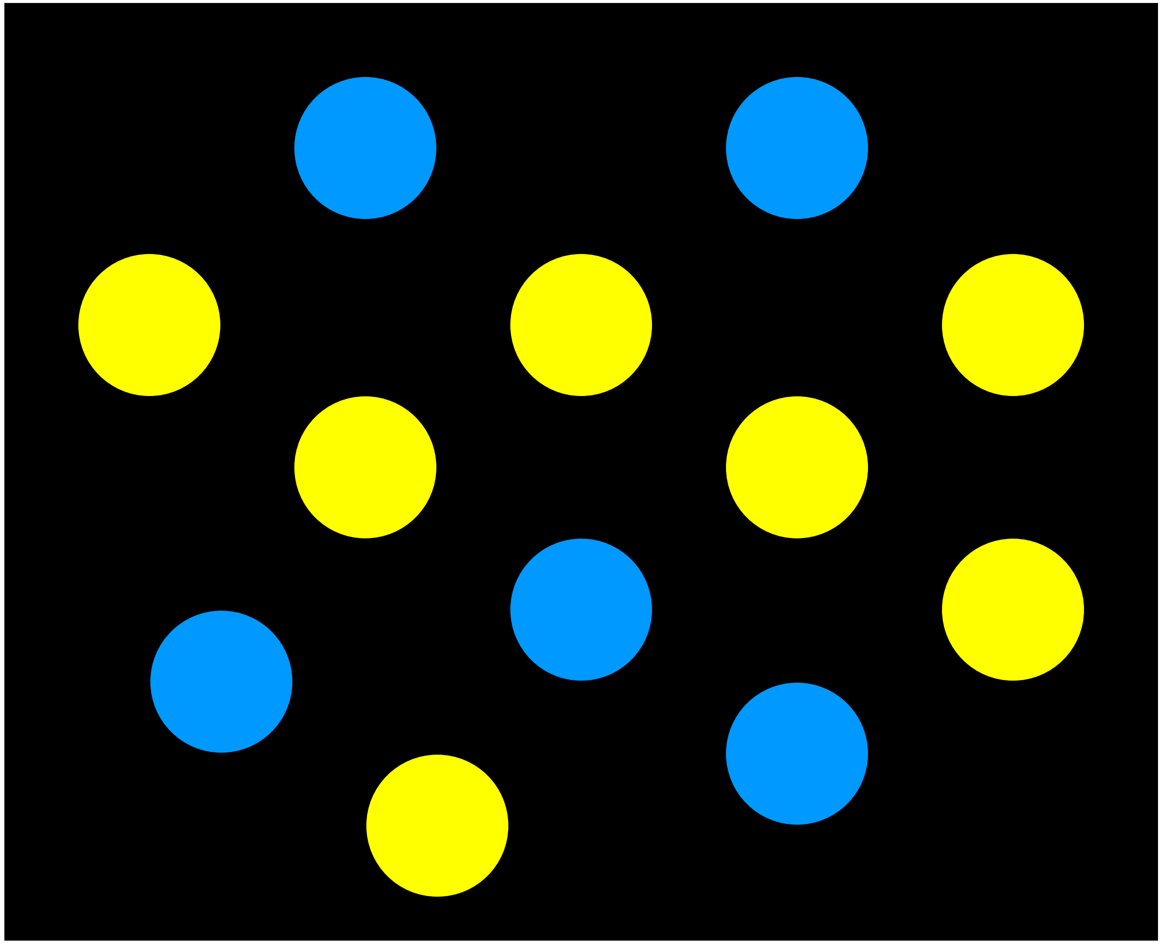
Count the number of blue dots.

Touch each blue dot as you count out loud.

The total is? What was the previous total?



Count the number of blue dots. Touch each blue dot as you count out loud. The total is? What were the previous totals, in order?



Count the number of blue dots. Touch each blue dot as you count out loud. The total is? What were the previous totals, in order?

This requires

(a) selective attention (inhibiting attention to the yellow dots),

(b) holding information in mind while executing another mental operation (counting),

(c) updating the information held in mind, and

(d) temporal order memory (keeping track of the order of the totals computed across trials).

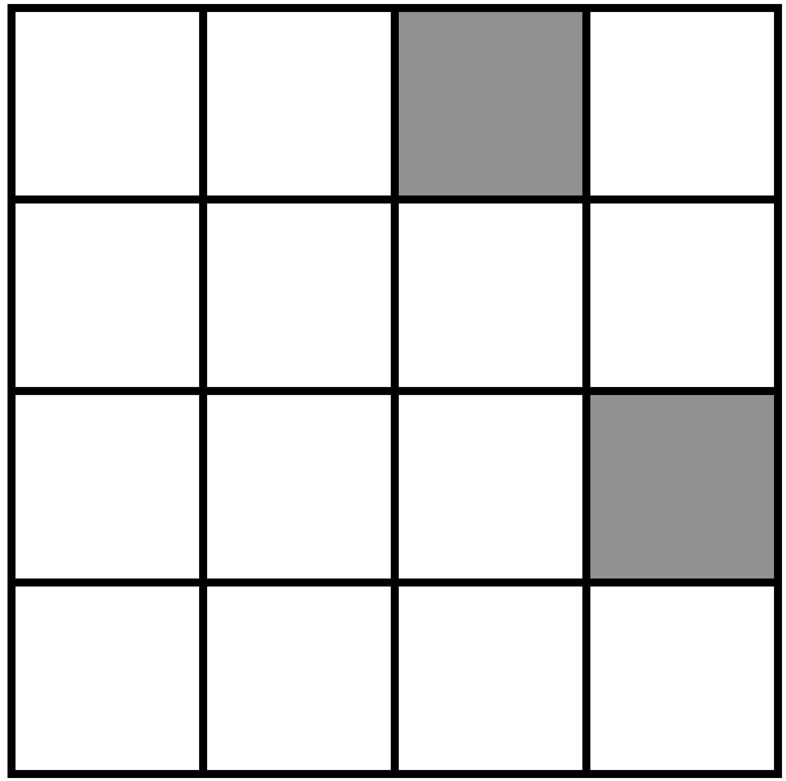
Spatial Span Task

(Robbie Case, 1992a; 1992b)

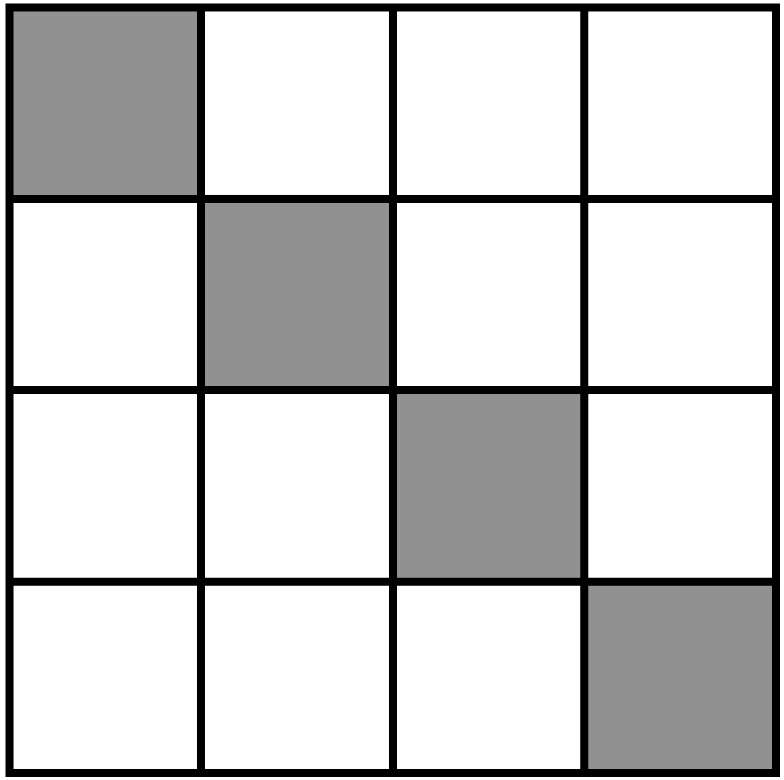
Note which cells are shaded.

After you see a filler pattern, you'll be asked to point to all the cells that had been shaded.

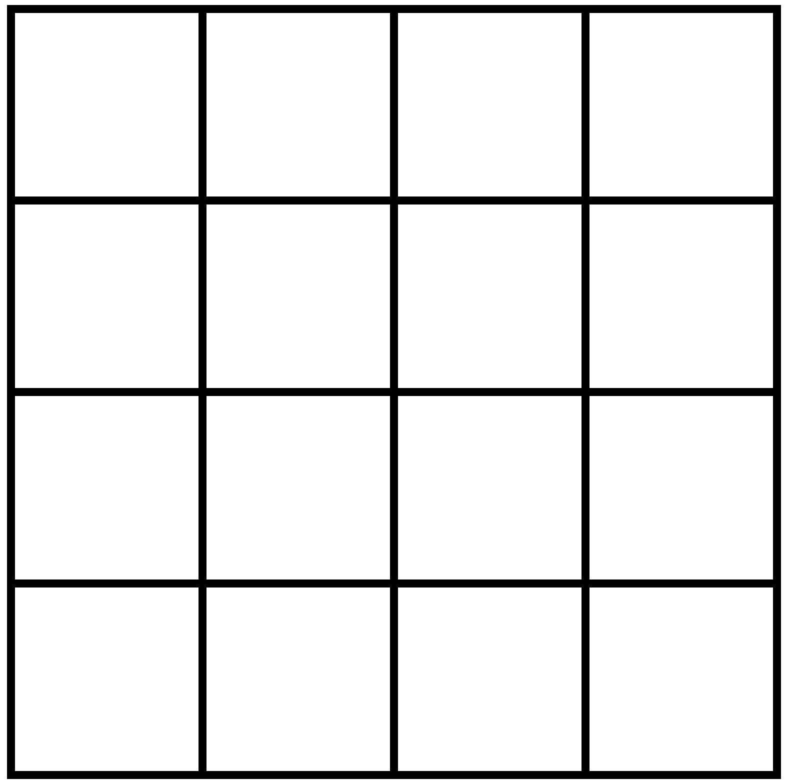
Get ready



Remember which boxes are shaded in

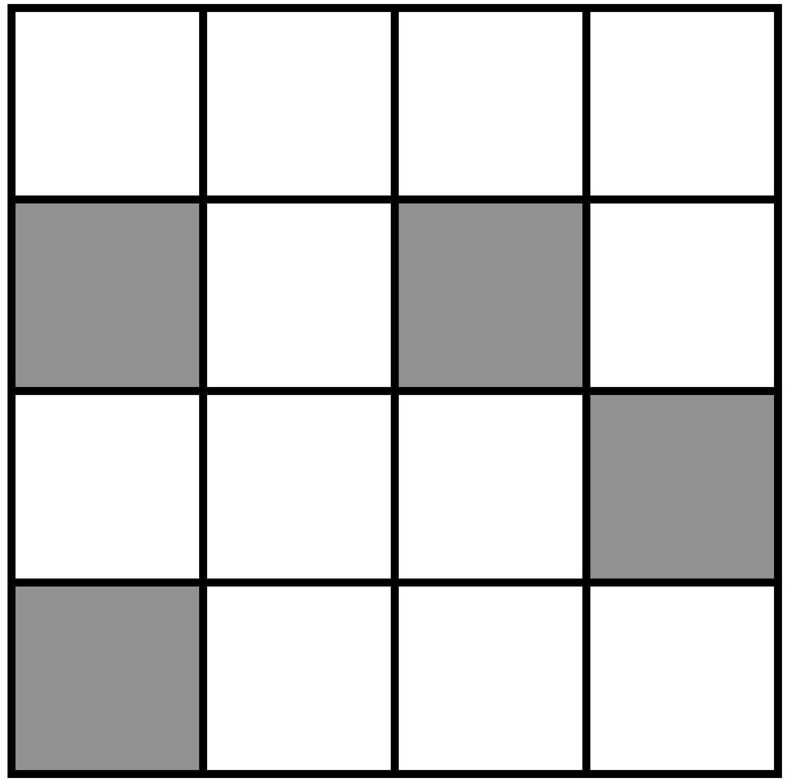


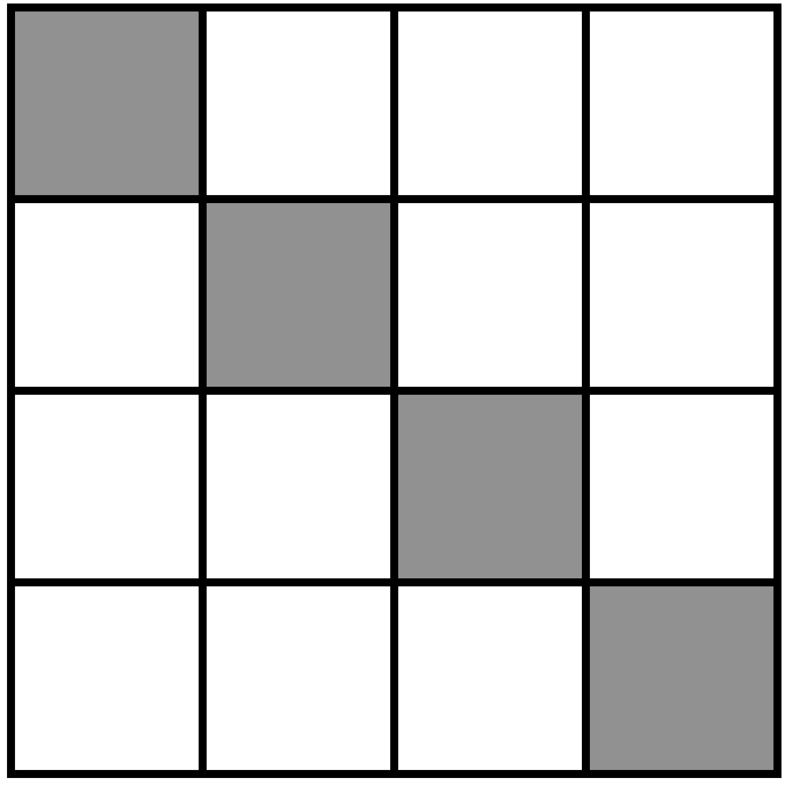
This is a ‘mask’ to make it harder
for you to remember.

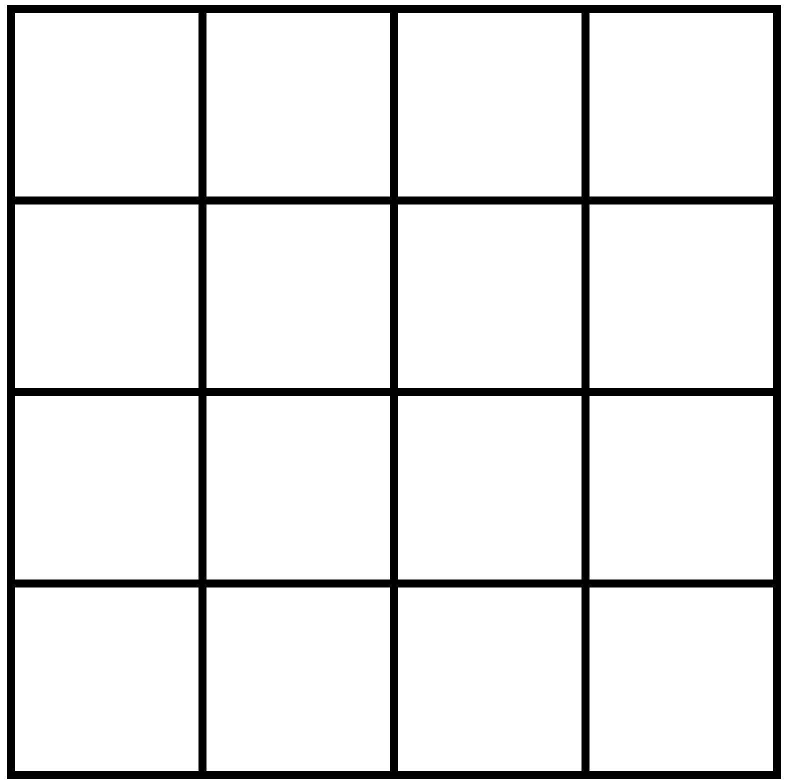


Point to the boxes that had been shaded at the beginning of this trial.

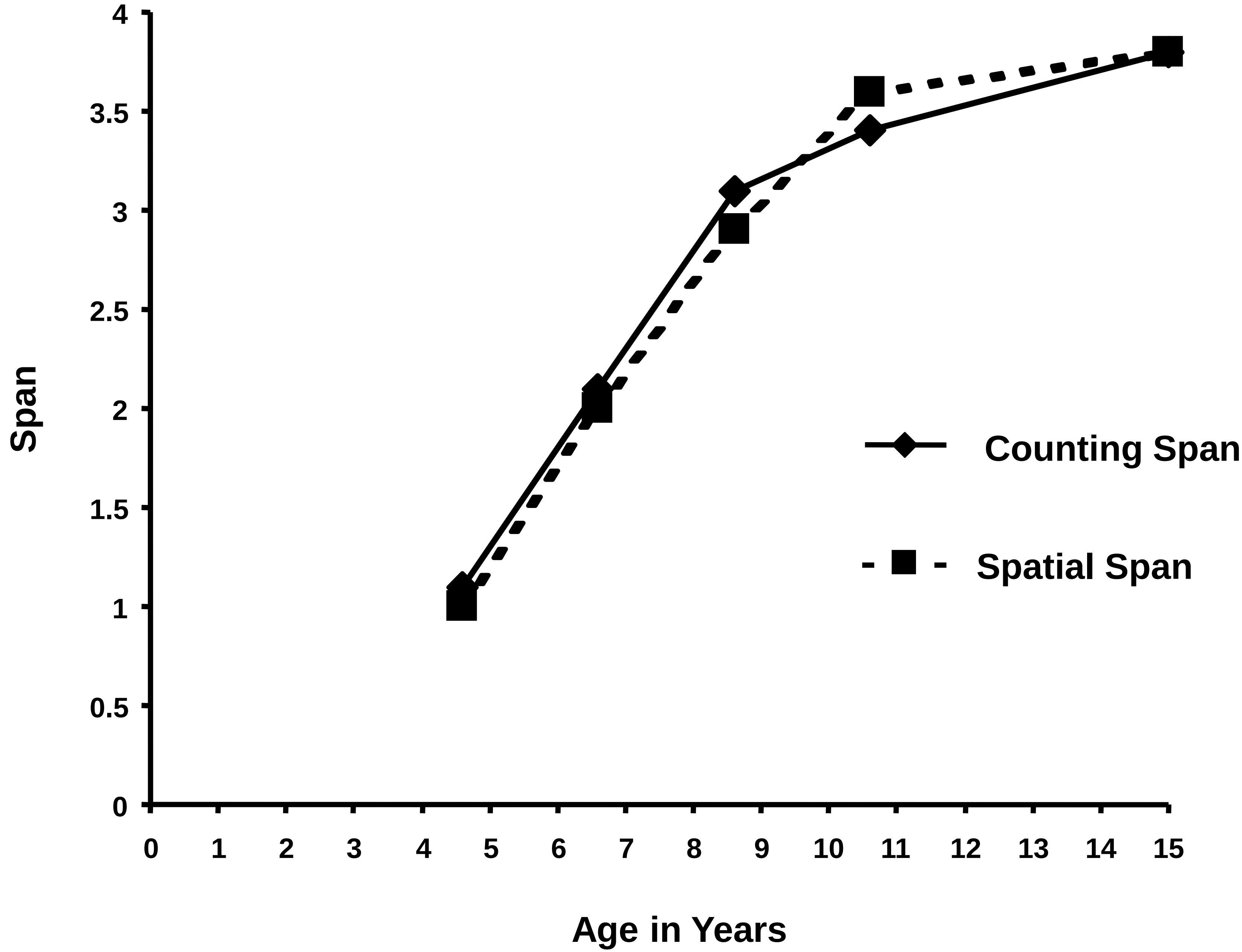
Get ready



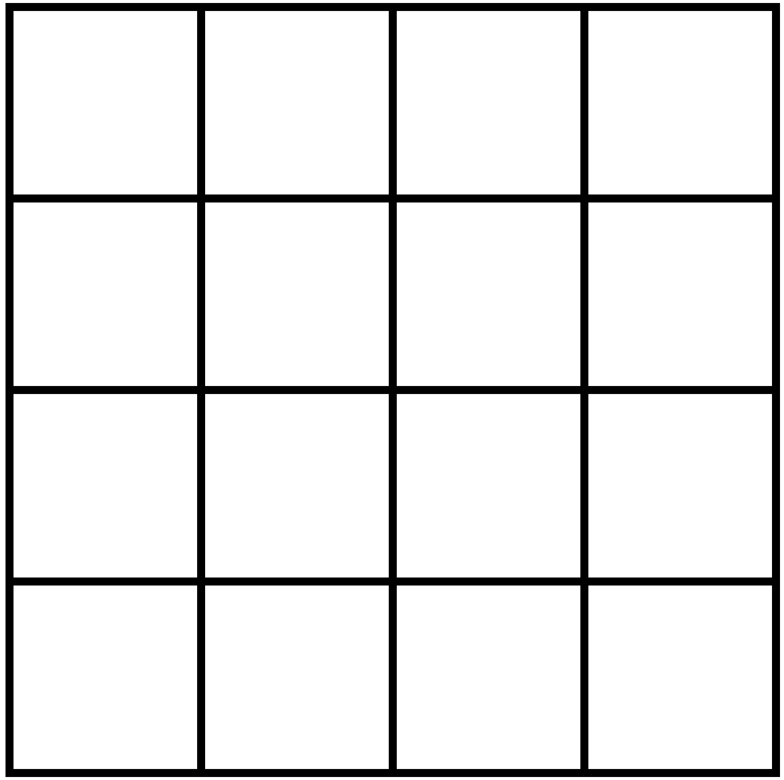




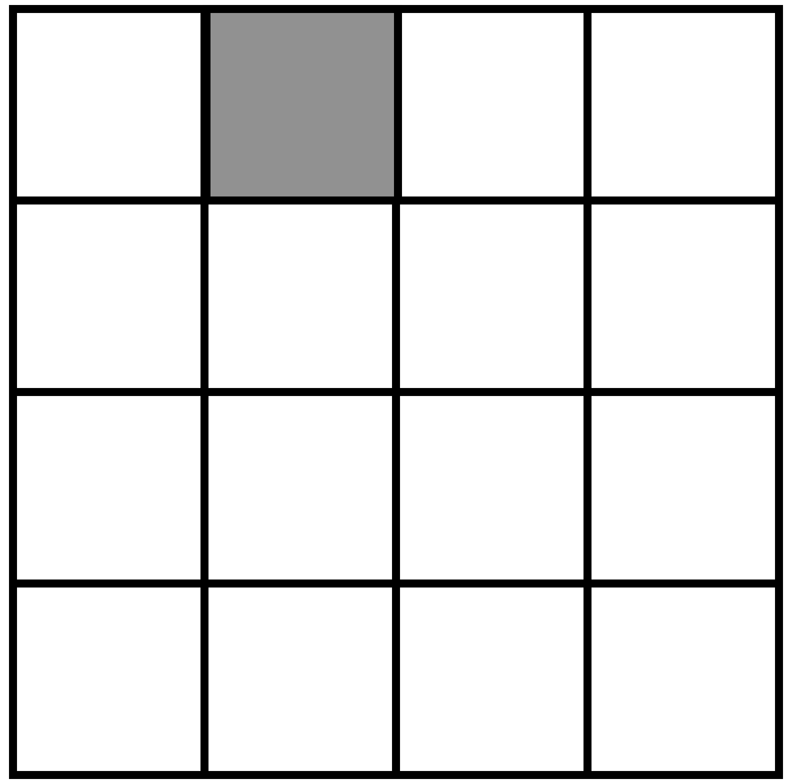
Point to the boxes that had been shaded on this trial.

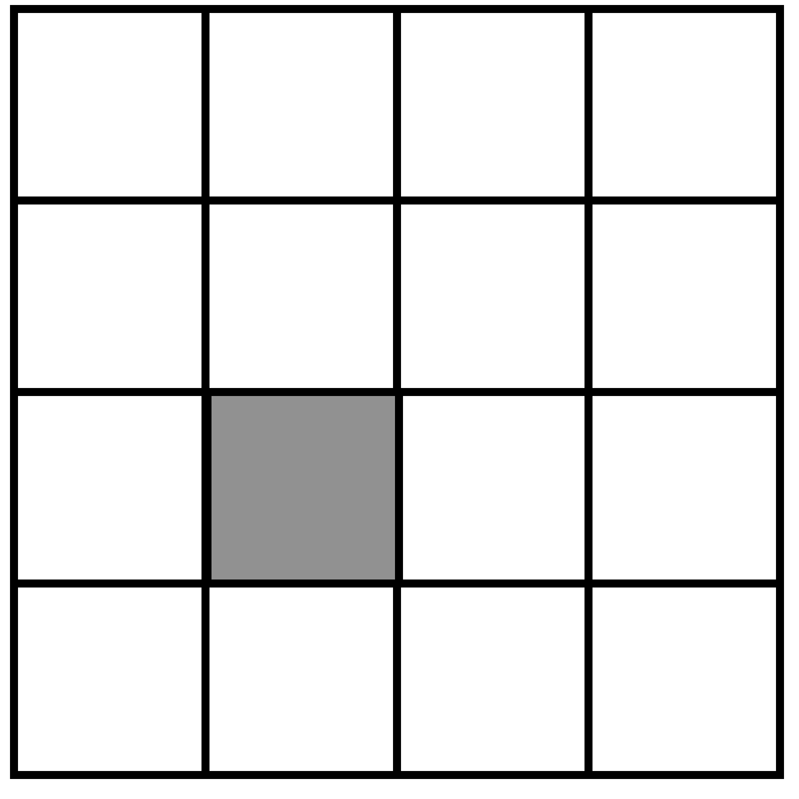

Span
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Age in Years
Counting Span
Spatial Span

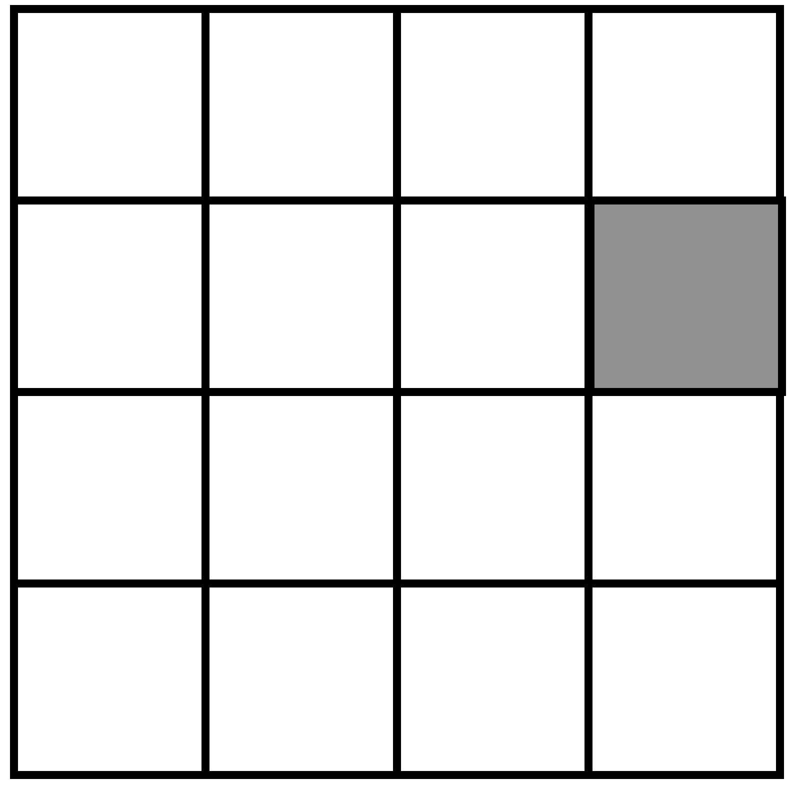
Now, point to the boxes that get shaded <u>in the order</u> in which they get shaded.

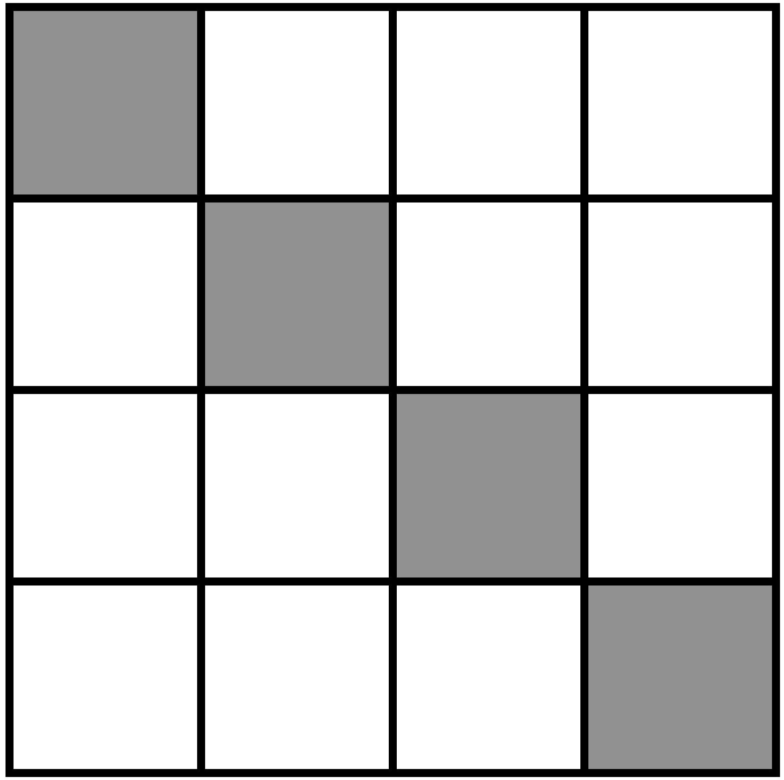


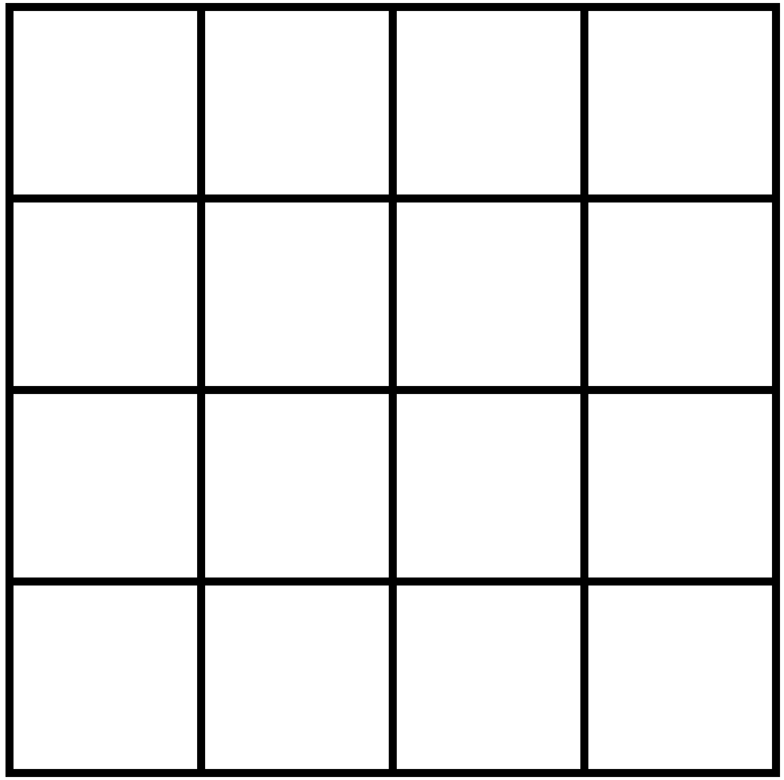
Get ready









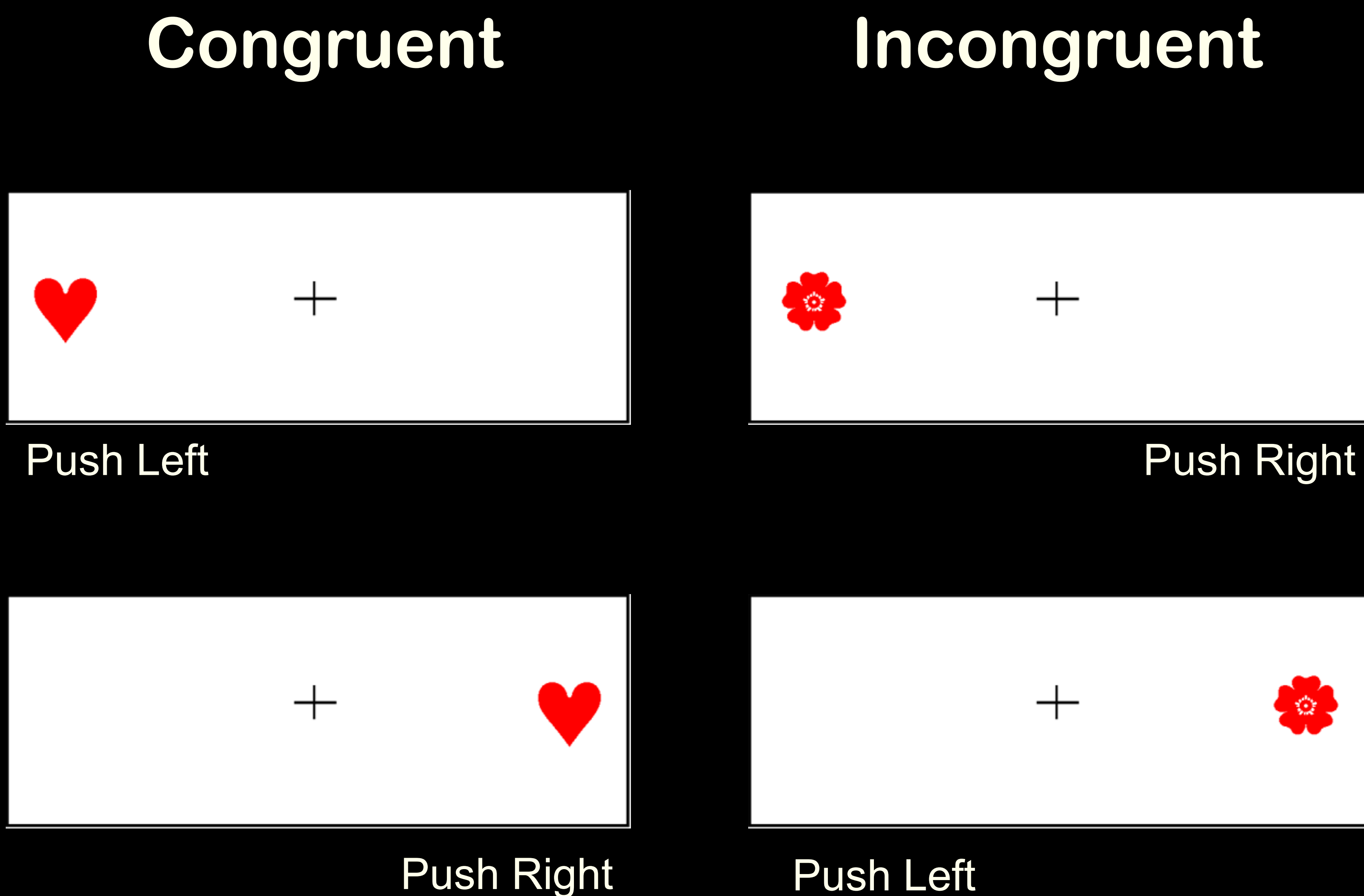


Point to the boxes that had been shaded in the order in which they were shaded.

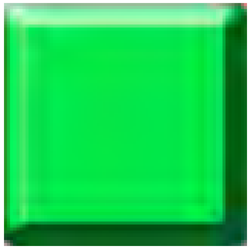
As long as the masking stimulus is used, this fits Engle & Kane's definition of WM: "the ability to keep a representation active in the face of interference."

But many spatial span tasks don't include a mask, e.g., Corsi Blocks, making them essentially a spatial version of Forward Digit Span (a STM measure).

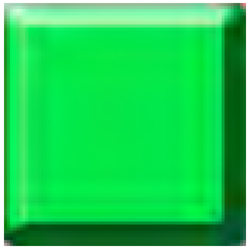
HEARTS & FLOWERS



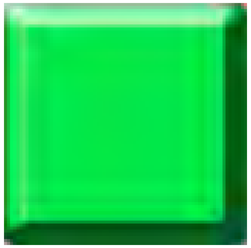

MicroTouch
3M



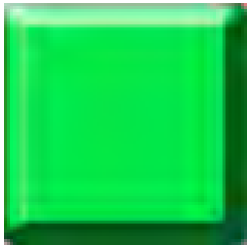
Button Practice



- - - - - Example 1 (Left side) - - - - -



- - - - - Example 2 (Right side) - - - - -

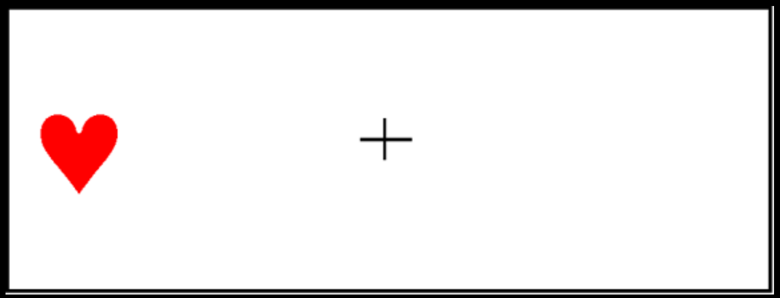


Gives a measure of Choice Reaction Time

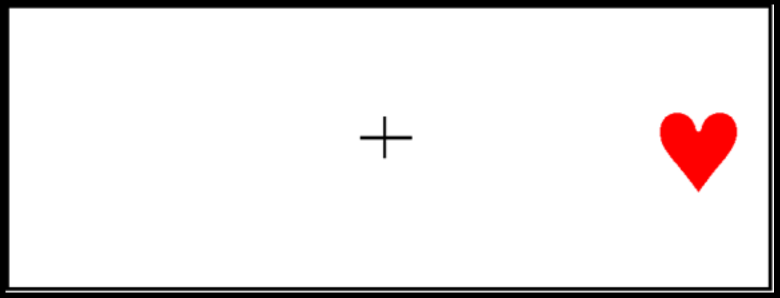
HEARTS & FLOWERS

Congruent	Incongruent

Congruent

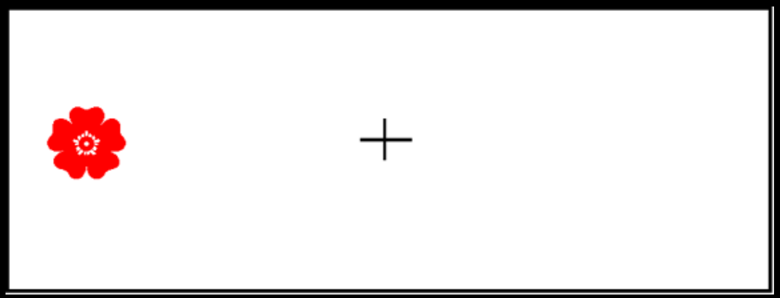


Push Left

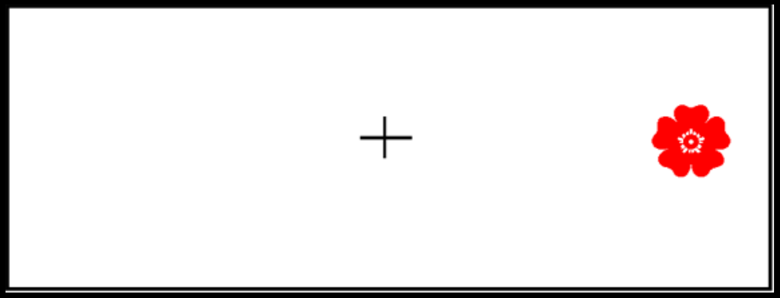


Push Right

Incongruent



Push Right



Push Left

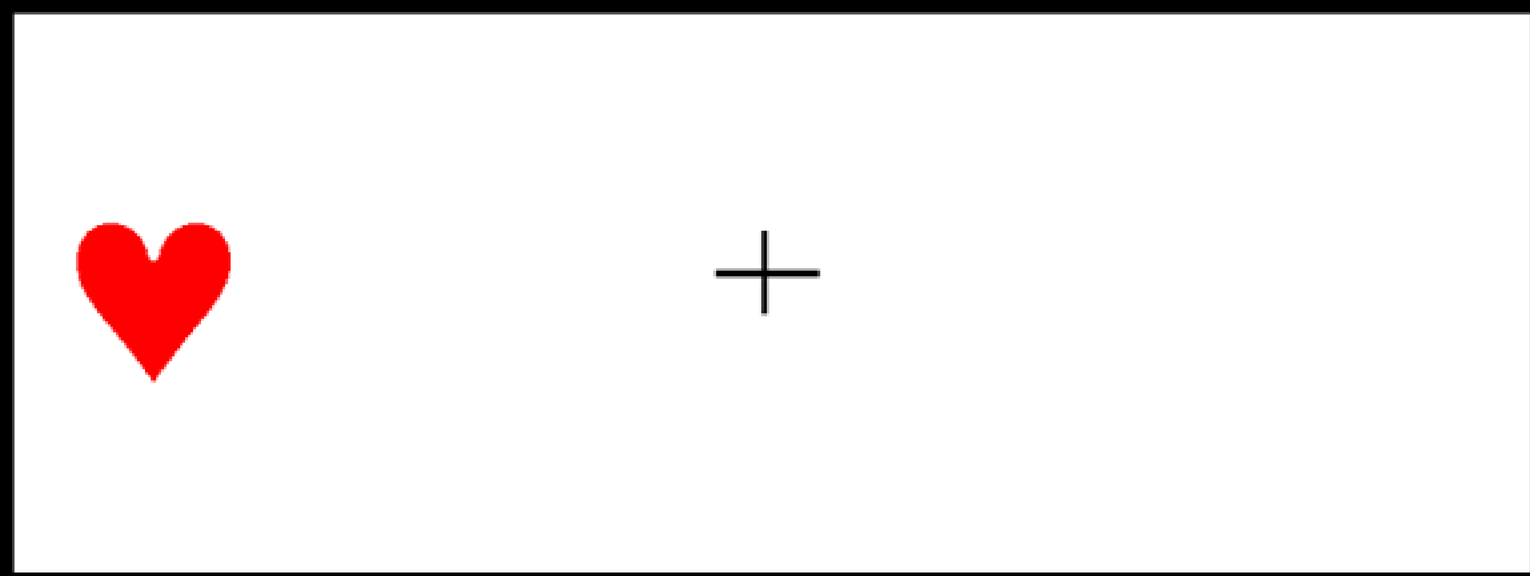
HEARTS – CONGRUENT

Each time you see a HEART, press with the thumb or forefinger on the SAME side as the stimulus.

For example, if the heart appears on the left, press with your left hand.

Remember:

PRESS ON THE SAME SIDE AS THE HEART



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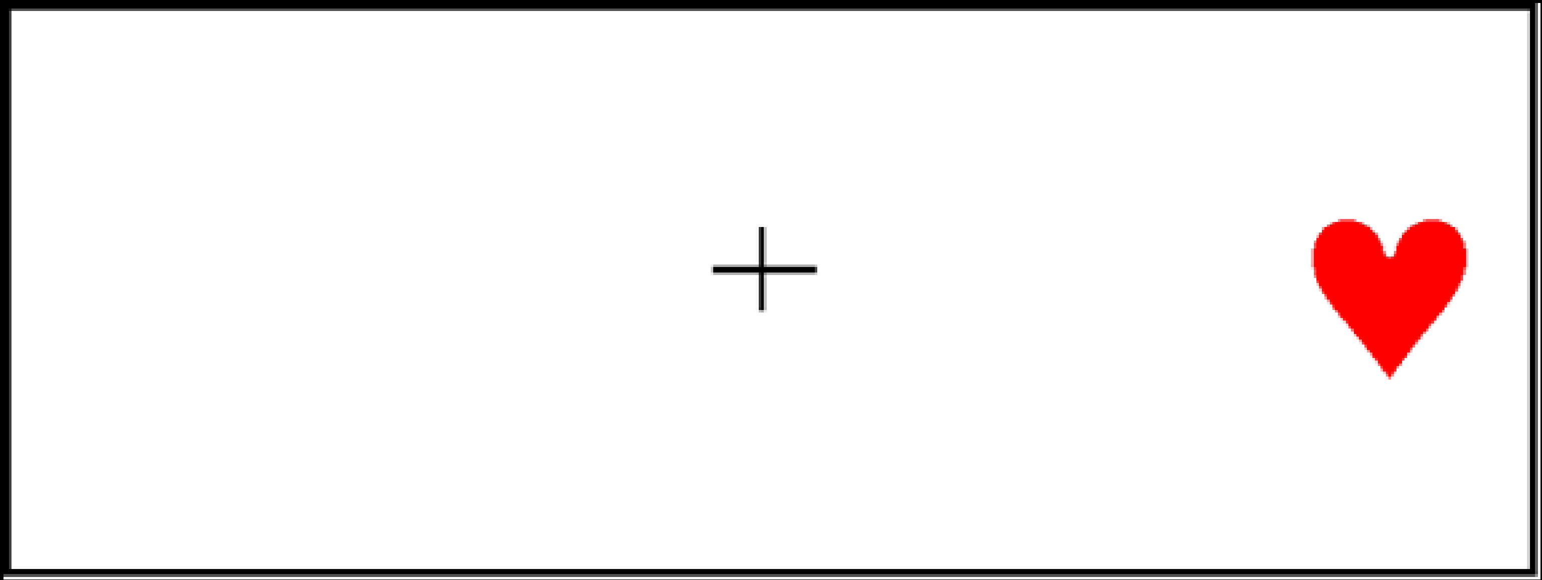


FLOWERS - INCONGRUENT

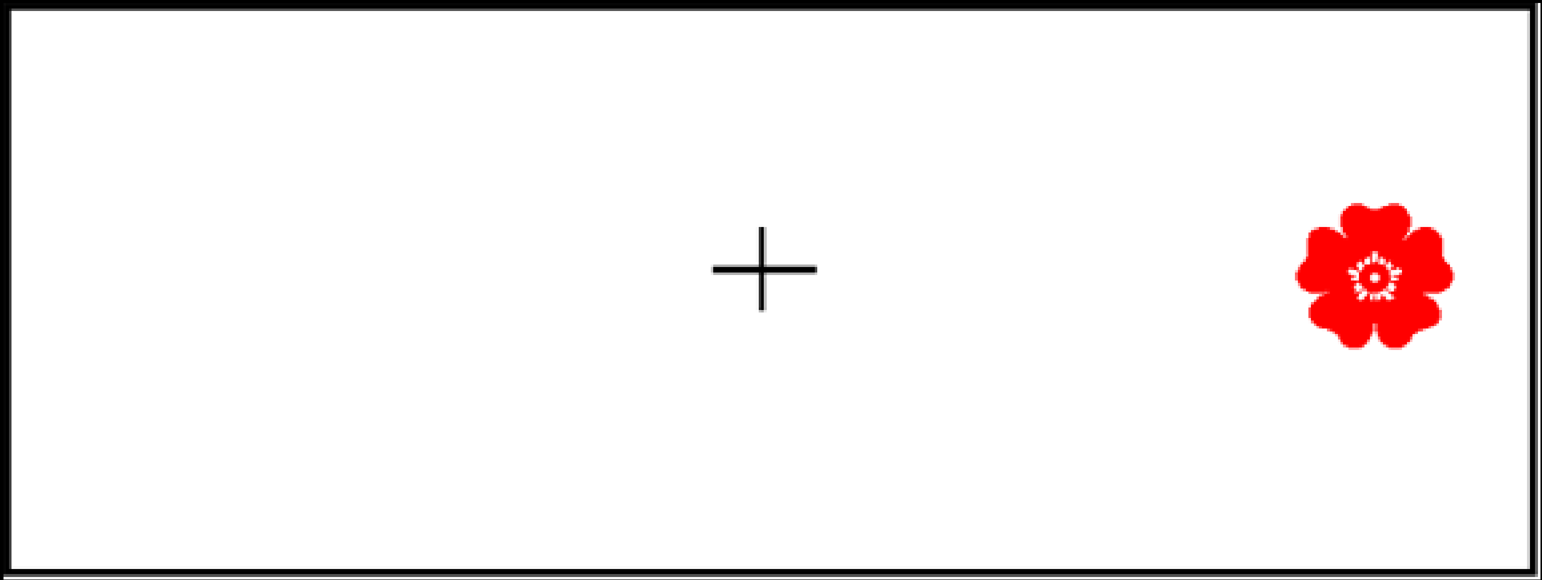
Now you'll see a flower. Press on the side OPPOSITE the flower.

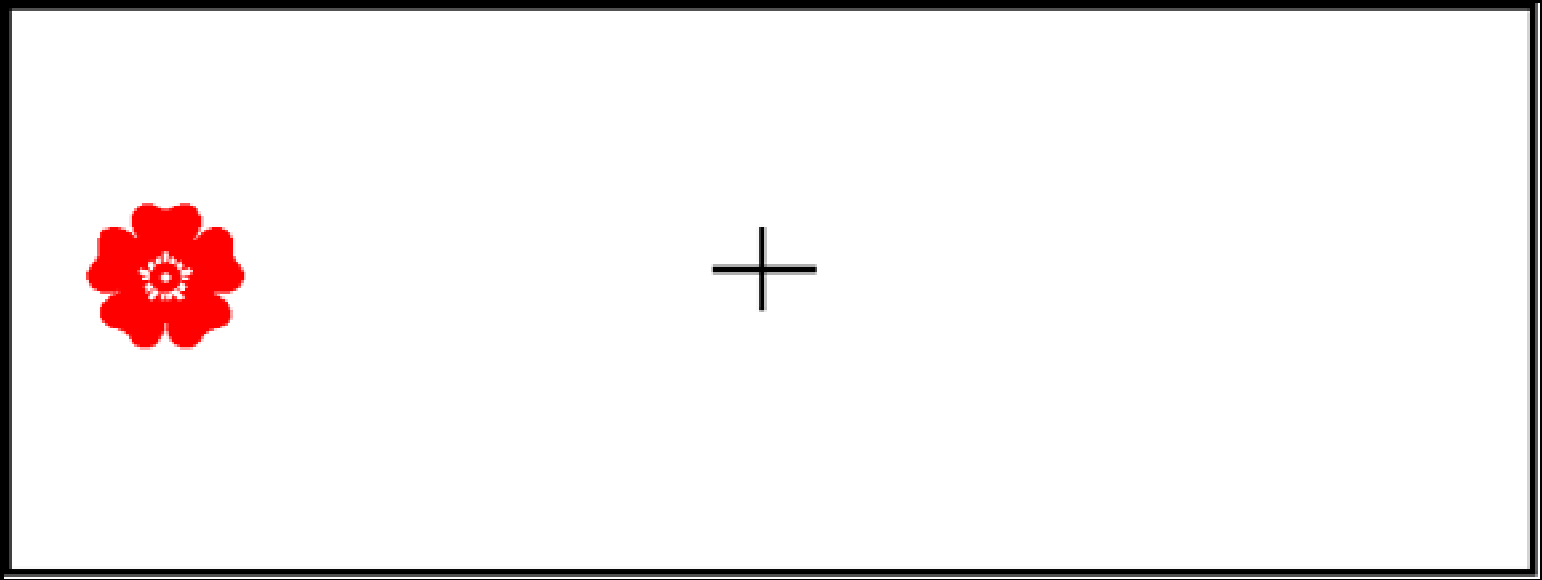
For example, if a flower appears on the left, press with your right hand.

(Here, you'll need to inhibit on every trial the natural tendency to respond on the same side as the stimulus)

Remember:

PRESS ON THE SIDE <u>OPPOSITE</u> THE FLOWER





HEARTS & FLOWERS-MIXED: Now you will sometimes see a heart and sometimes a flower.

On only half the trials will you have to inhibit the tendency to press on the same side as the stimulus, BUT you'll have to switch between the same-side and opposite-side rules.

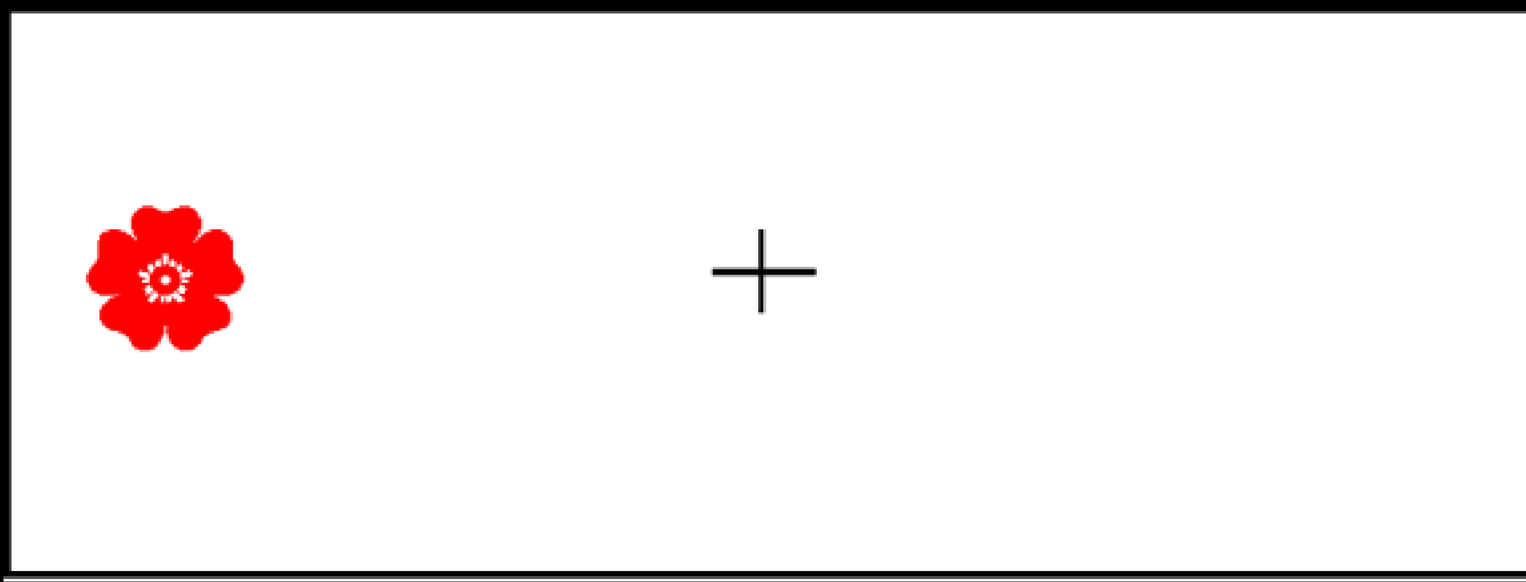
The rules stay the same:

For HEARTS, press on the SAME side.

For FLOWERS, press on the OPPOSITE side.

HEARTS – SAME SIDE

FLOWERS – OPPOSITE SIDE



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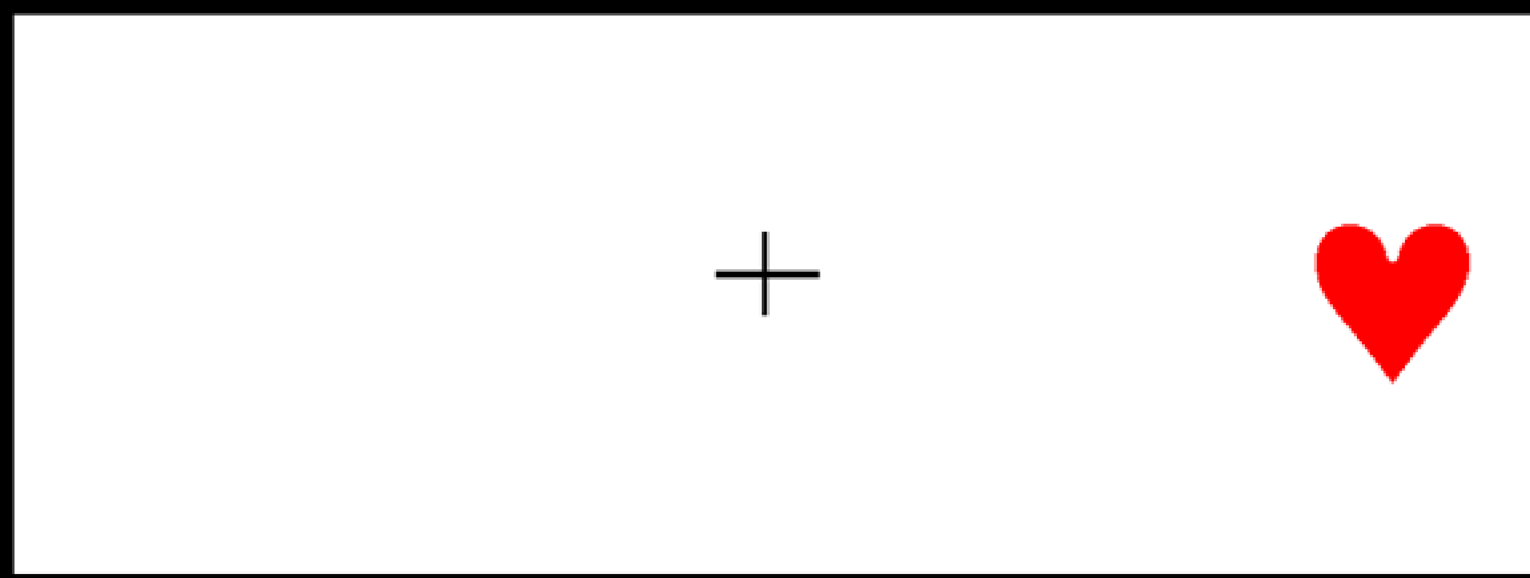
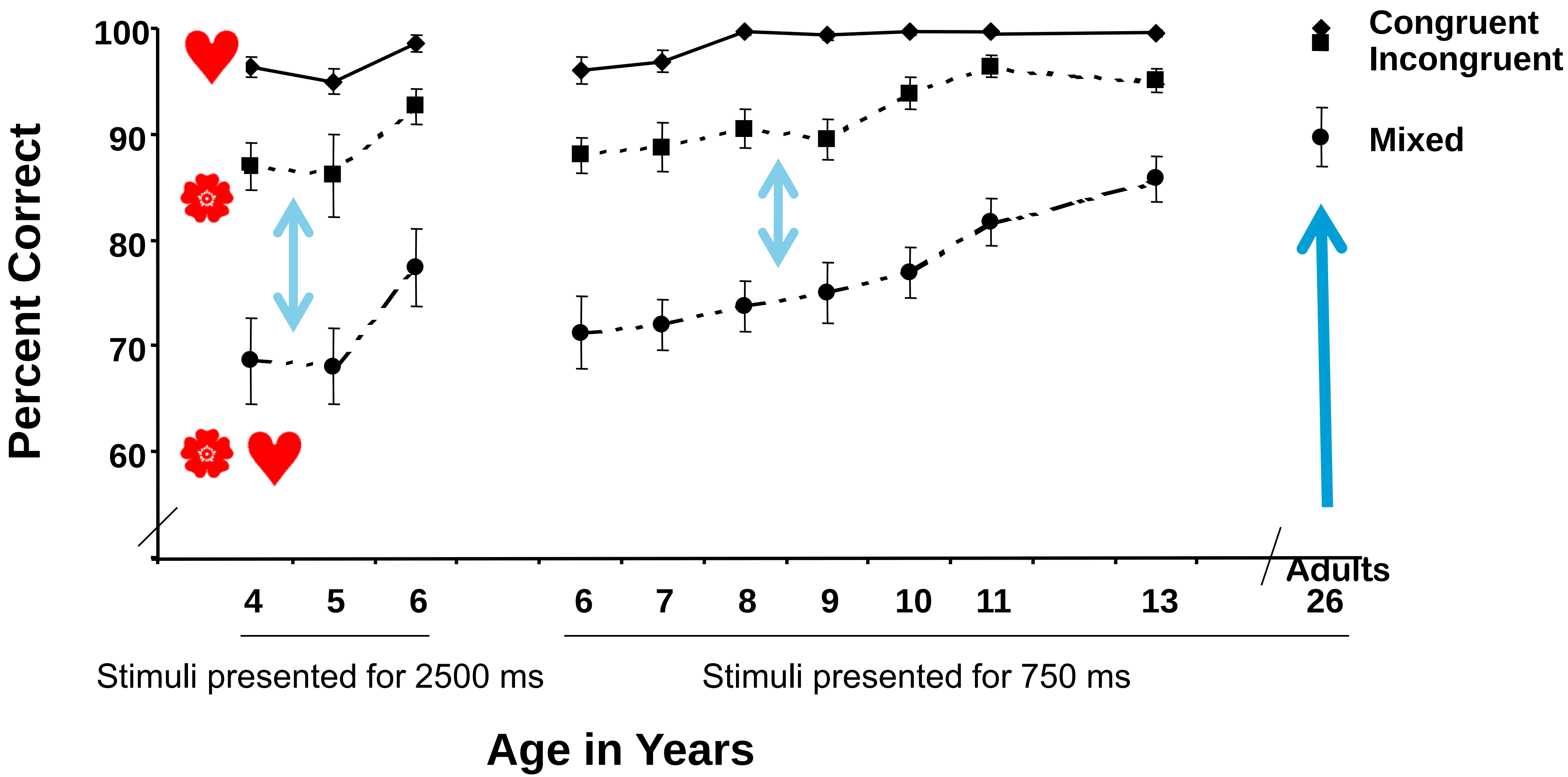


It is *not* that children forget the rules.

Indeed, children often call out the correct higher-order rule on trials in the mixed condition (e.g., “same,” “opposite,” “opposite,” “same”) even as they are making errors.

The problem seems to be in quickly translating the rule into the correct response.

Hearts and Flowers Task: Accuracy



Davidson et al. (2006). Neuropsychologia, 44, 2037 - 2078

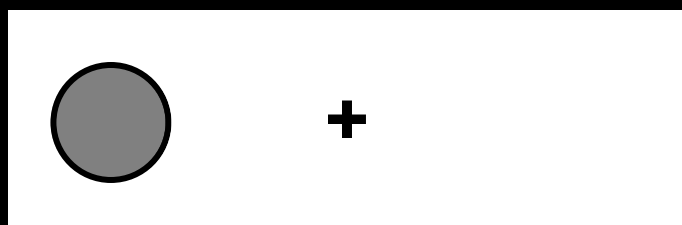
It is SWITCHING back and forth

(Cog. Flex.) --

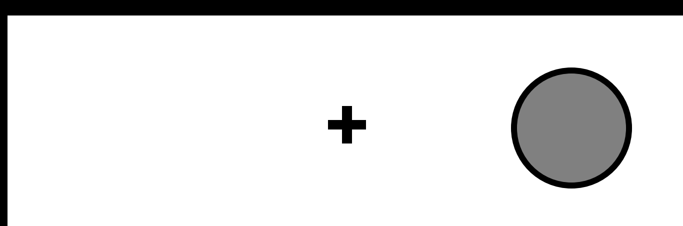
re-setting one's attentional focus,
re-orienting one's mindset --

that is most difficult.

Dots - Congruent

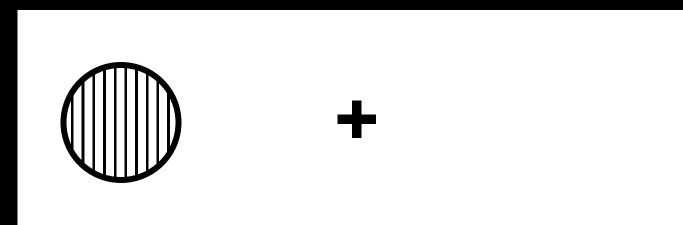


Push Left



Push Right

Dots - Incongruent



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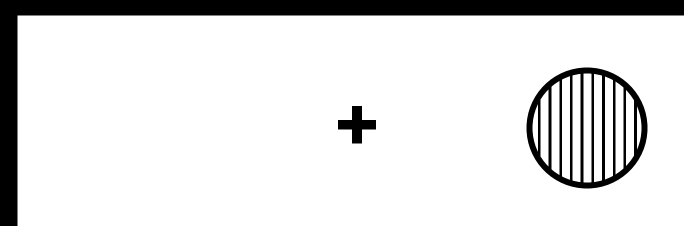
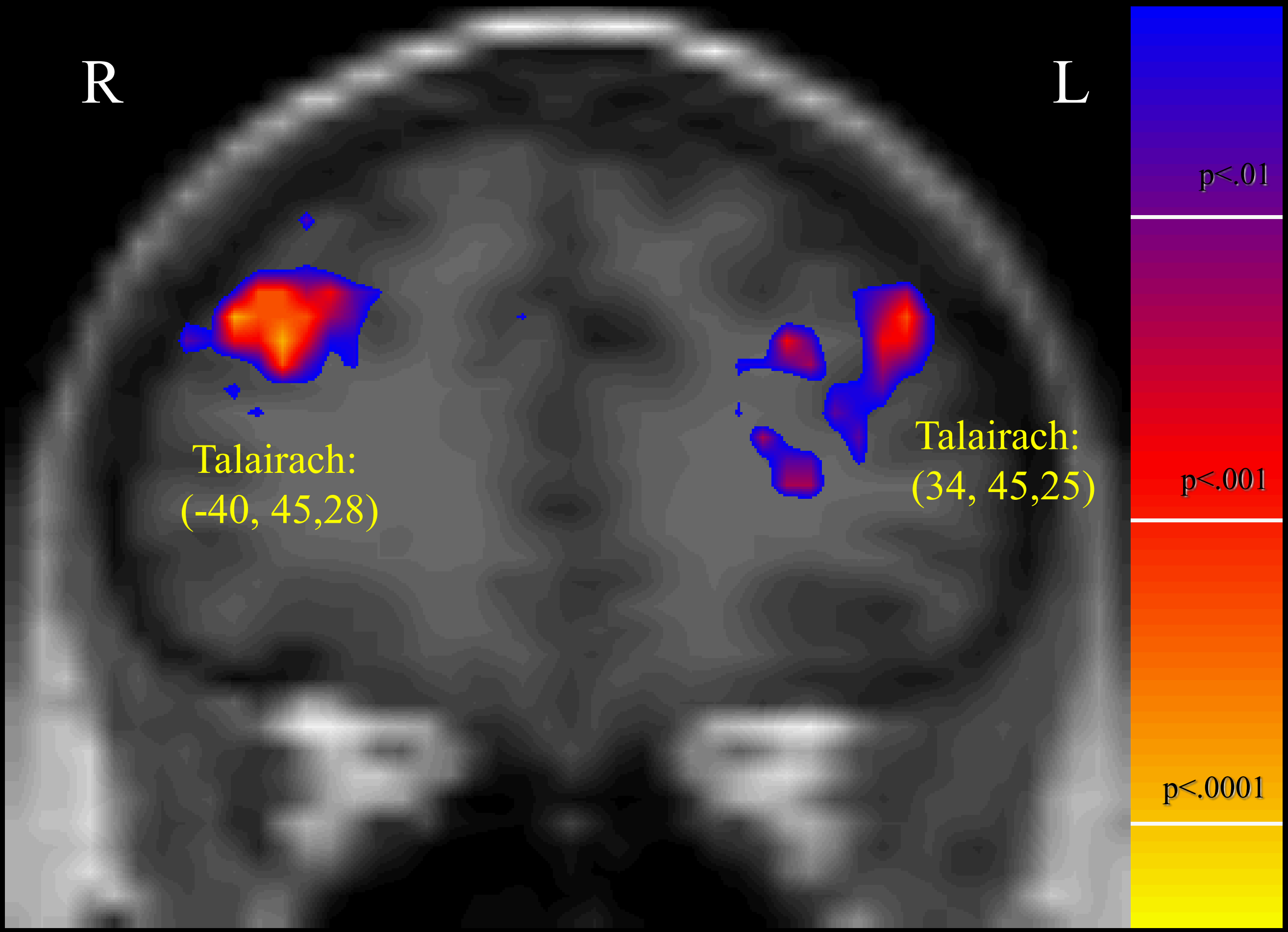
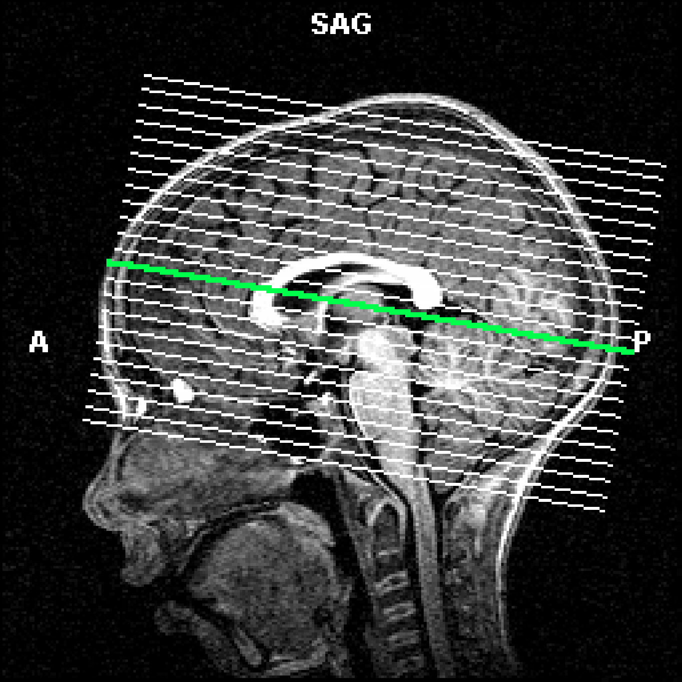


Push Left

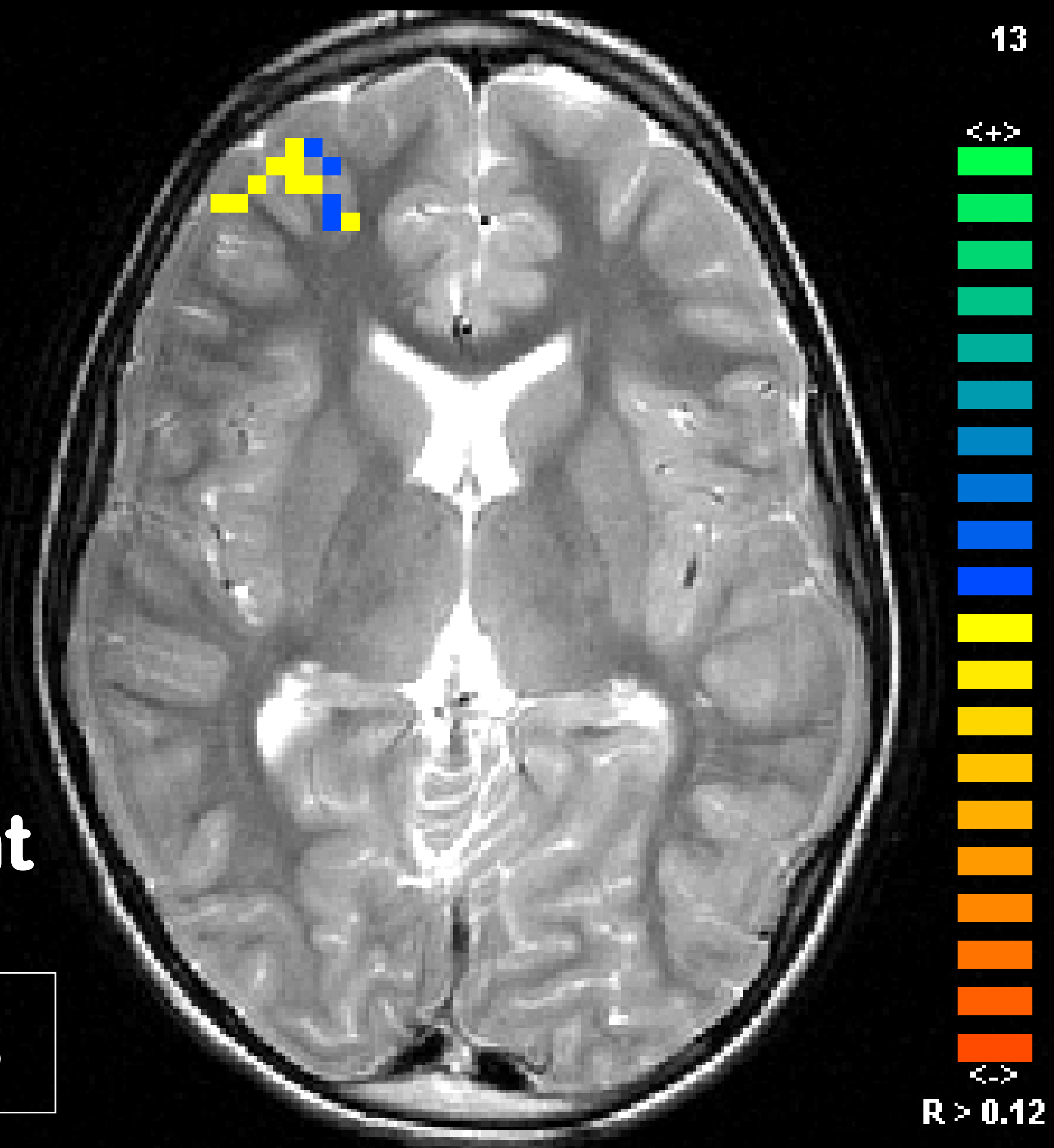
Increased Activation of Dorsolateral PFC (Area 46/9) Dots-Mixed minus Dots-Congruent



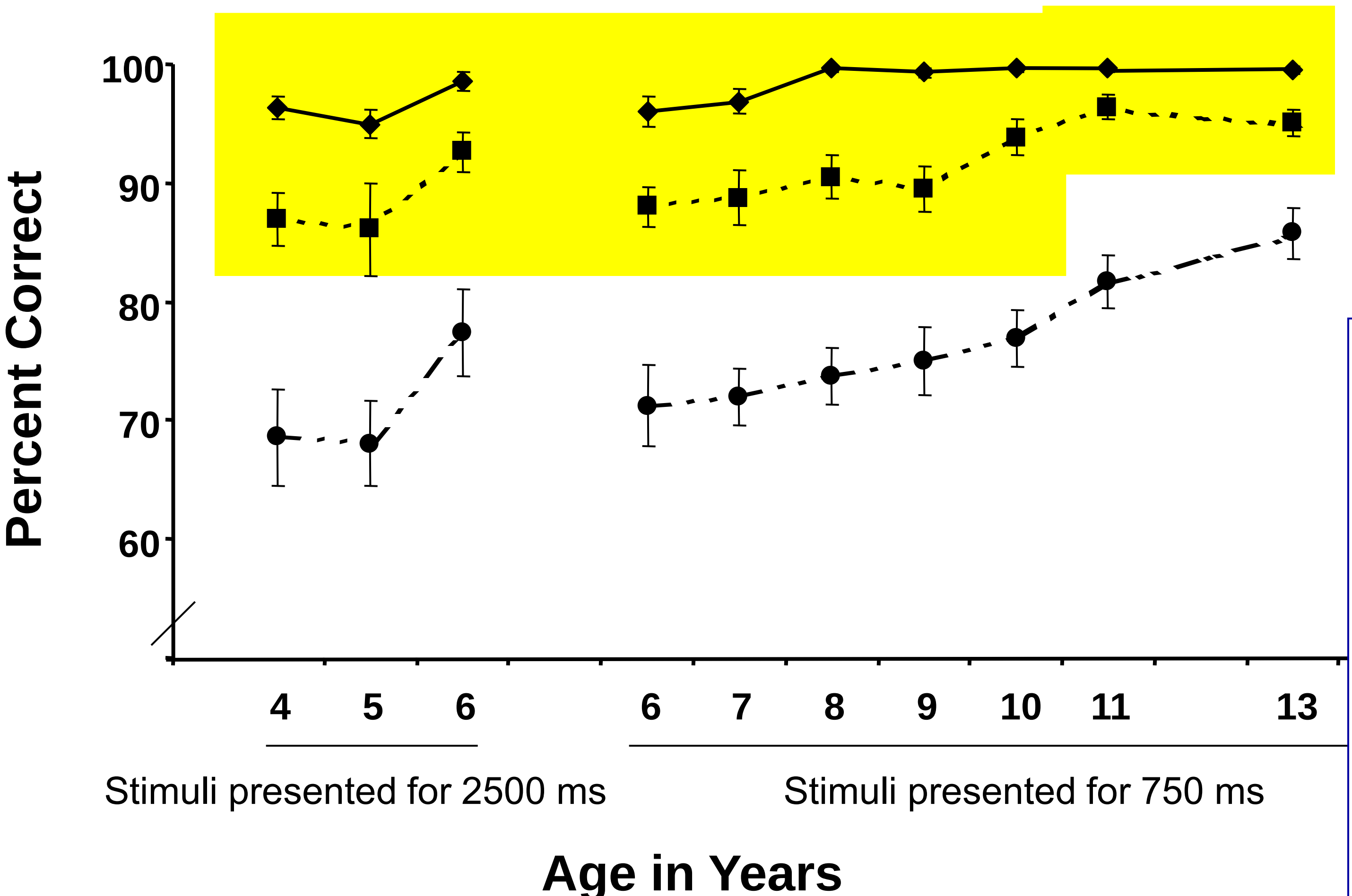


Dots-Mixed minus Dots-Congruent

10-year-olds



Hearts and Flowers Task: Accuracy



<u>At every age studied</u>, children were slower & less accurate on the Flower block than on the Heart block.

That effect is *completely* absent in adults.

Even over many trials, adults are as fast & as accurate on a block (a series) of Flower trials as they are on a block of Heart trials.

But that is not true of children. At every age tested, children are slower & less accurate on the Flower block than on the Heart block.

What's the difference between the Flower block and the Heart block?

The difference between the Flower and the Heart Blocks

Each block has only one rule ('press on the same [or opposite] side'). For Hearts, you need only do what comes naturally (pressing on the same side as the stimulus) but for Flowers you have to inhibit that and press on the opposite side. Consistently imposing that inhibitory demand on all trials takes a toll on children's behavior, but not adults.

It doesn’t matter whether Hearts are presented first or Flowers.

Wright & Diamond (2014)

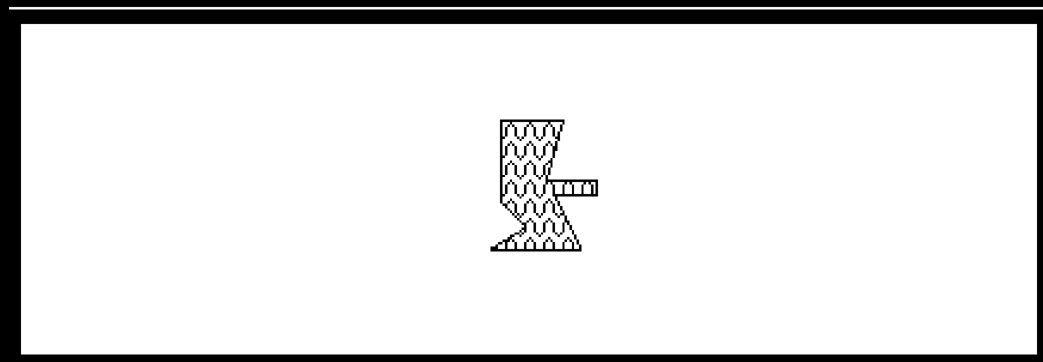
An effect of inhibitory load in children while keeping working memory load constant.

Frontiers in Psychology, 5, 1-9.

(Special issue on Development of Executive Function during Childhood)

Even very young children have excellent memories. Inhibition is a far greater challenge for them than holding information in mind.

Abstract Figures - Center Presentation



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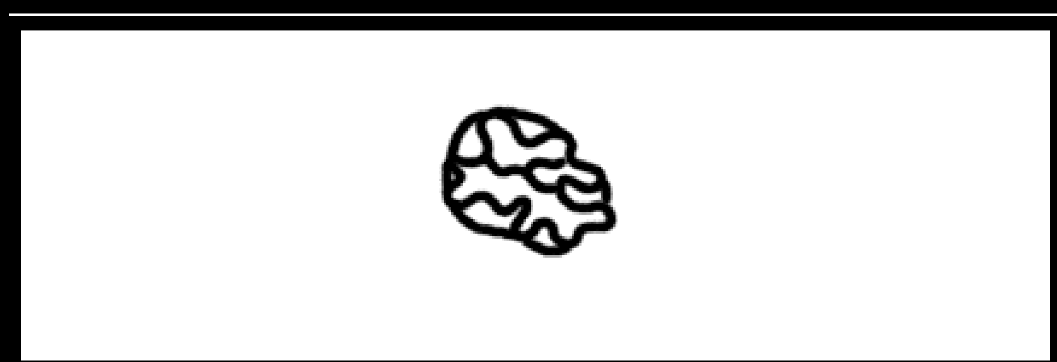
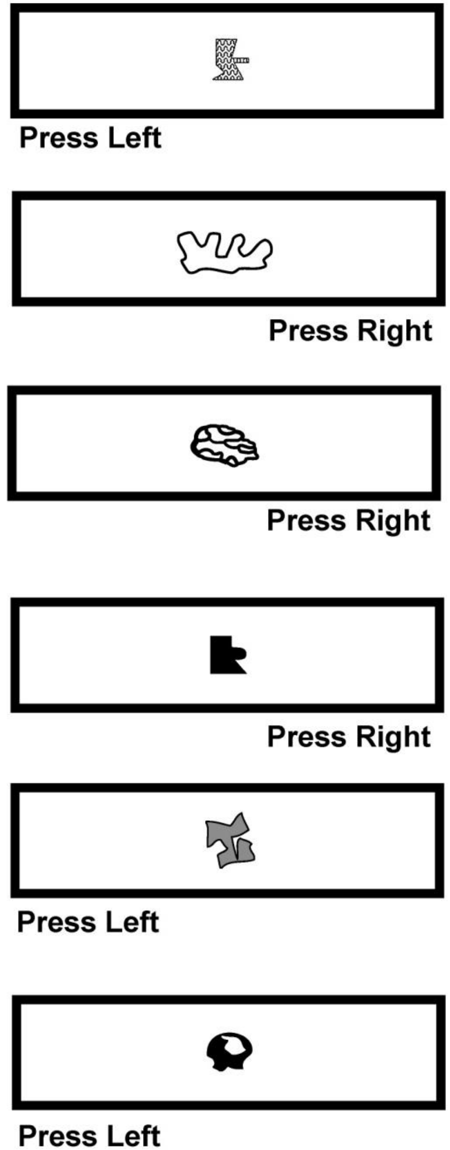


Push Right

ABSTRACT SHAPES TEST: A MEMORY LOAD TASK



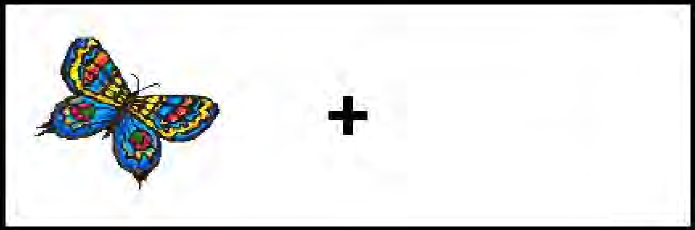
Increasing demands on INHIBITION (the Flower block vs. the Heart block) are more difficult for young children (ages 4-9 years) than increasing demands on how much information they must hold in mind (2 to 6 items).

The opposite is true for us adults:

Increasing MEMORY demands is *far* more difficult for us than increasing demands on inhibition.

We adults may not appreciate how inordinately difficult inhibition is for young children because it is so much less taxing for us.

Pictures – Congruent



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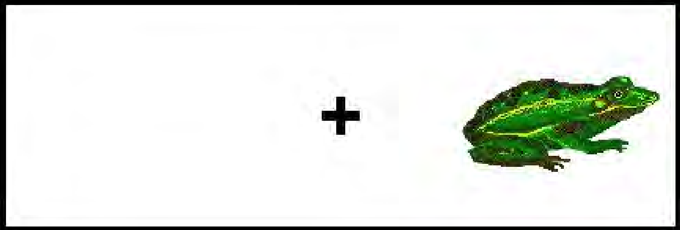

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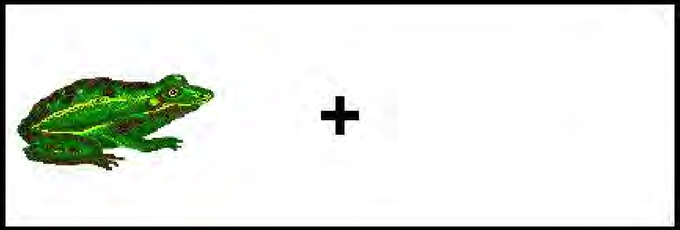
Pictures – Incongruent



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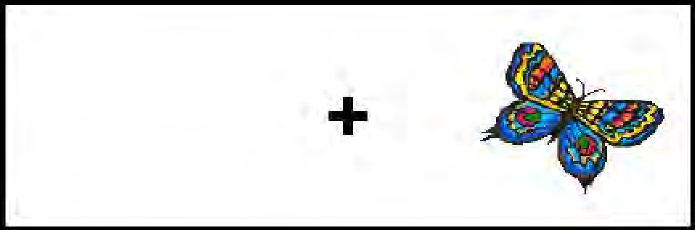


Push Left

A Classic Simon Task

A Simon Task

The Rules are:

Whenever you see a BUTTERFLY, press LEFT.

Whenever you see a FROG, press RIGHT.

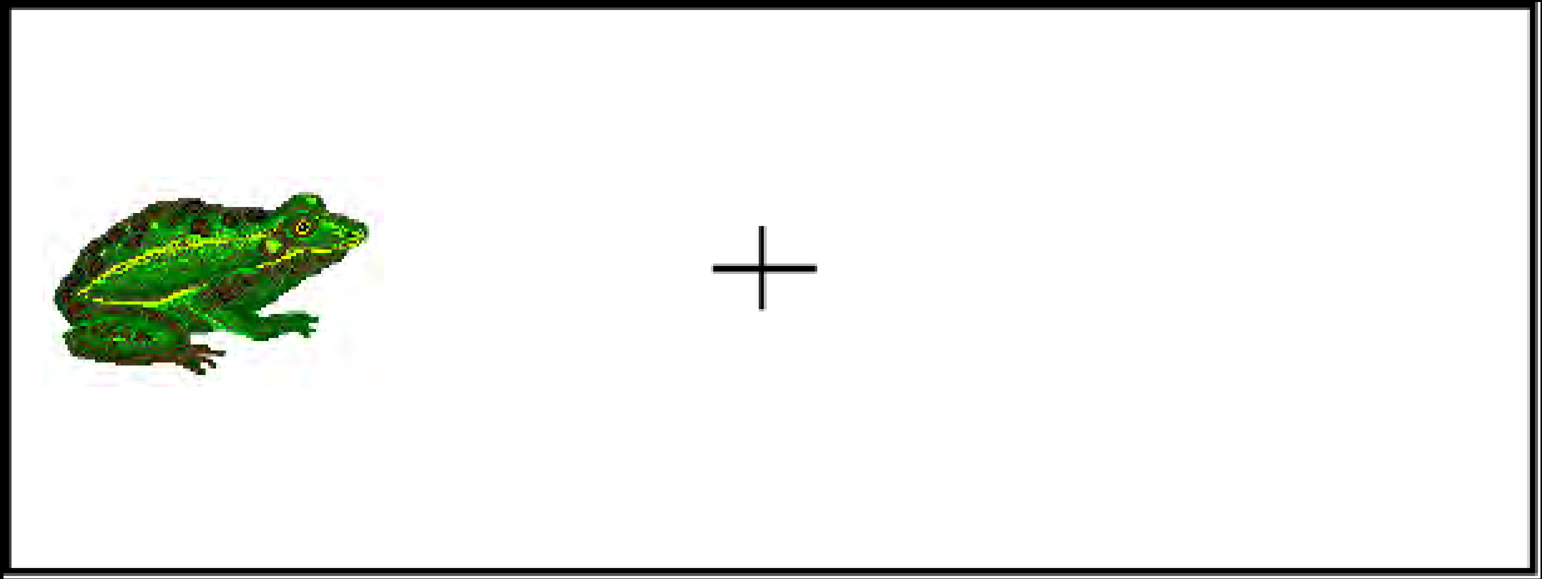
This is for Real

Remember:

BUTTERFLY - LEFT

FROG - RIGHT

+



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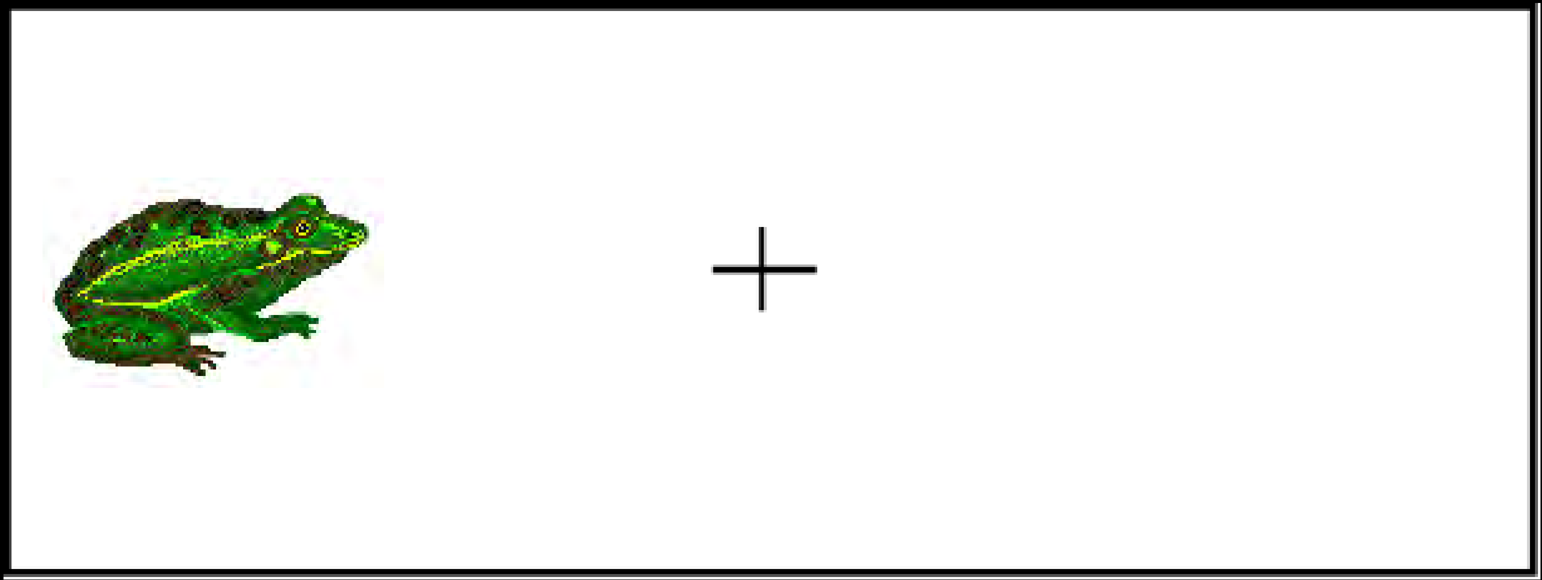

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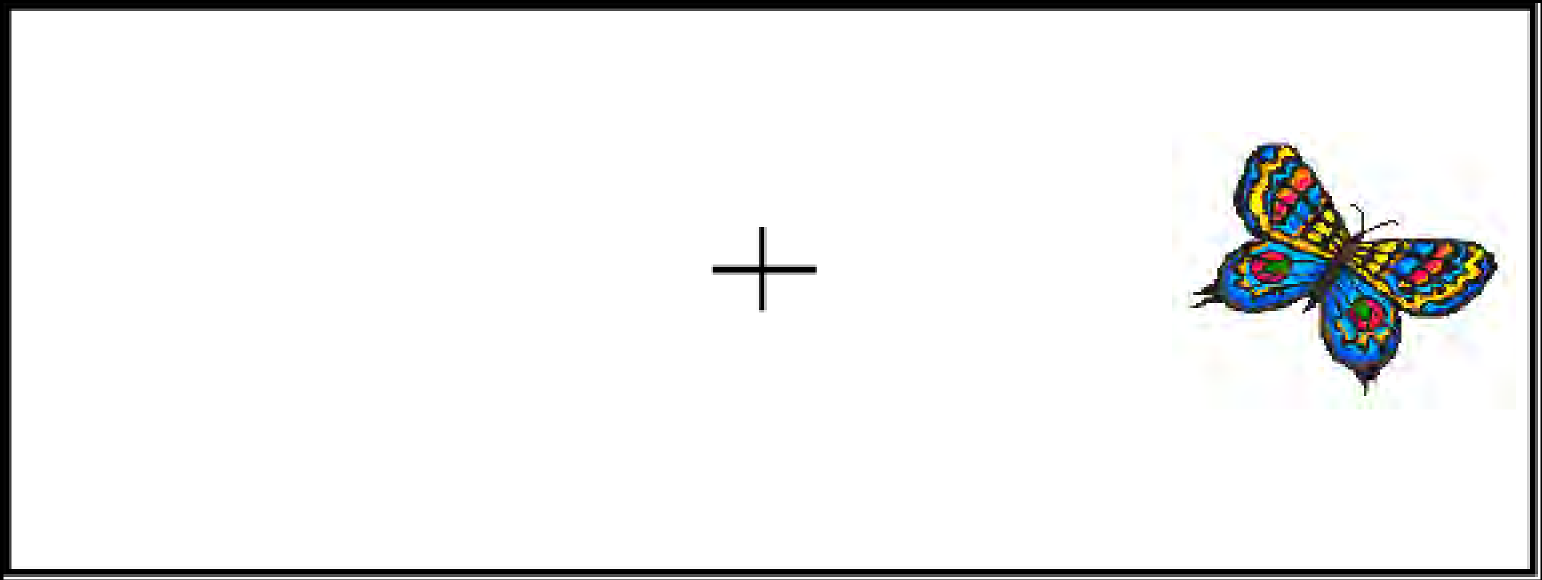

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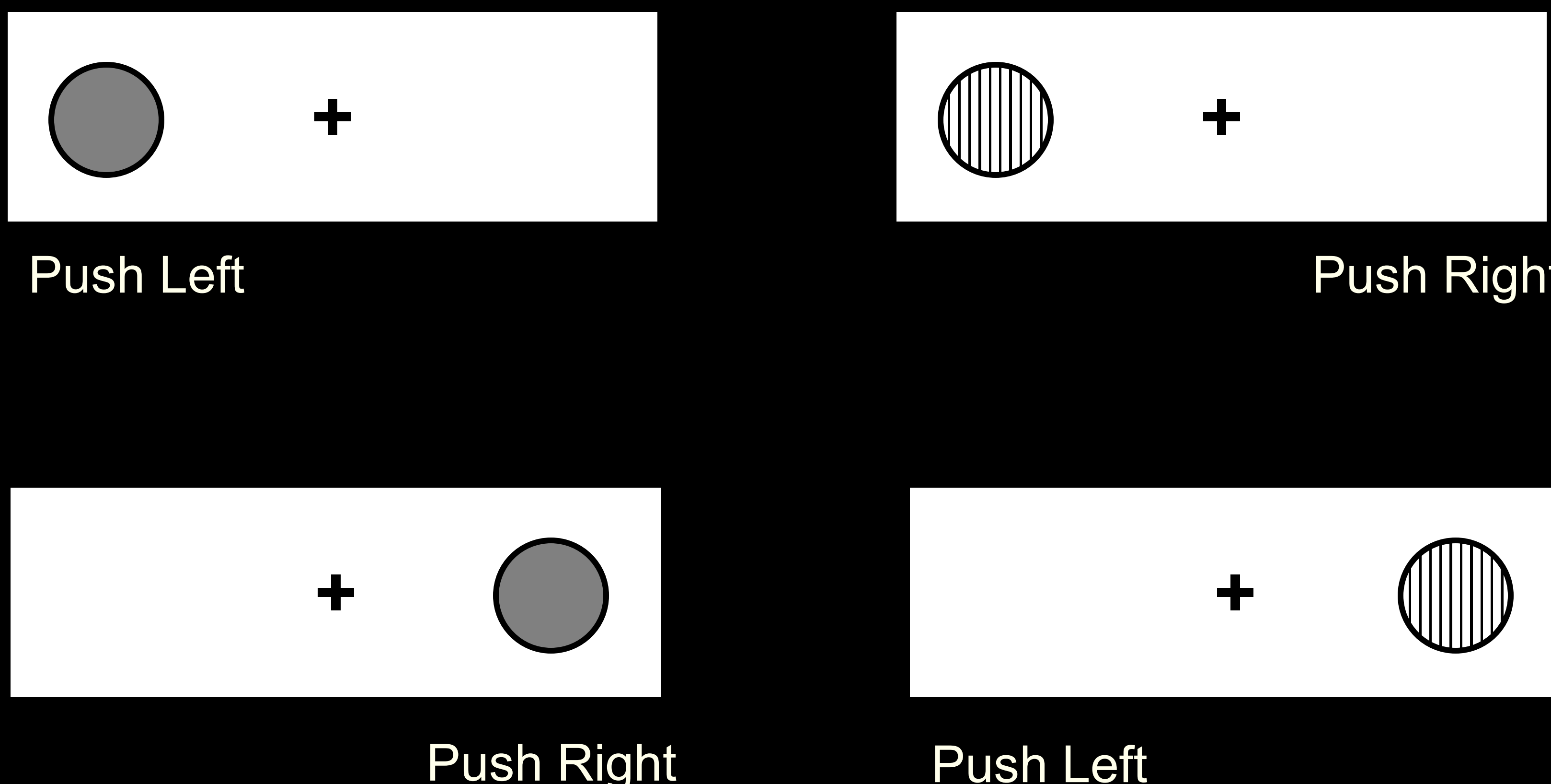
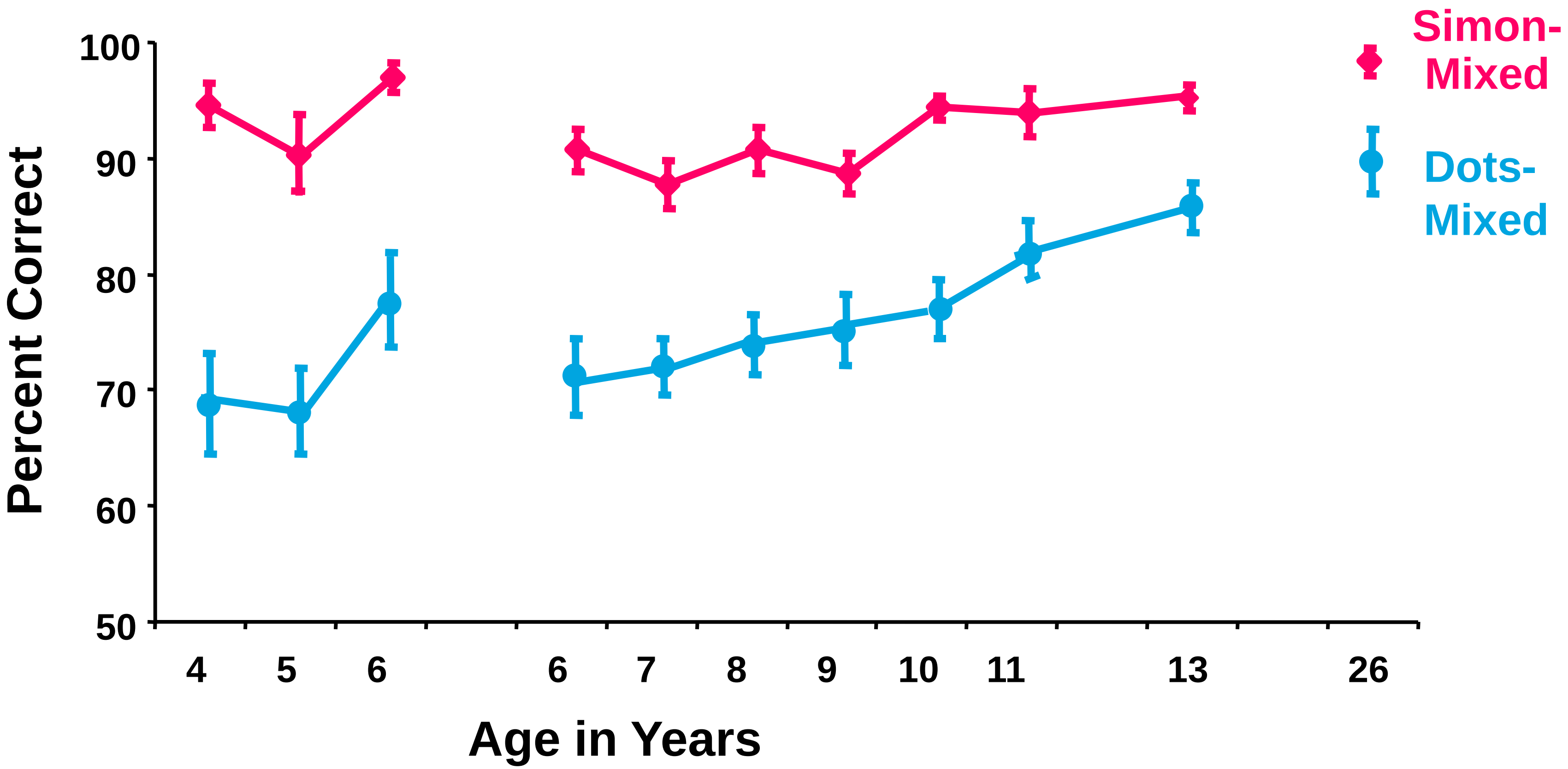
Dots - Congruent

Dots - Incongruent



Comparison of Mixed Conditions of Hearts-Flowers and Simon in Percentage of Correct Responses



Stimuli presented for 2500 ms

Stimuli presented for 750 ms

Davidson et al. (2006). Neuropsychologia, 44, 2037 - 2078

Why?

(Both Dots-Mixed & the Simon task require holding 2 rules in mind & making Incongruent as well as Congruent responses.)

Dots (or Hearts and Flowers):

requires the extra step of
mentally translating same/ opposite
into Left or Right.

It requires integrating object identity &
object location information.

It requires Working Memory.

– – – – – – – – – – – – – –

The Simon task

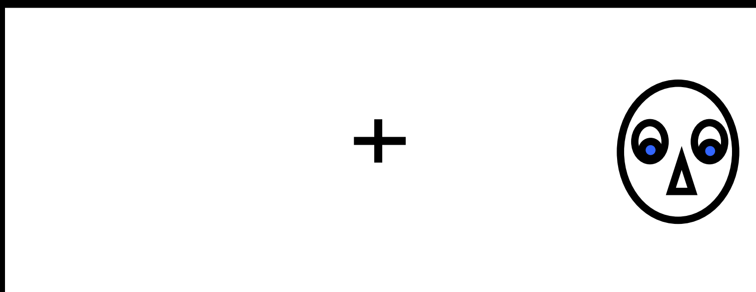
only requires holding the 2 rules in mind.

It requires short-term memory.

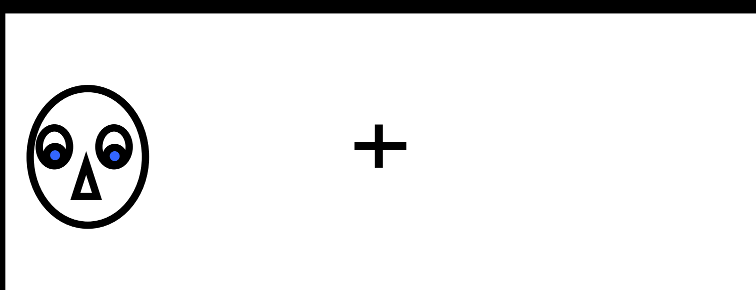
Working Memory & just holding information in mind (Short-Term Memory) are distinct.

Eyes Looking (a control task)

Congruent

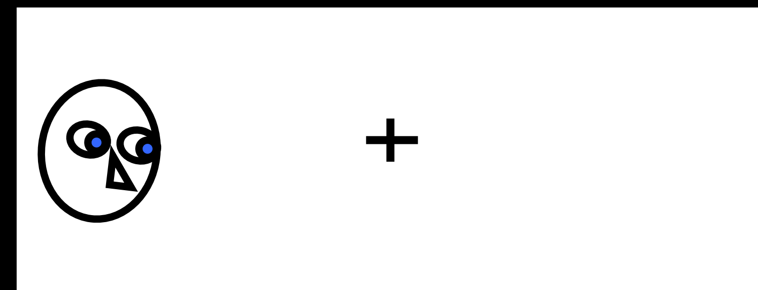


Push Right

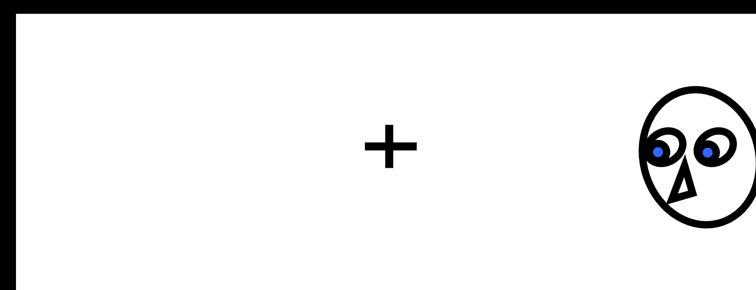


Push Left

Incongruent



Push Right



Push Left

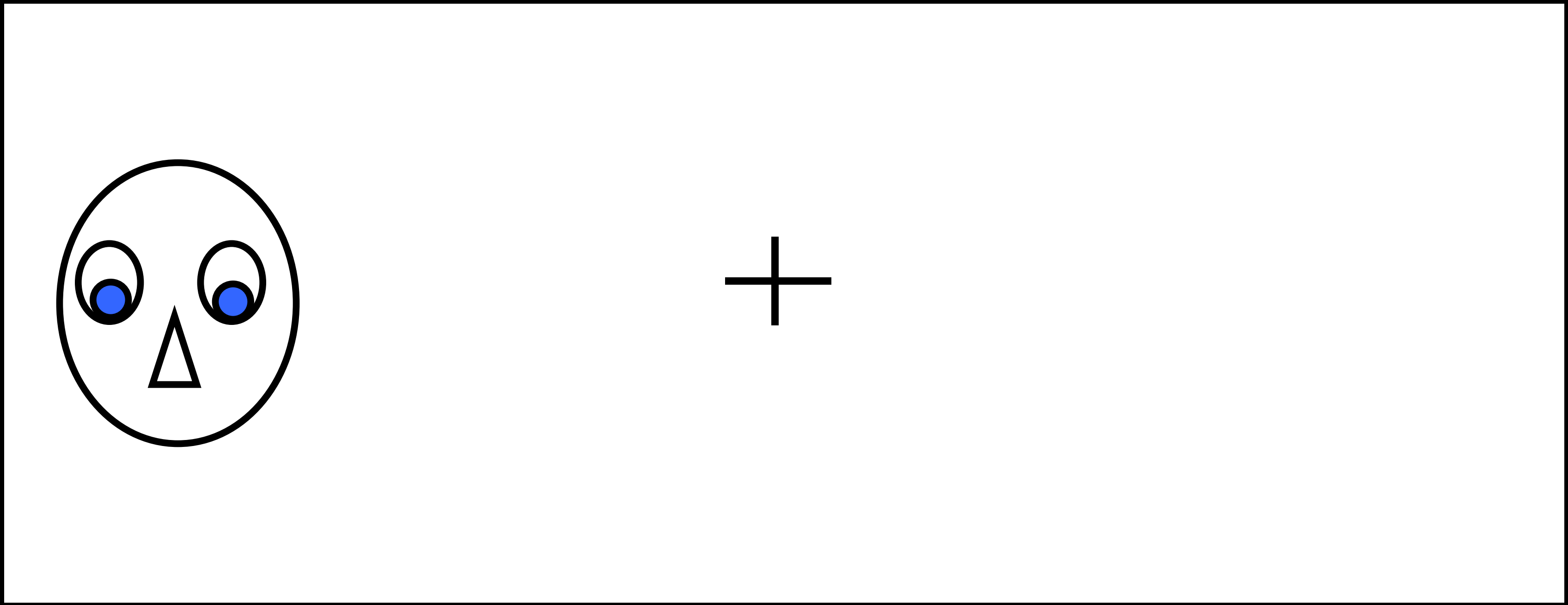
EYES – MIXED

Now sometimes the eyes will be looking straight down and sometimes they will be looking diagonally to the opposite side.

Remember:

PRESS WHERE THE EYES ARE LOOKING

+



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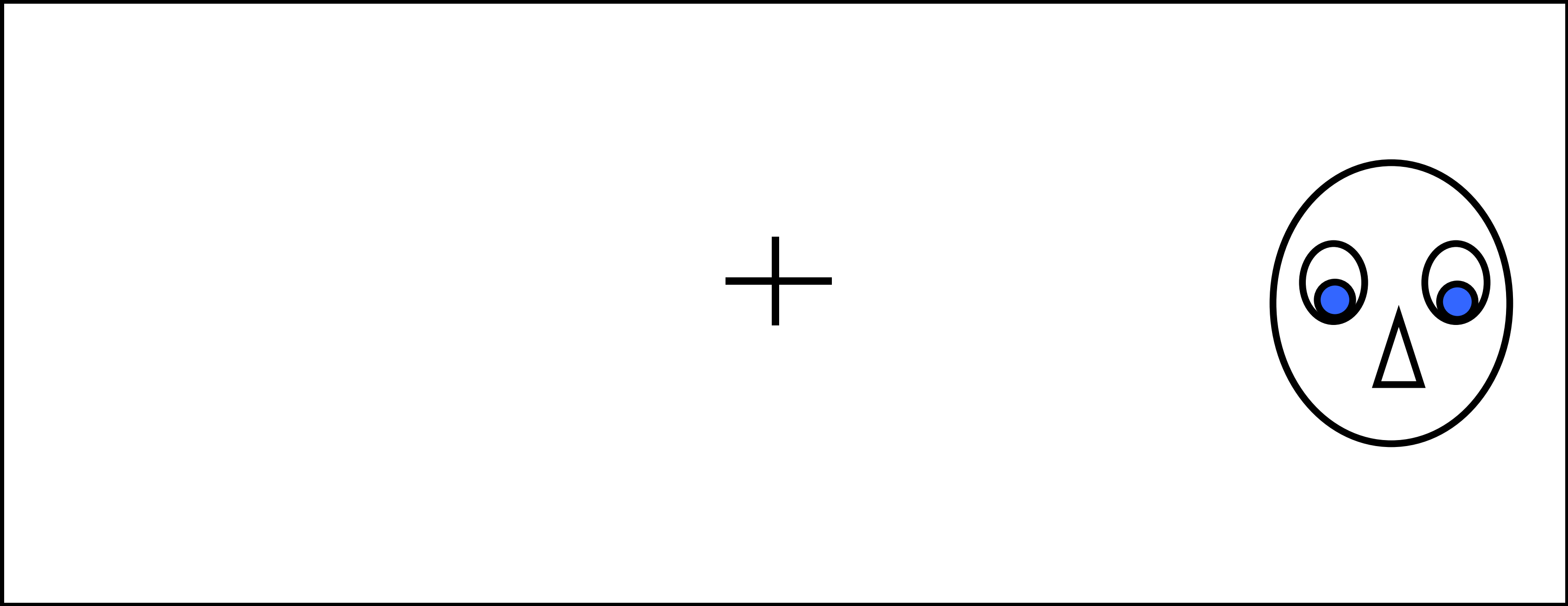

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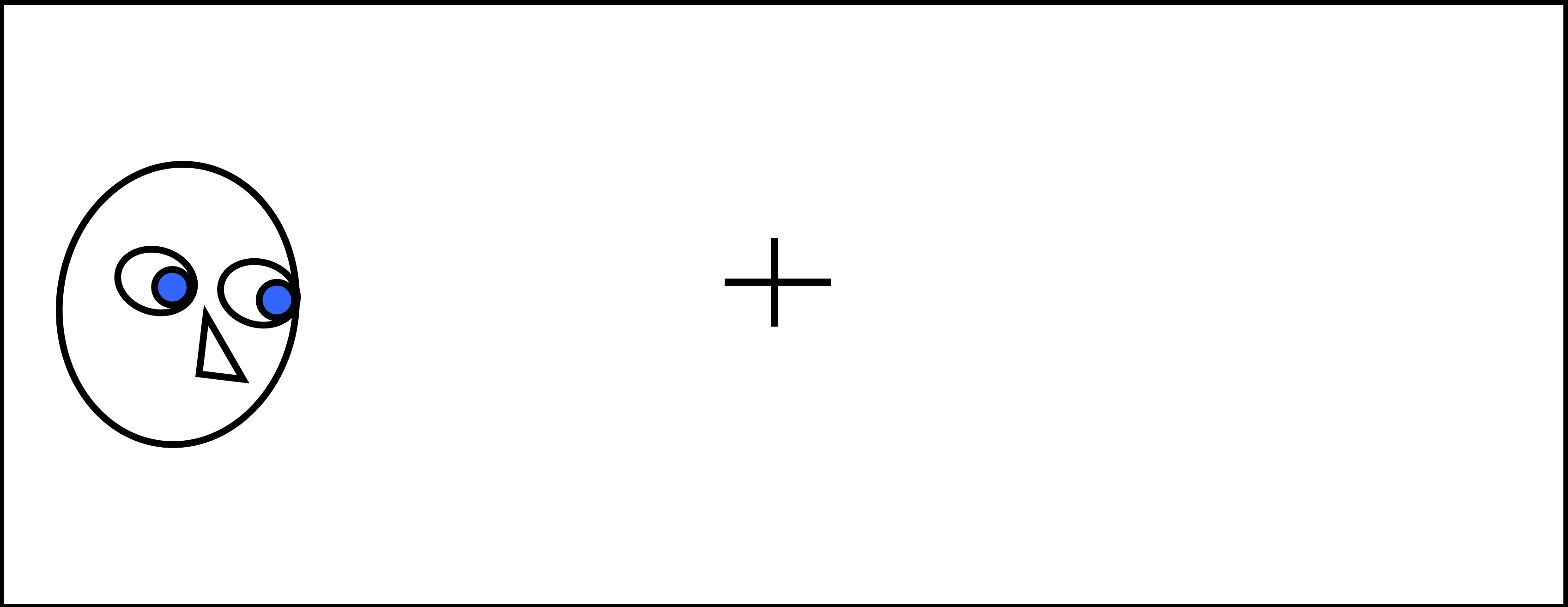

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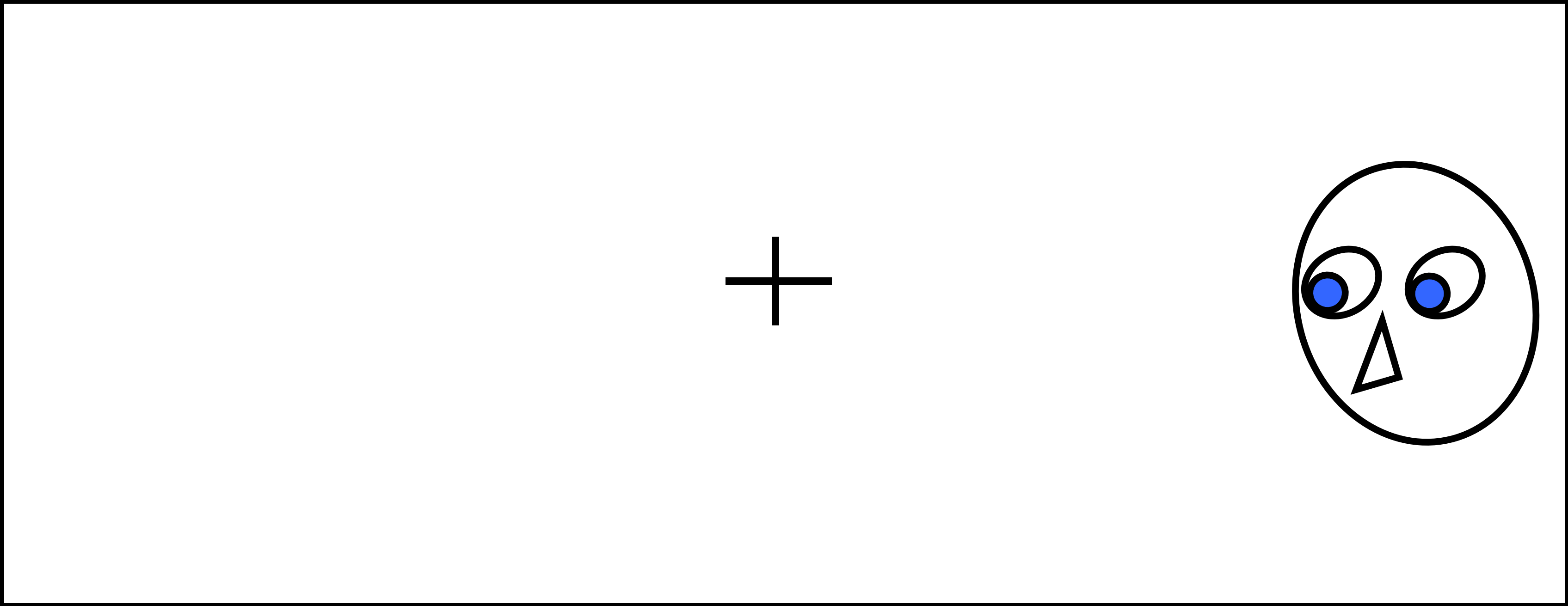
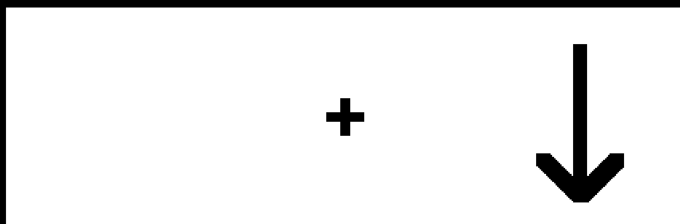
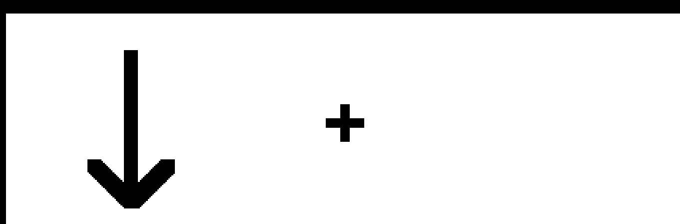


What's ability does Eyes Looking require?

Arrows - Congruent

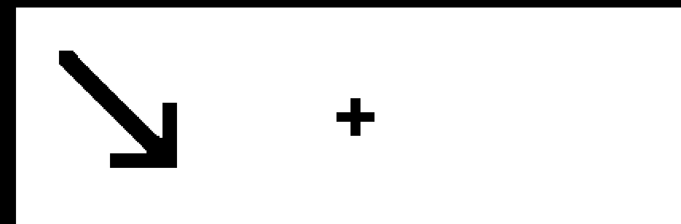


Push Right



Push Left

Arrows - Incongruent



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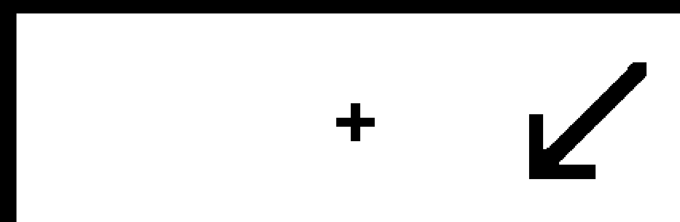
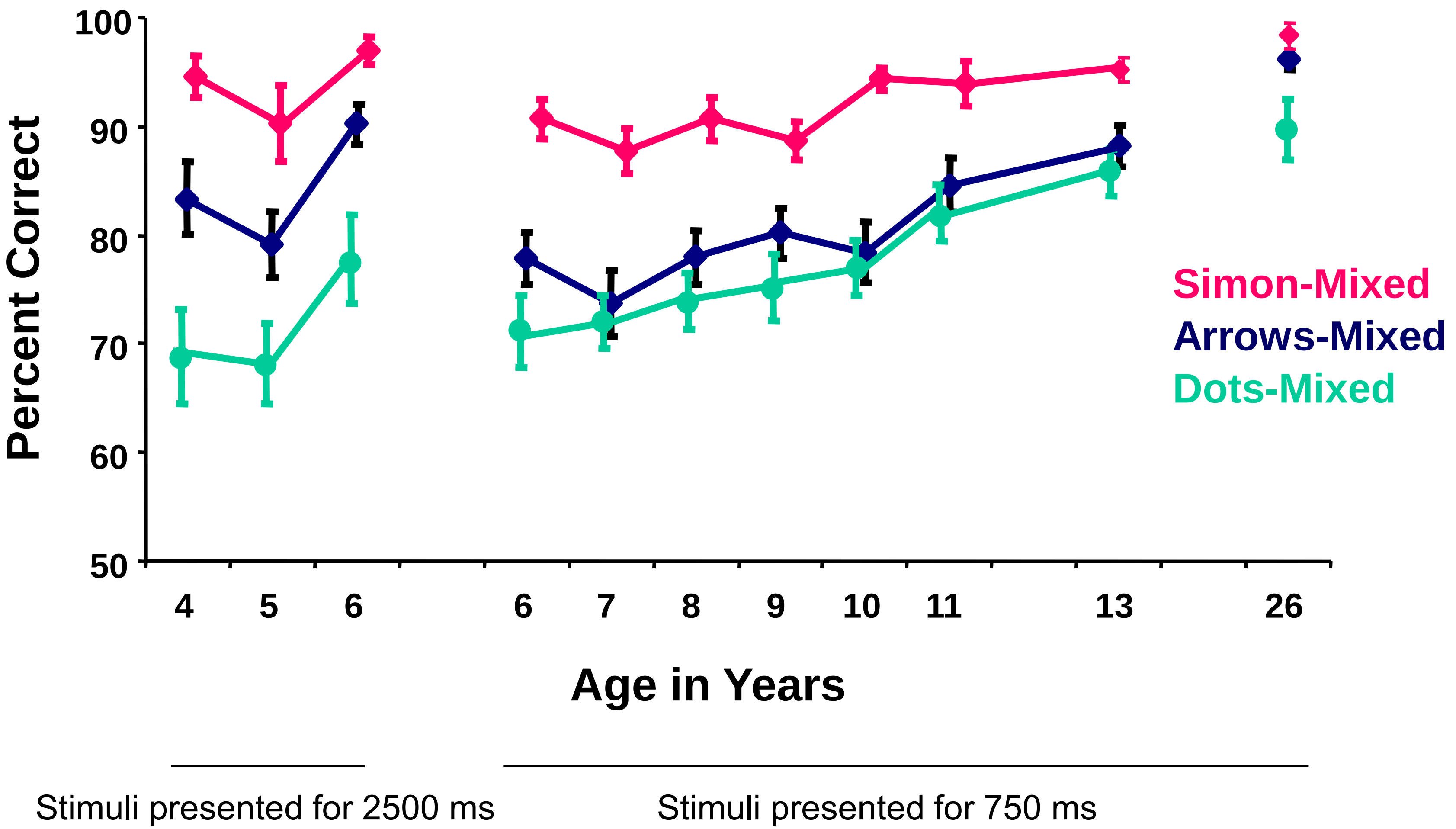
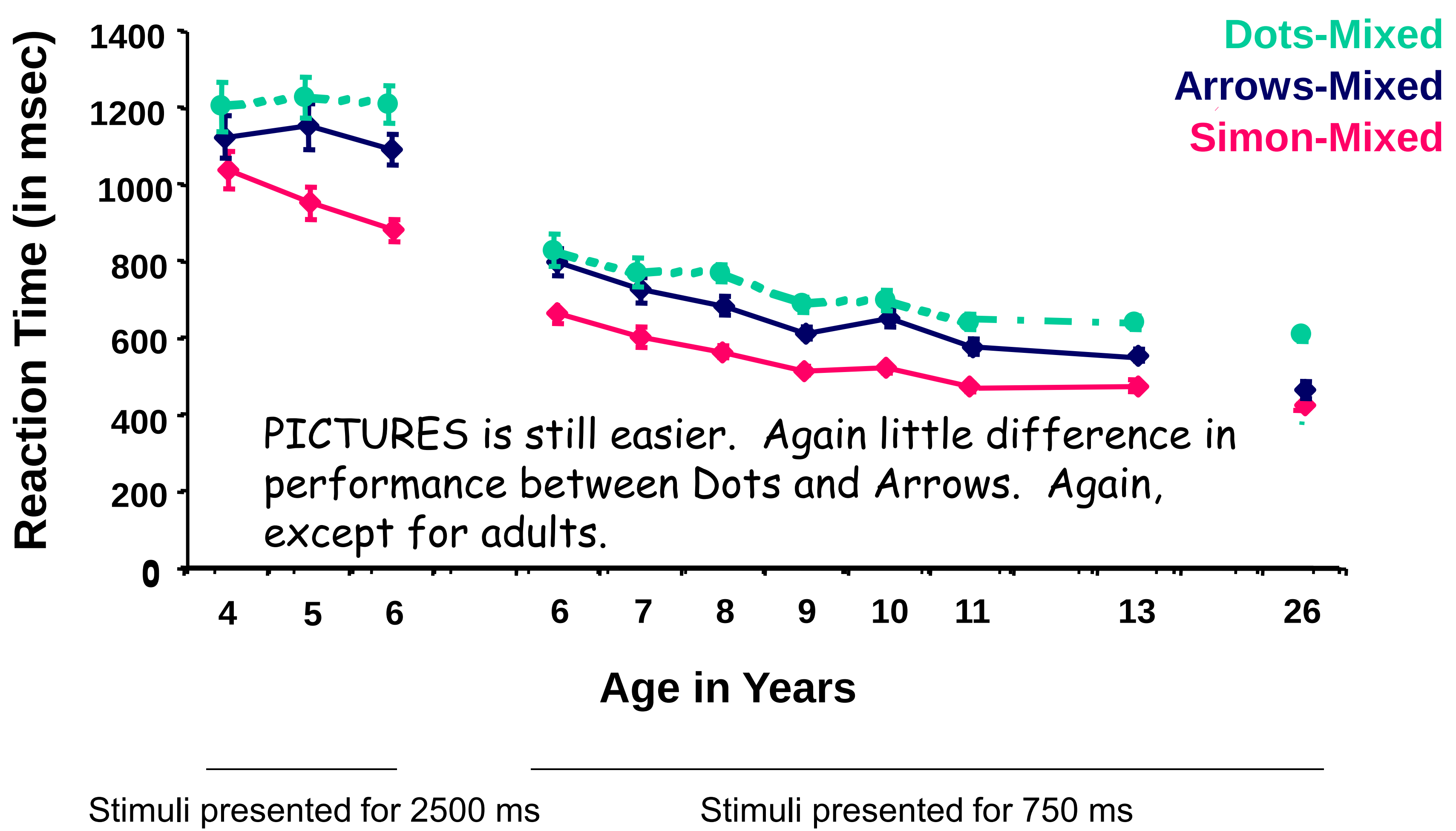


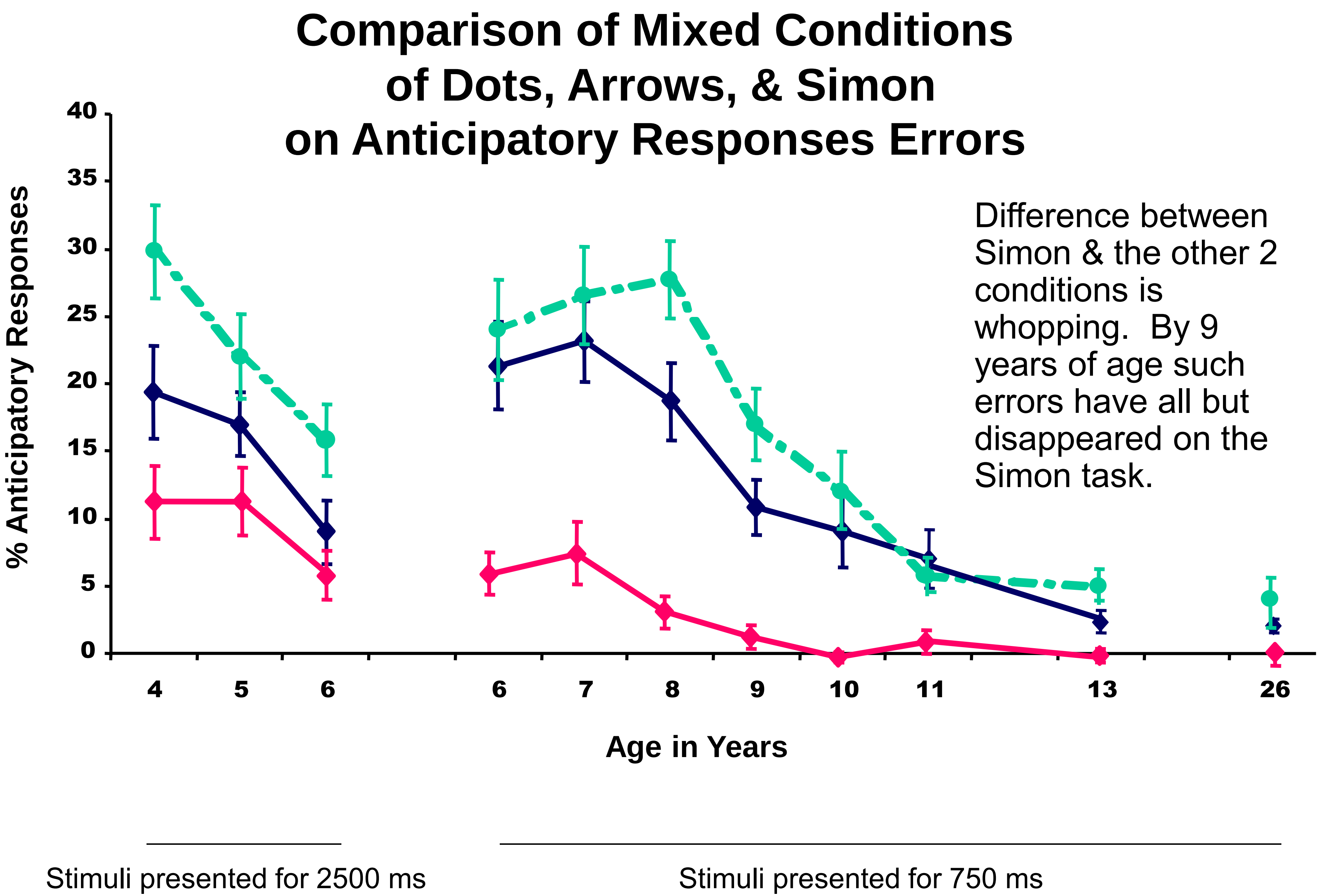
Push Left

Comparison of Mixed Conditions of Dots, Arrows, & Simon in Percentage of Correct Responses



Comparison of Mixed Conditions of Dots, Arrows, & Simon in Speed of Responding




Comparison of Mixed Conditions
of Dots, Arrows, & Simon
on Anticipatory Responses Errors
% Anticipatory Responses
40
35
30
25
20
15
10
5
0
Difference between Simon & the other 2 conditions is whopping. By 9 years of age such errors have all but disappeared on the Simon task.
4
5
6
6
7
8
9
10
11
13
26
Age in Years
Stimuli presented for 2500 ms
Stimuli presented for 750 ms

Spatial Stroop

First, the easy condition.

Press on the side where the arrow is (regardless of which way the arrow is pointing)

Now the more difficult condition.

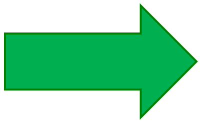
Press where the arrow is pointing

(regardless of which side the arrow is on)

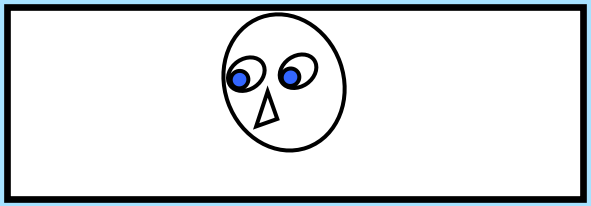
One Test from the Amsterdam Neuro-psychological Battery (ANT)

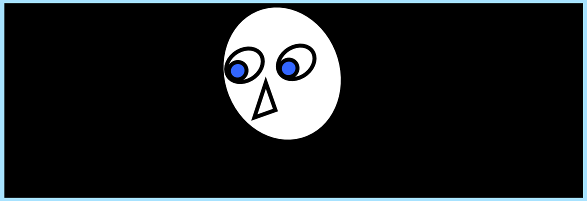
Press in the direction the green arrow is pointing, but…

Press in the direction opposite to where the purple arrow is pointing.



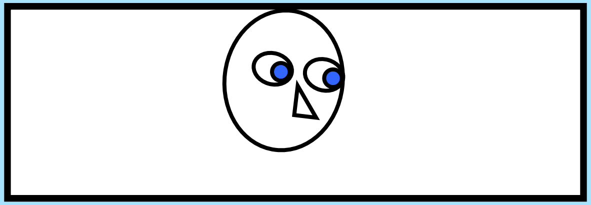
EYES - CENTER

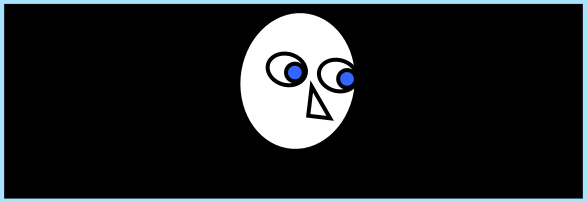




Press Left

Press Right

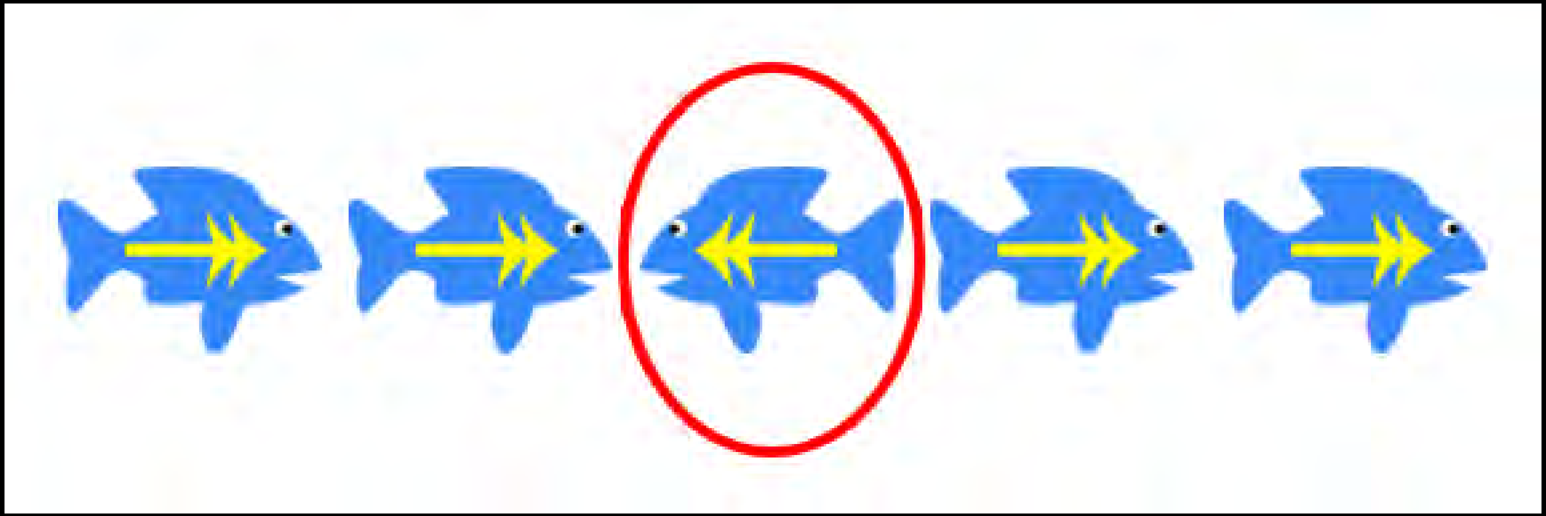


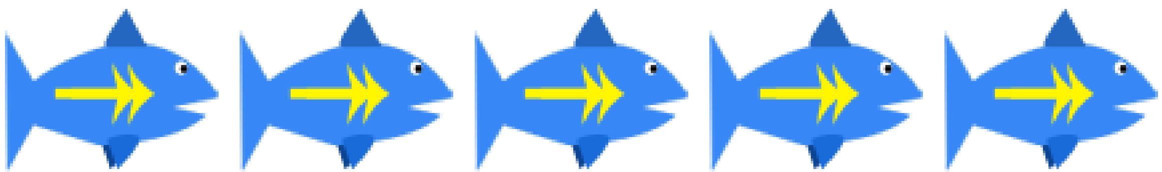


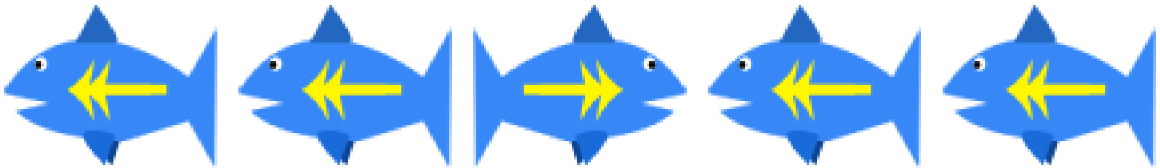
Press Right

Press Left

Flanker Task

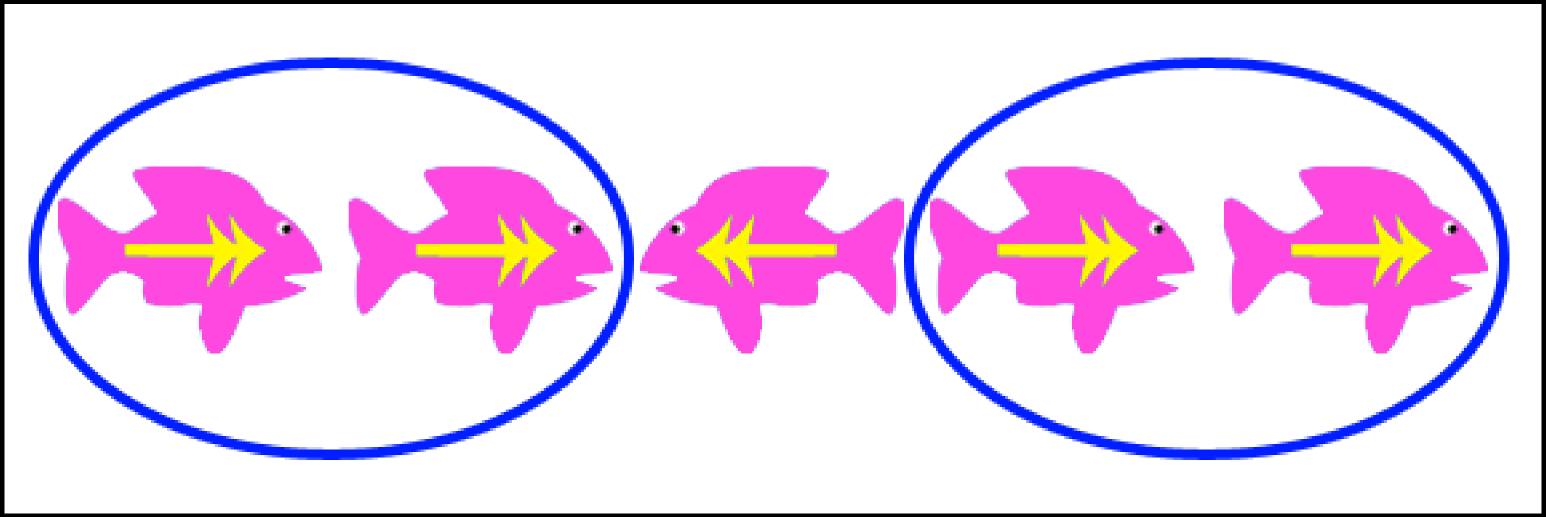


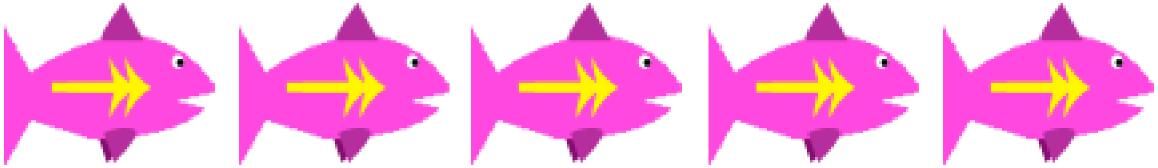


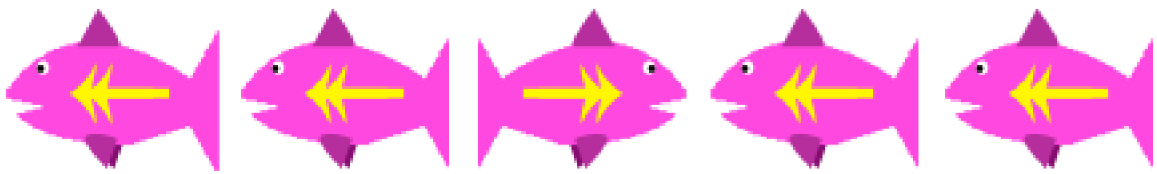


Reverse Flanker

attend to the flankers

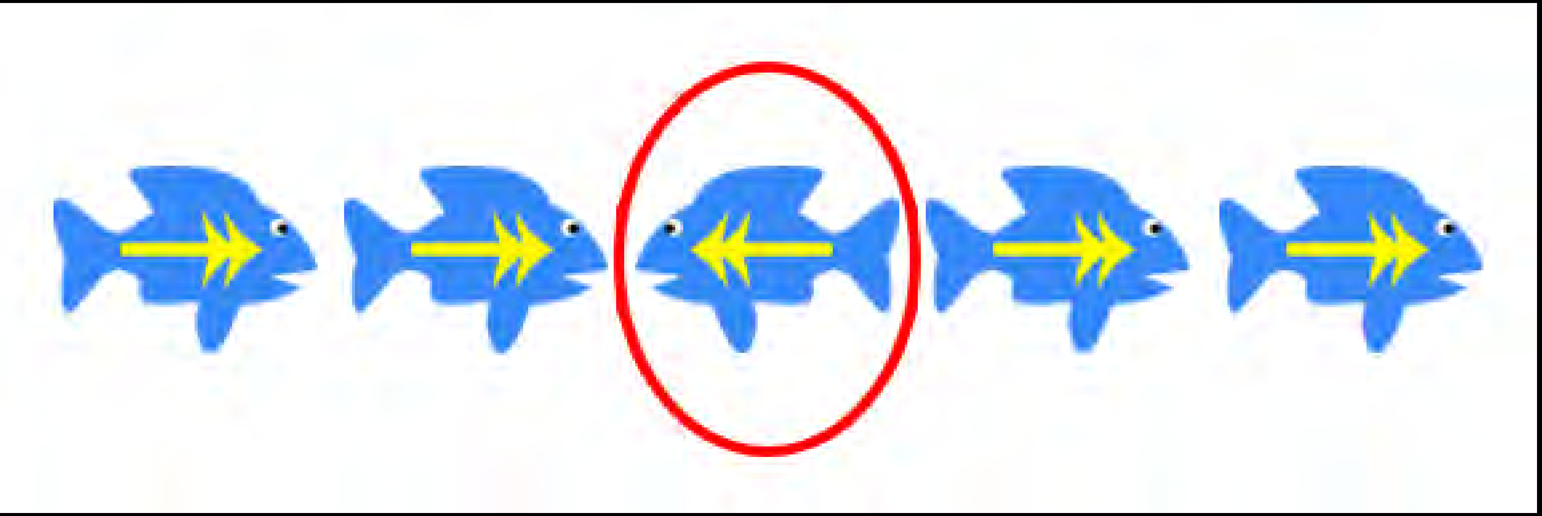




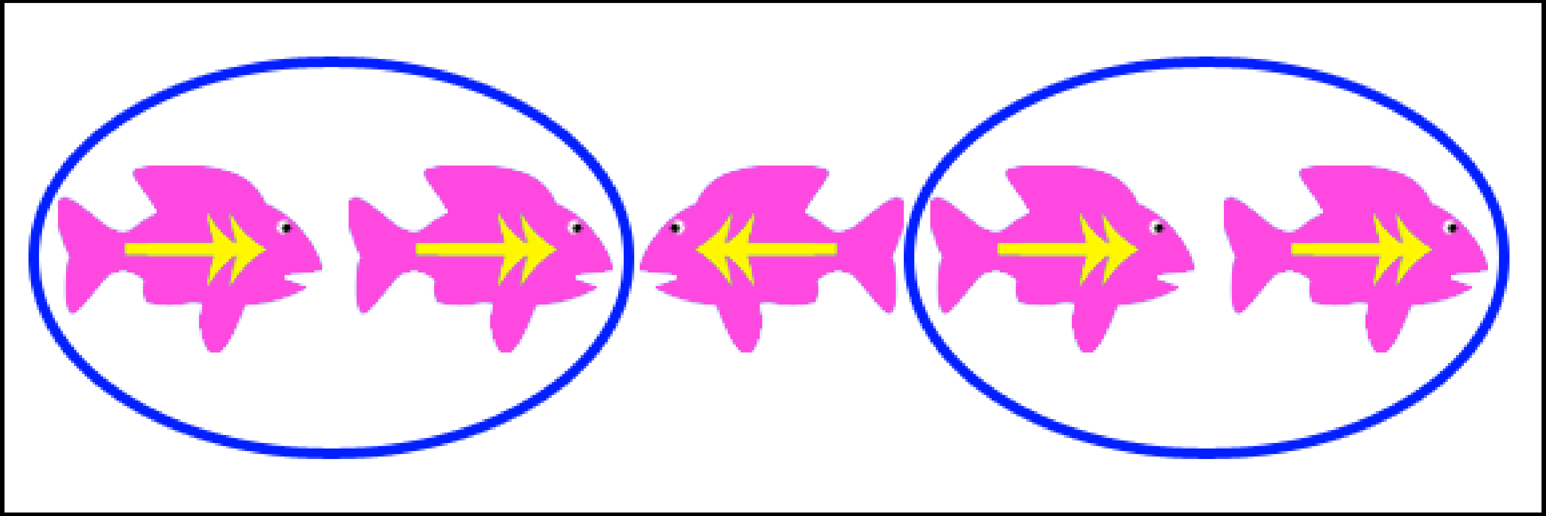


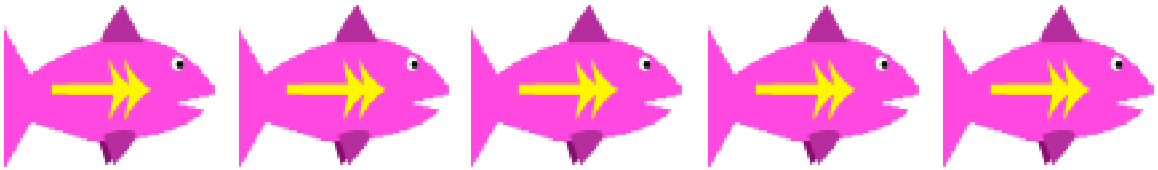
Mixed Flanker Block

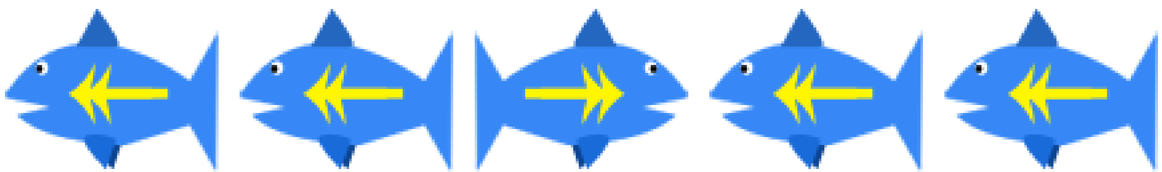
remember: Blue - inside

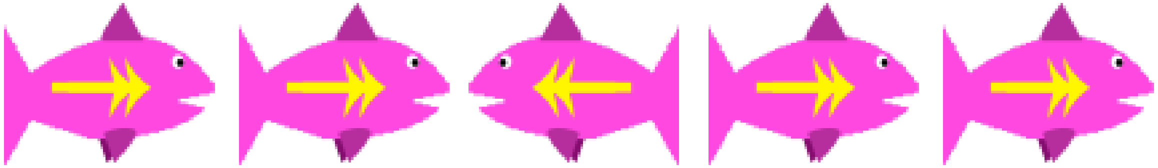


Pink - Outside

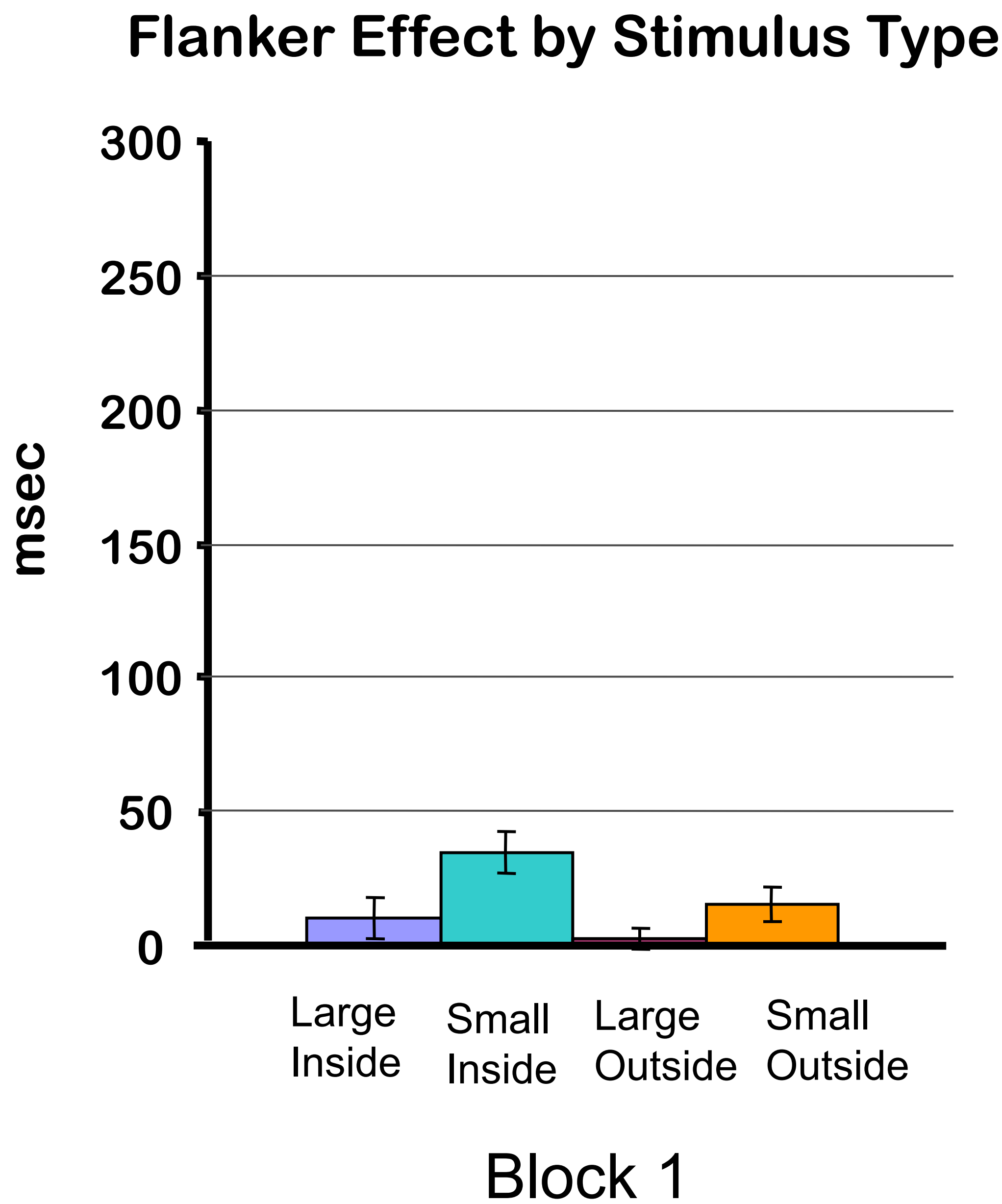








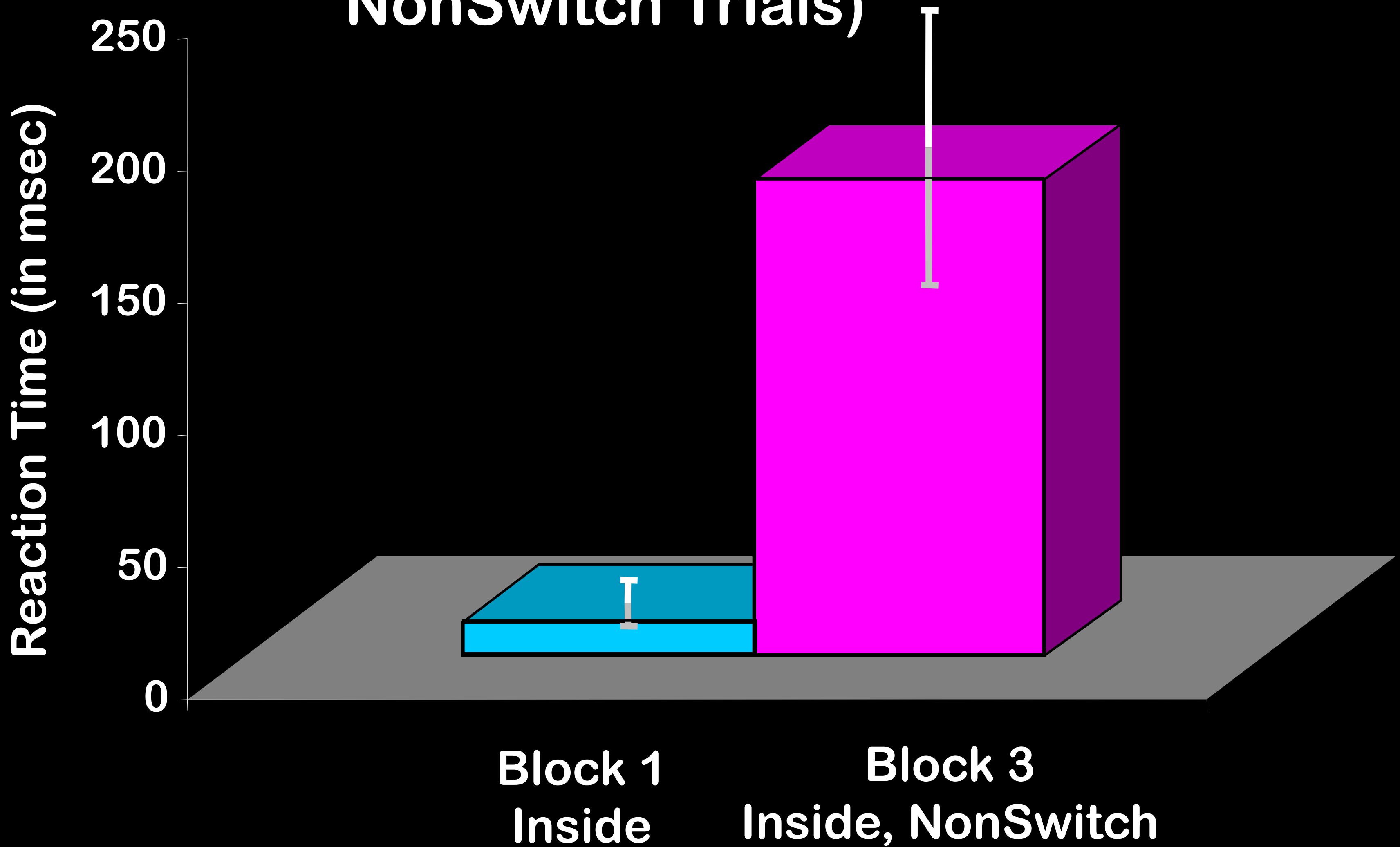

GREAT JOB!



The Flanker Effect has been replicated many times, but it is small & quite sensitive to stimulus parameters.

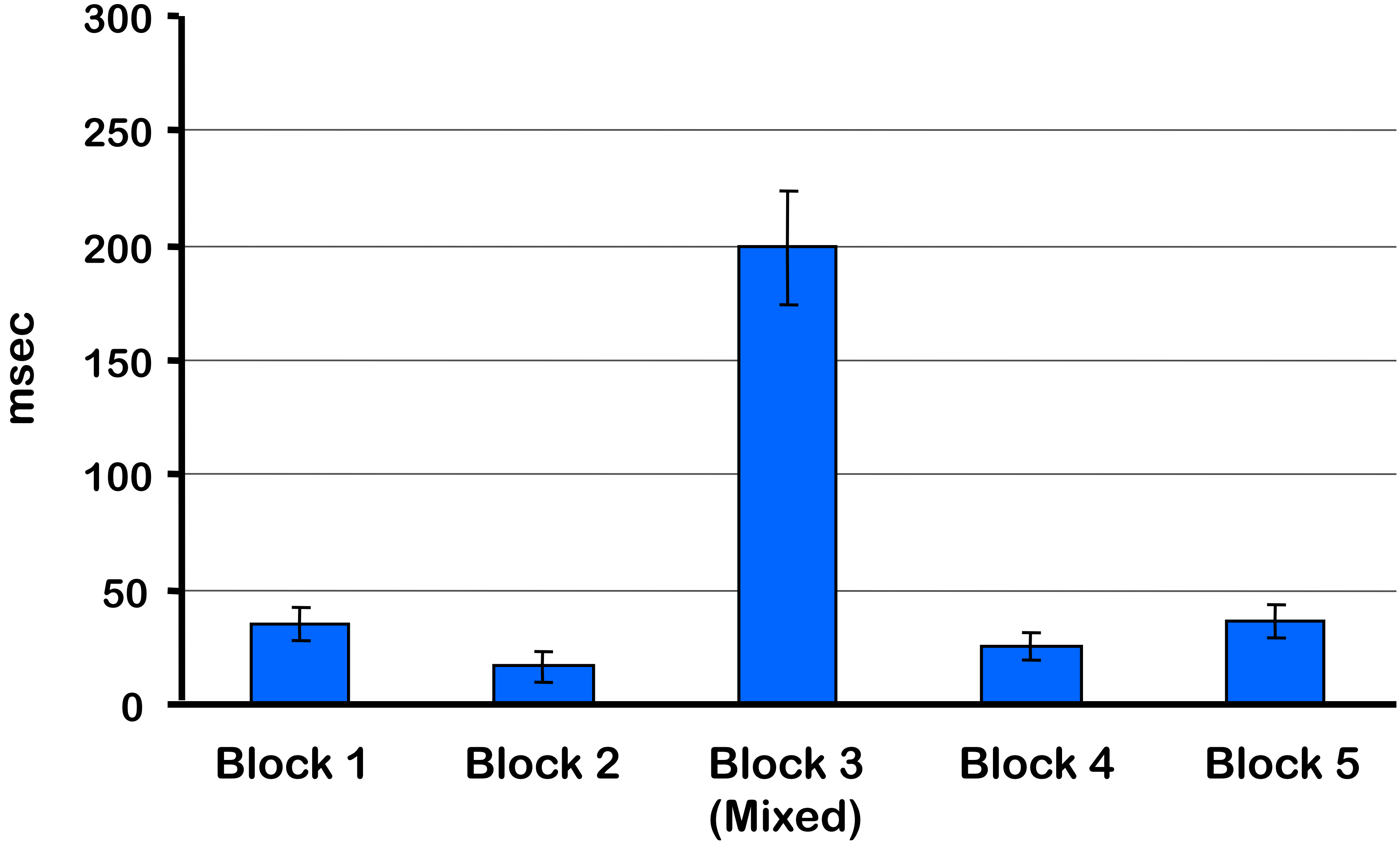
For instance, here you can see that there is a Flanker Effect for both standard (Inside) Flanker and for reverse (Outside) Flanker, but the effect essentially disappears when the stimuli are large.

Flanker Effect in the Standard Condition (Block 1 – Inside) vs. in a Switching Context (Block 3 – Inside, NonSwitch Trials)



Flanker Effect by Block (Standard vs. Mixed)

INSIDE Non-Switch trials ONLY

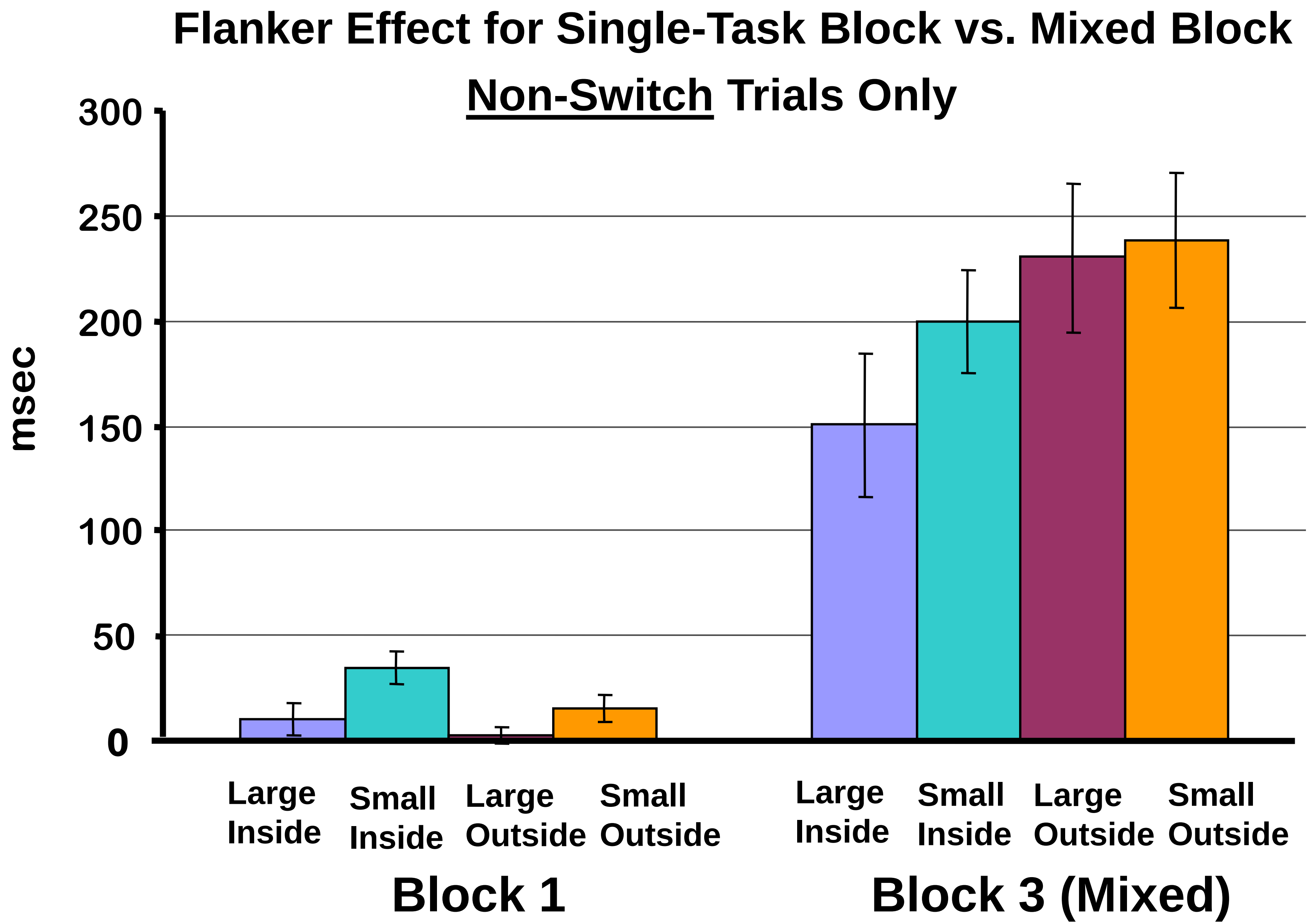


This dramatic increase in Flanker Effect is **NOT** due to practice effects.
And, the order in which the Inside Block was received had no significant effect.

Not only is

1. **the Flanker effect far LARGER**

2. **It is far more ROBUST in the face of variations in stimulus characteristics**



Regardless of stimulus size, or whether a trial has an Inside or Outside target, the Flanker Effect is far larger (6-10 times larger) when standard and reverse Flanker trials are intermixed

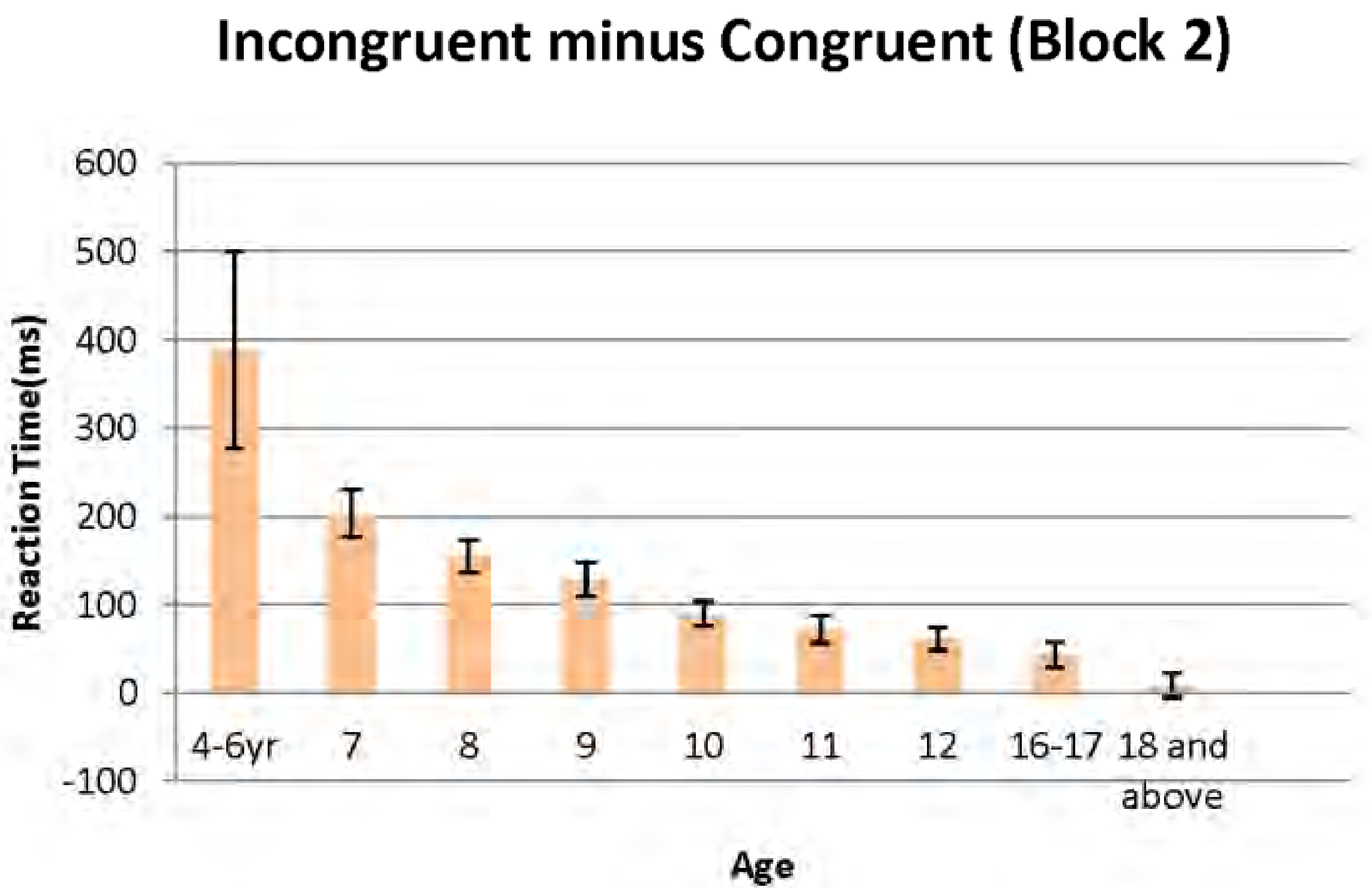
Dramatically Larger Flanker Effects

Sarah Munro, Cecil Chau, Karine Gazarian,

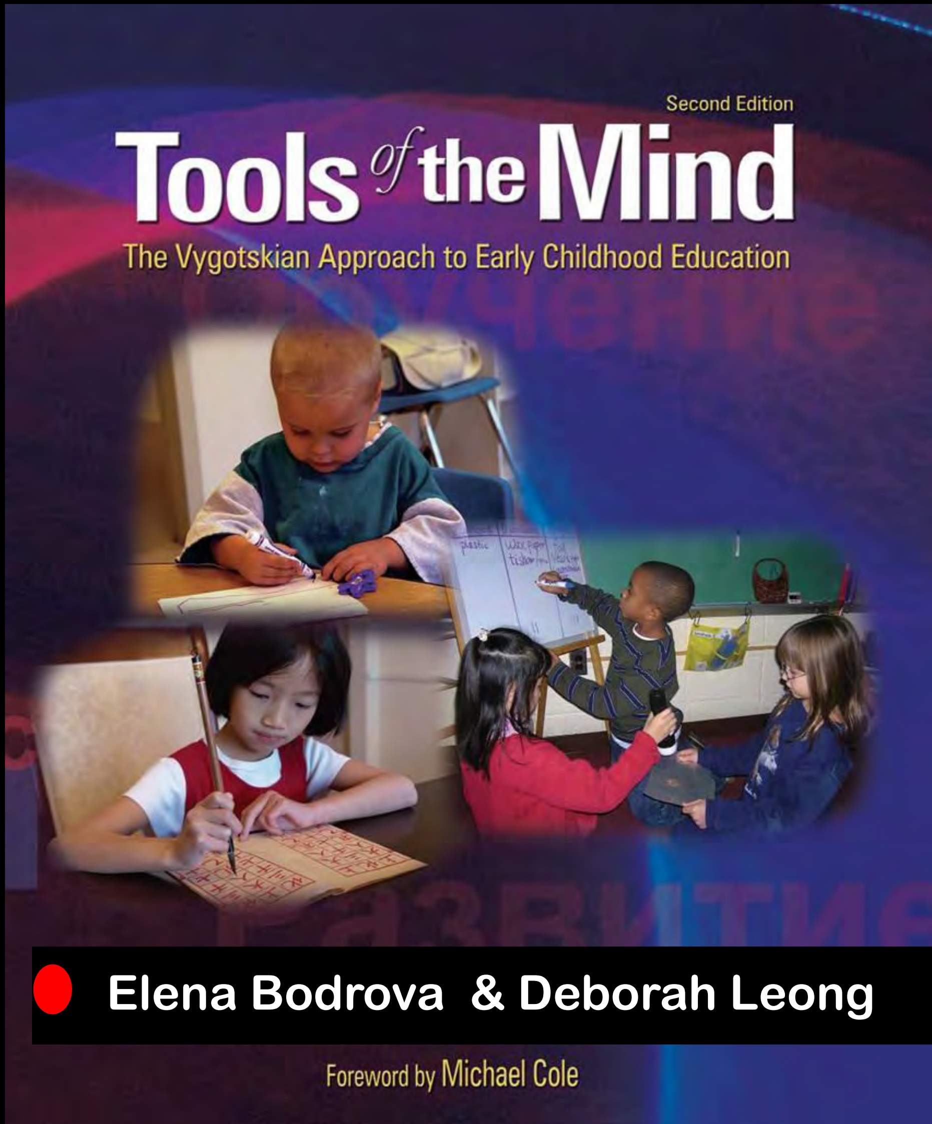
& Adele Diamond

Presented at the Cognitive Neuroscience Society Annual Meeting, San Francisco, CA, April 9, 2006.

1. the Flanker effect far LARGER
2. It is far more ROBUST in the face of variations in stimulus characteristics
3. Developmental progression extends far LONGER


Incongruent minus Congruent (Block 2)
Reaction Time(ms)
600
500
400
300
200
100
0
-100
4-6yr
7
8
9
10
11
12
16-17
18 and above
Age

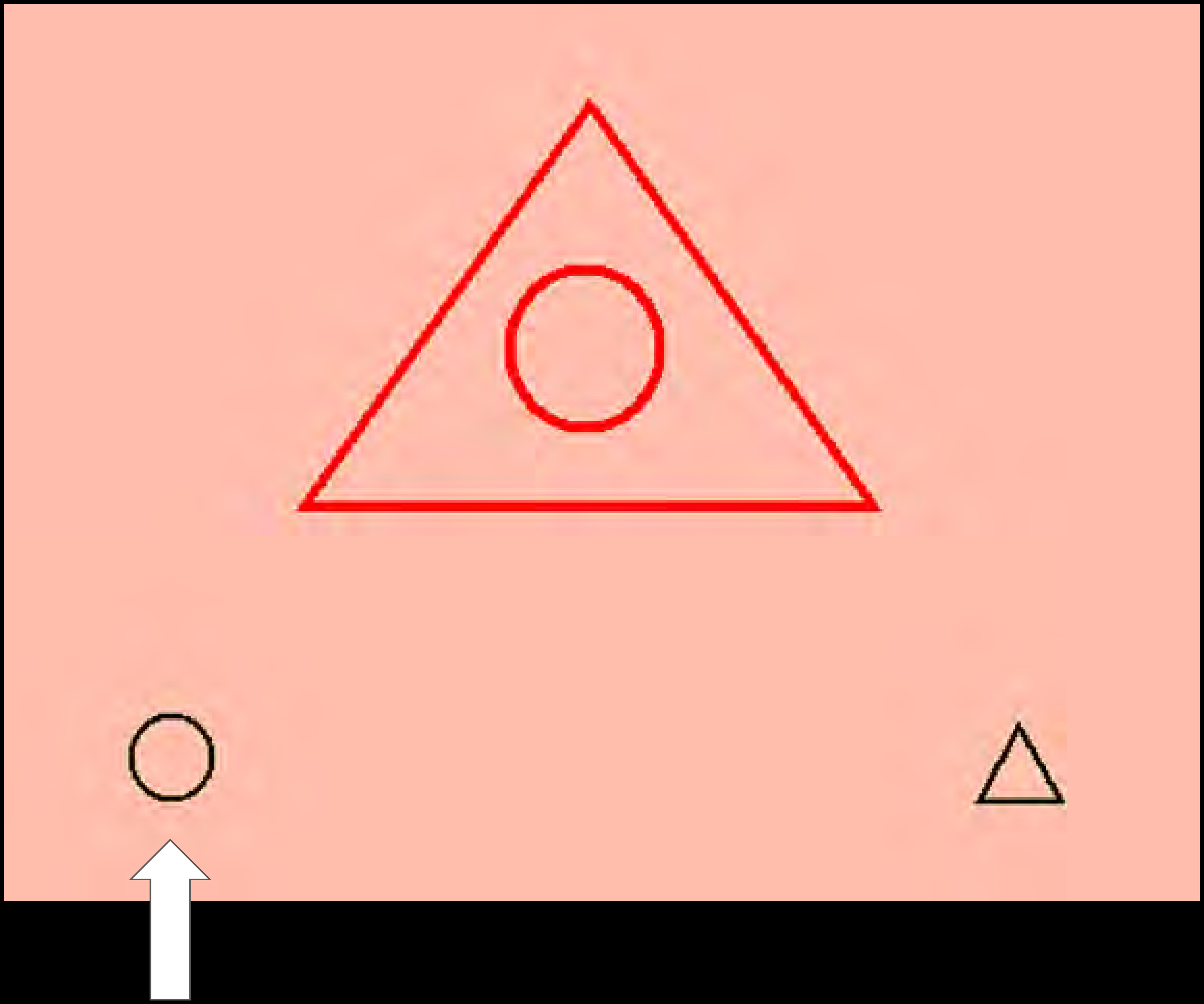
1. the Flanker effect far LARGER
2. It is far more ROBUST in the face of variations in stimulus characteristics
3. Developmental progression extends far LONGER
4. More SENSITIVE to treatment effects - & I predict to group differences such as clinical vs. controls

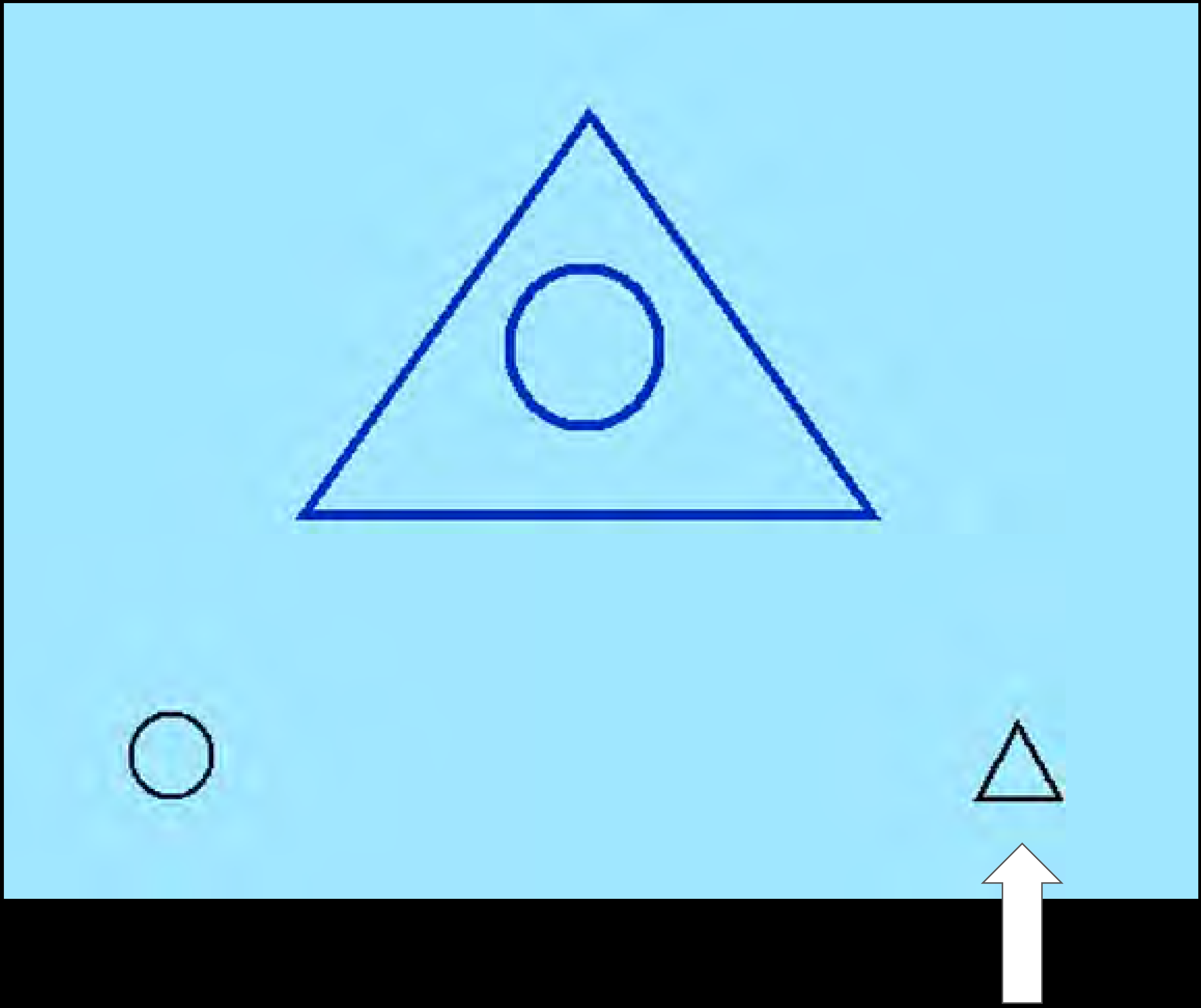


Elena Bodrova & Deborah Leong

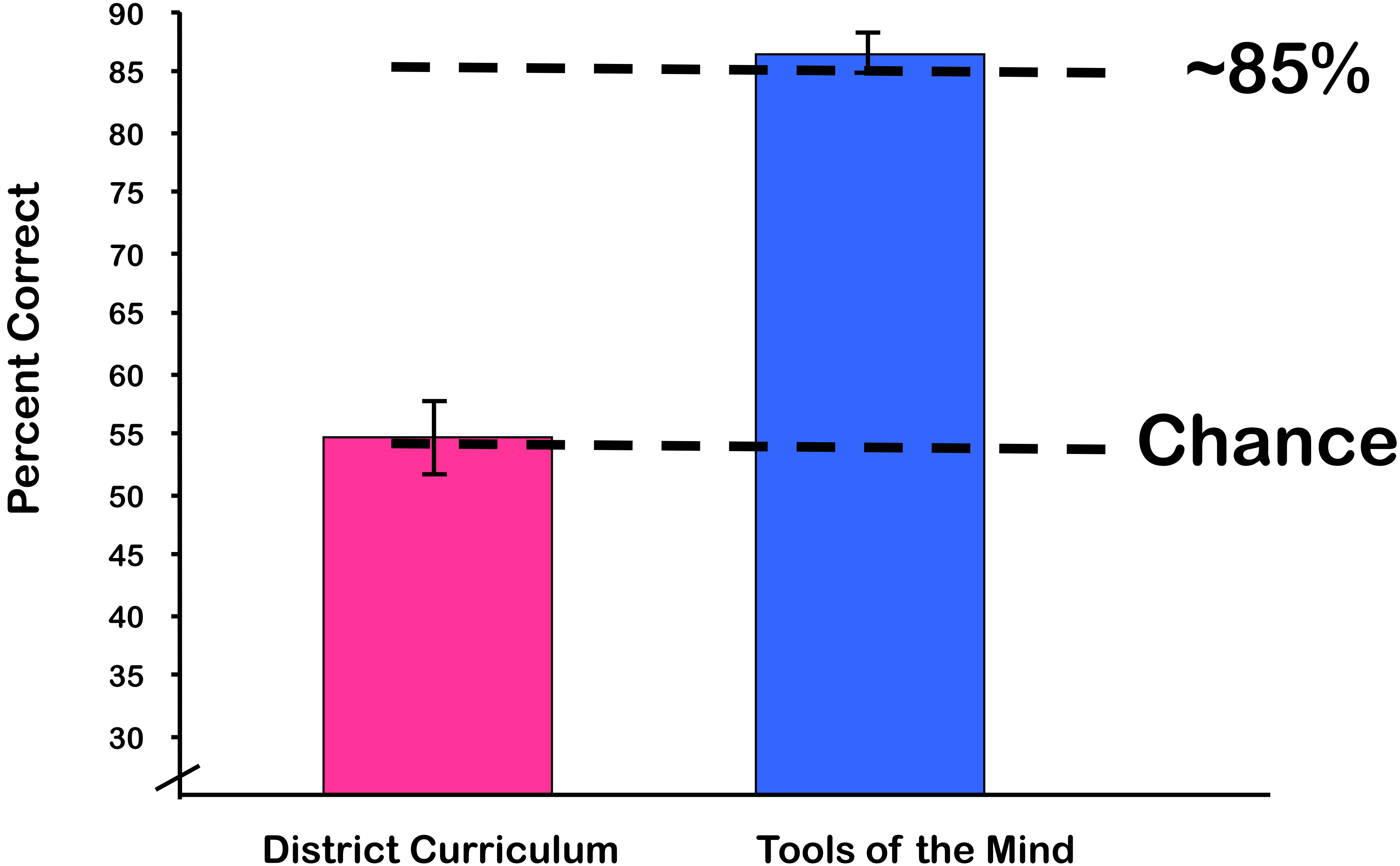
The Tools of the Mind program is based on theories of Vygotsky and Luria

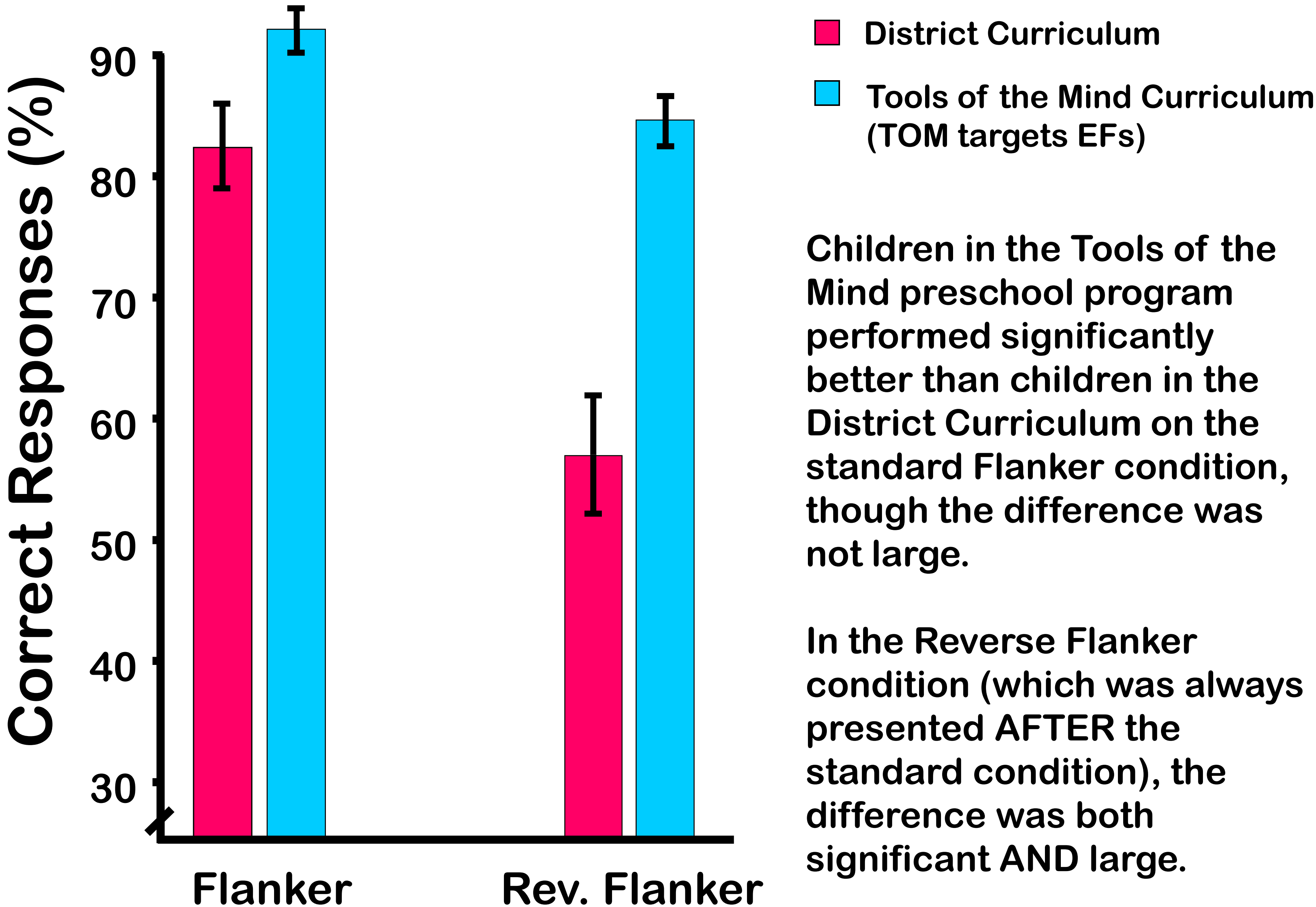
The standard and reverse Flanker conditions were used with 5-year-olds as part of a study to evaluate the efficacy of a preschool intervention that targets Executive Functions…





Percentage of Correct Responses on Reverse Flanker Trials





Children in the Tools of the Mind preschool program performed significantly better than children in the District Curriculum on the standard Flanker condition, though the difference was not large.

In the Reverse Flanker condition (which was always presented AFTER the standard condition), the difference was both significant AND large.

Science
AAAS
November 30, 2007

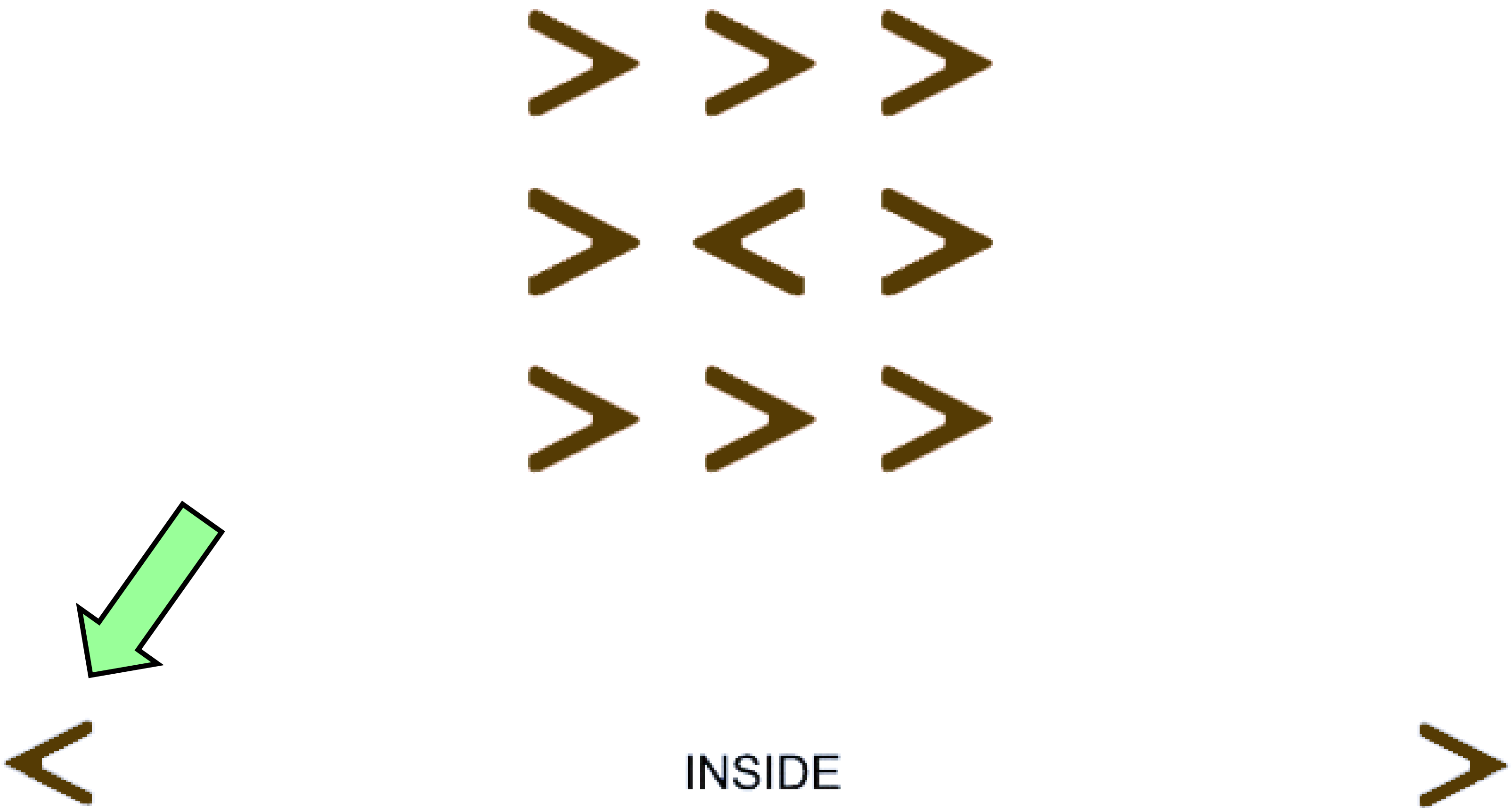
THE EARLY YEARS

Preschool Program Improves Cognitive Control

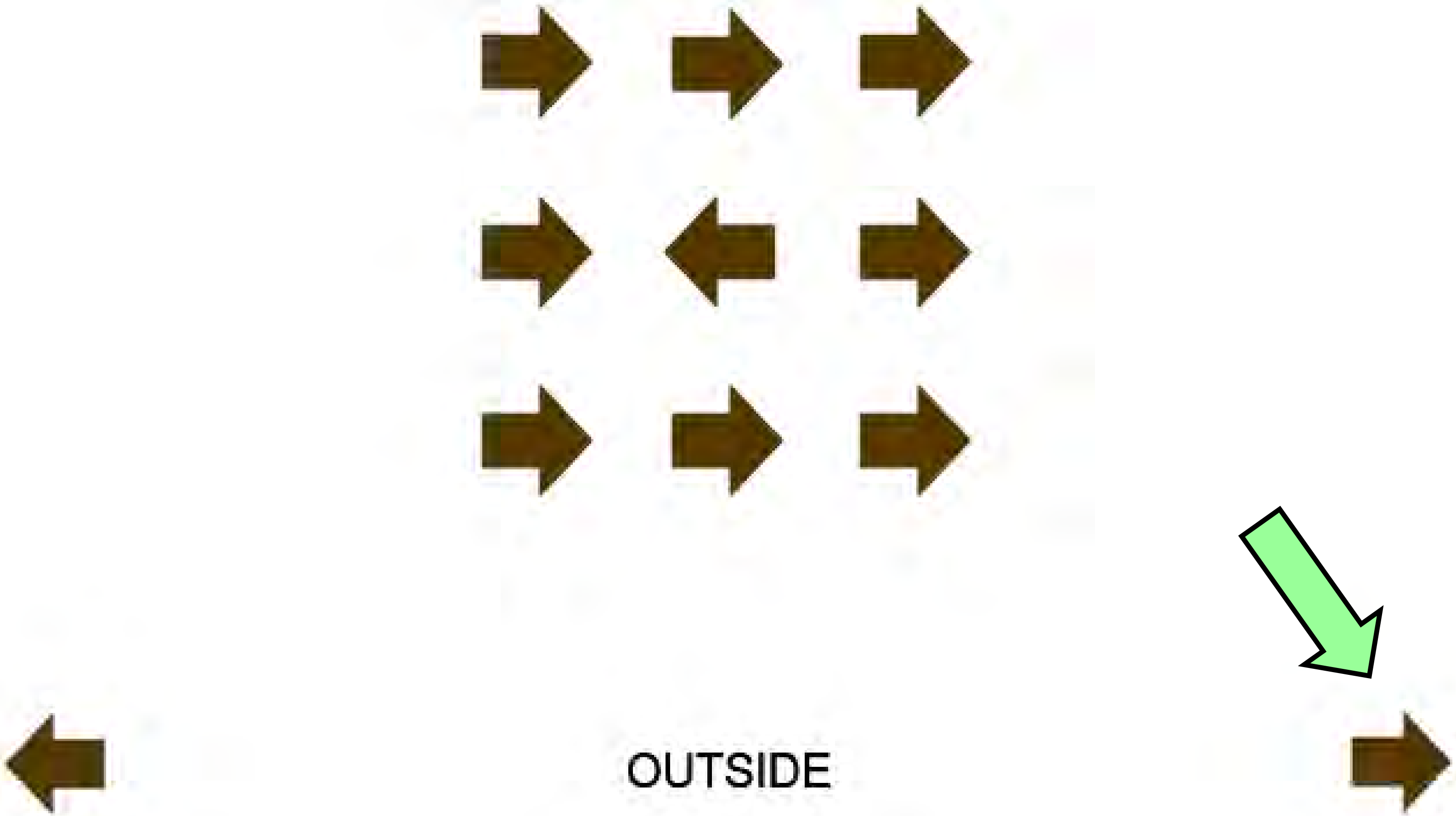
(Executive Functions)

Adele Diamond,[1*] W. Steven Barnett,[2] Jessica Thomas,[2] Sarah Munro[1]

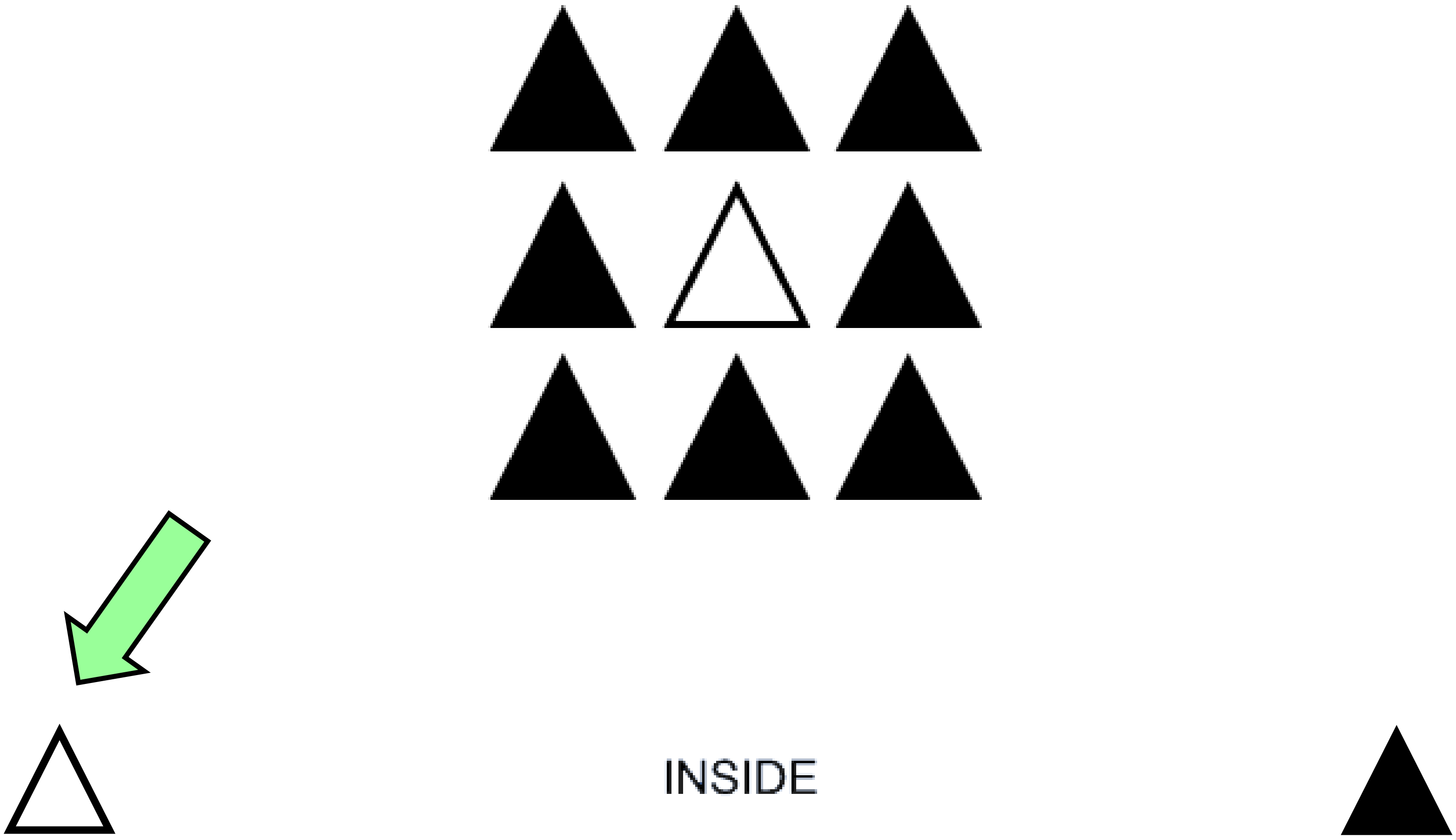
Integrated



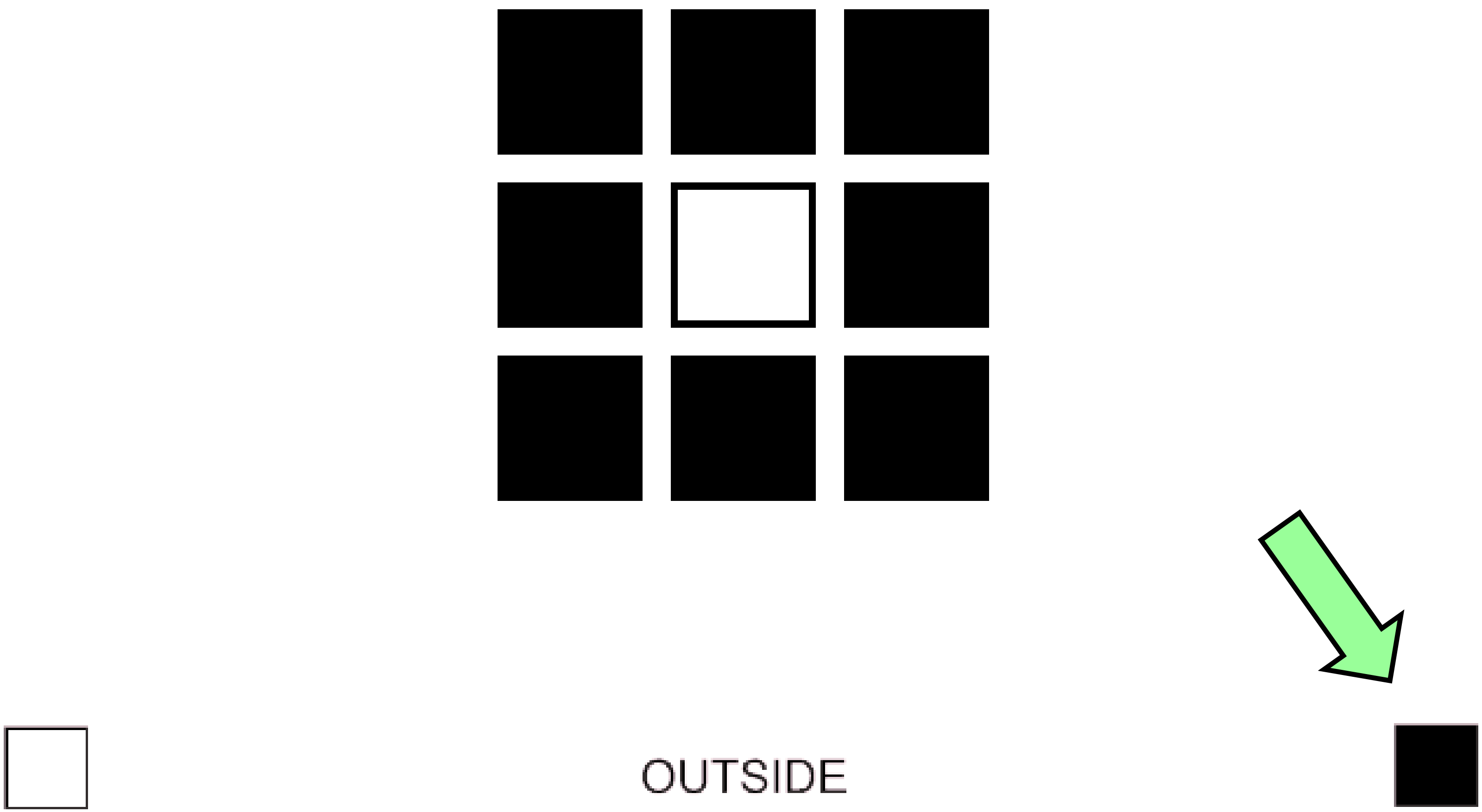
Integrated



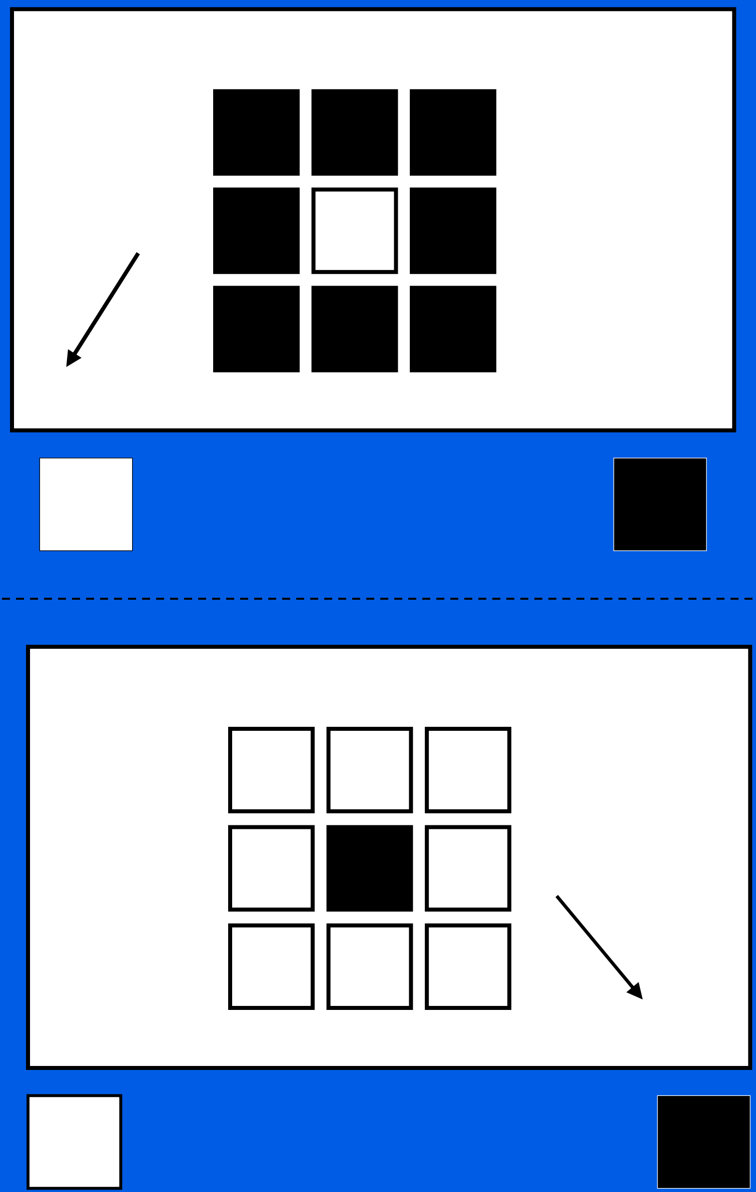
Integrated



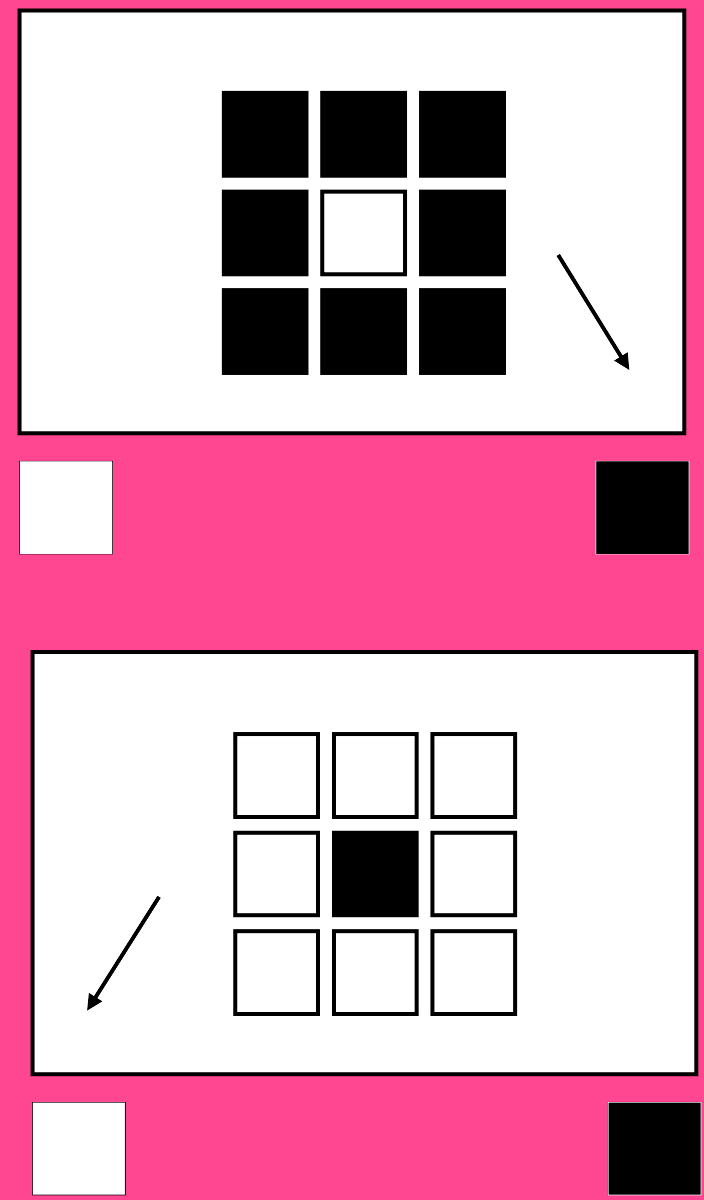
Integrated

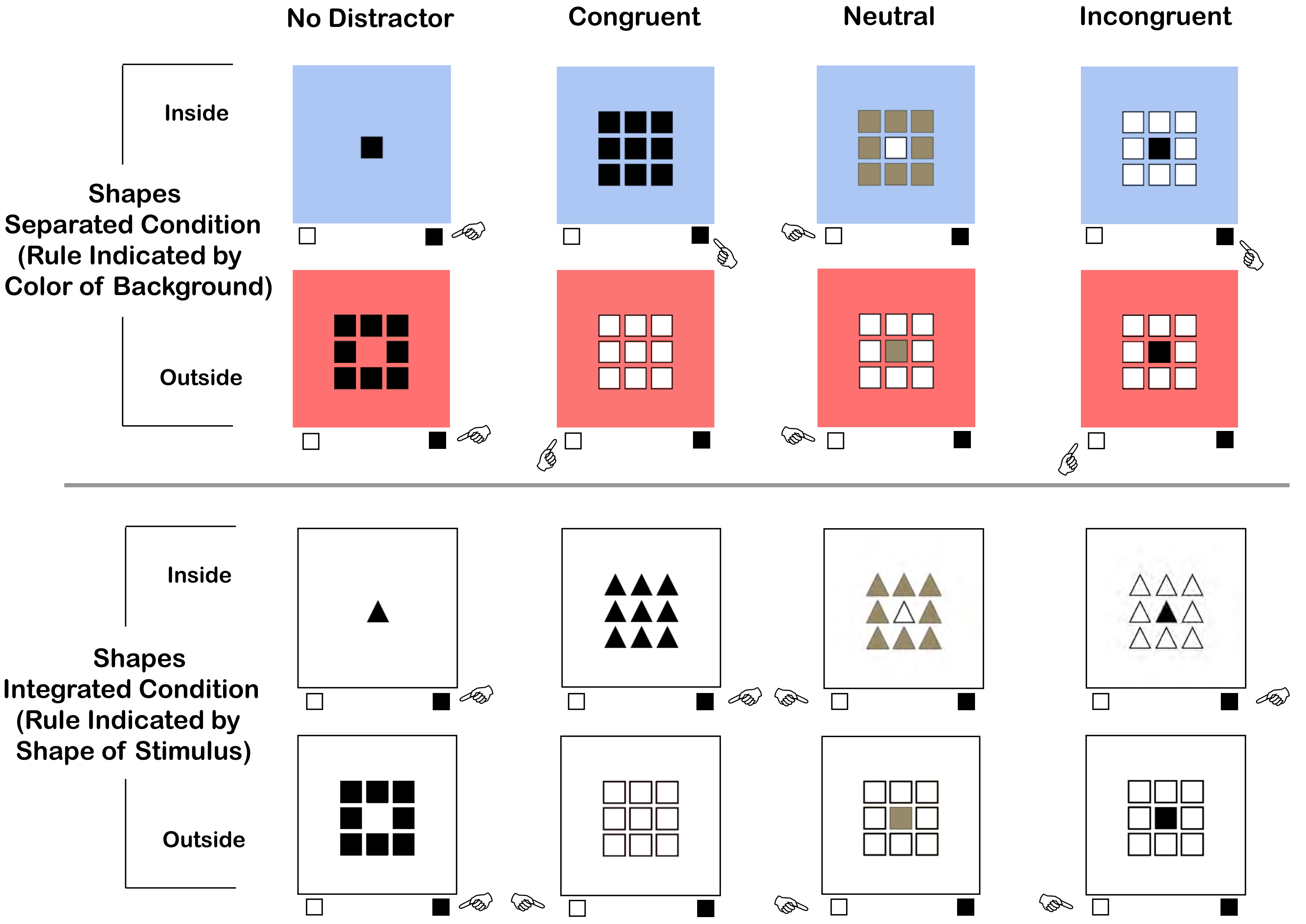


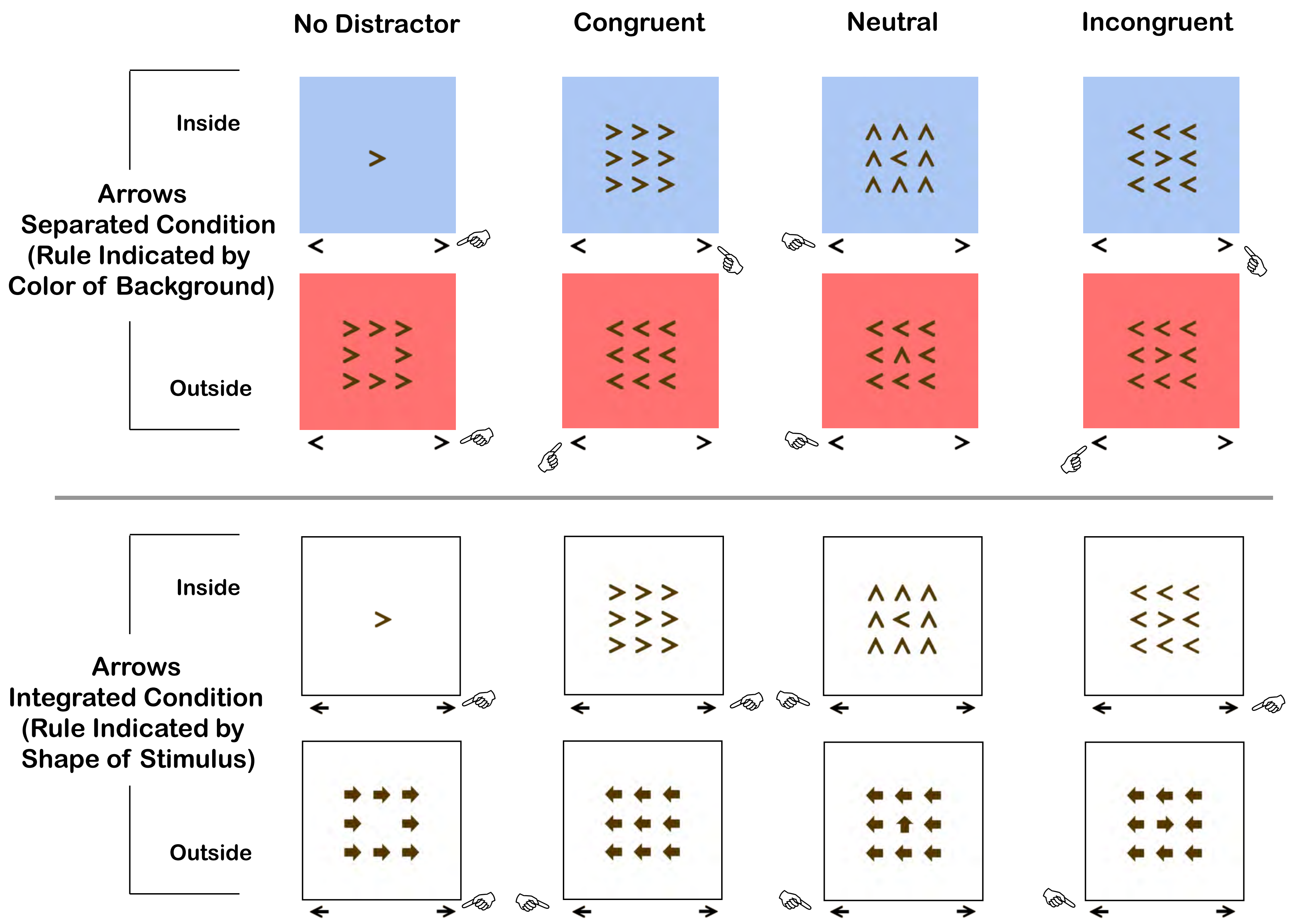
INSIDE



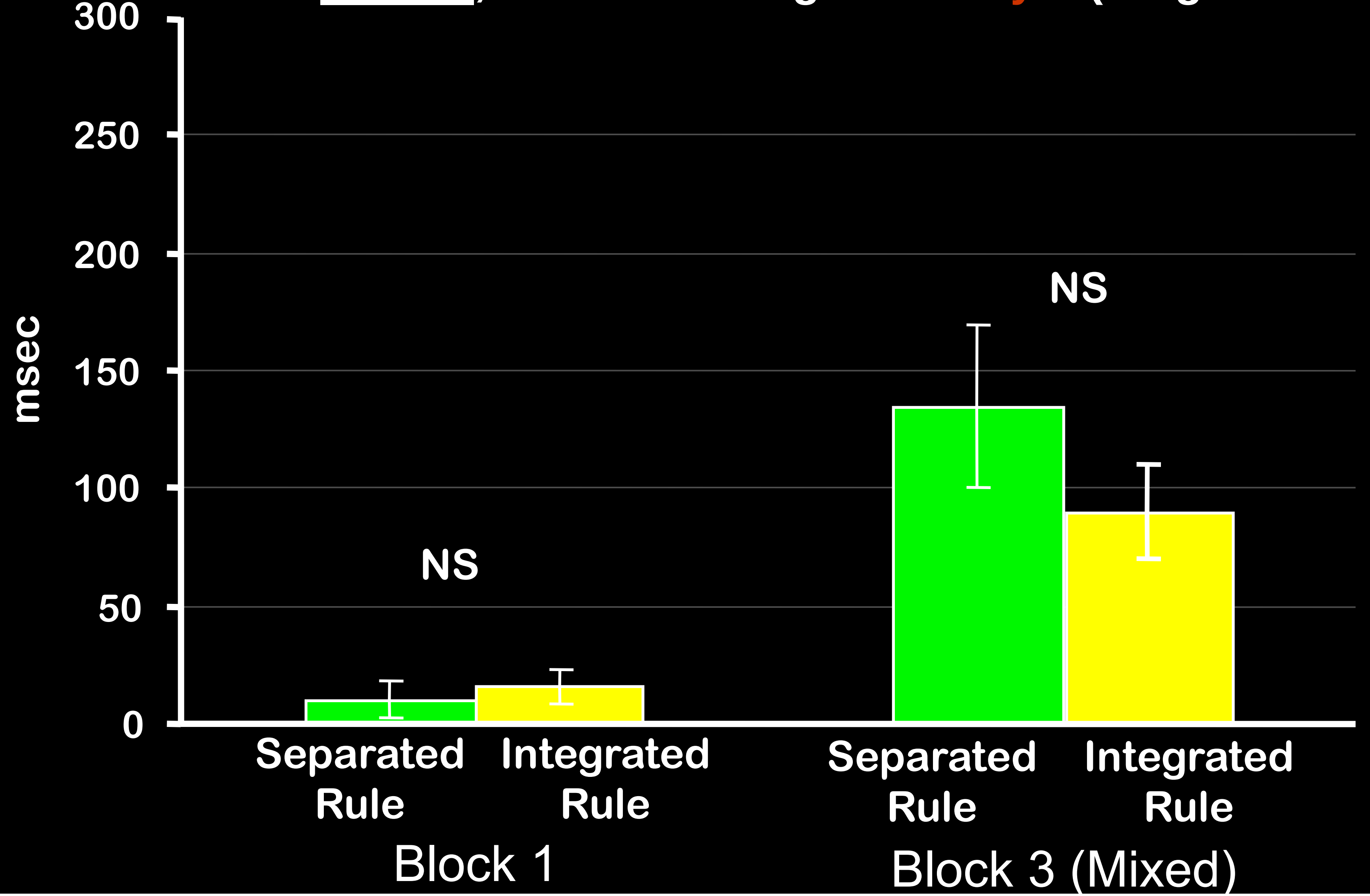
OUTSIDE




No Distractor
Congruent
Neutral
Incongruent
Inside
Shapes
Separated Condition
(Rule Indicated by
Color of Background)
Outside
Inside
Shapes
Integrated Condition
(Rule Indicated by
Shape of Stimulus)
Outside


No Distractor
Congruent
Neutral
Incongruent
Inside
Arrows
Separated Condition
(Rule Indicated by
Color of Background)
Outside
Inside
Arrows
Integrated Condition
(Rule Indicated by
Shape of Stimulus)
Outside

Flanker Effect: Separated vs. Integrated Rules for Block 1 and 3 INSIDE, Non Switching for Study 1 (Large Stimuli)



Rule type has an insignificant effect on the Flanker Effect for either the single-task block or the mixed block.

Dramatically Larger Flanker Effects

Sarah Munro,

Cecil Chau,

Karine Gazarian,

& Adele Diamond

Presented at the Cognitive Neuroscience Society Annual Meeting, San Francisco, CA,
April 9, 2006.

Anti-Saccade Task

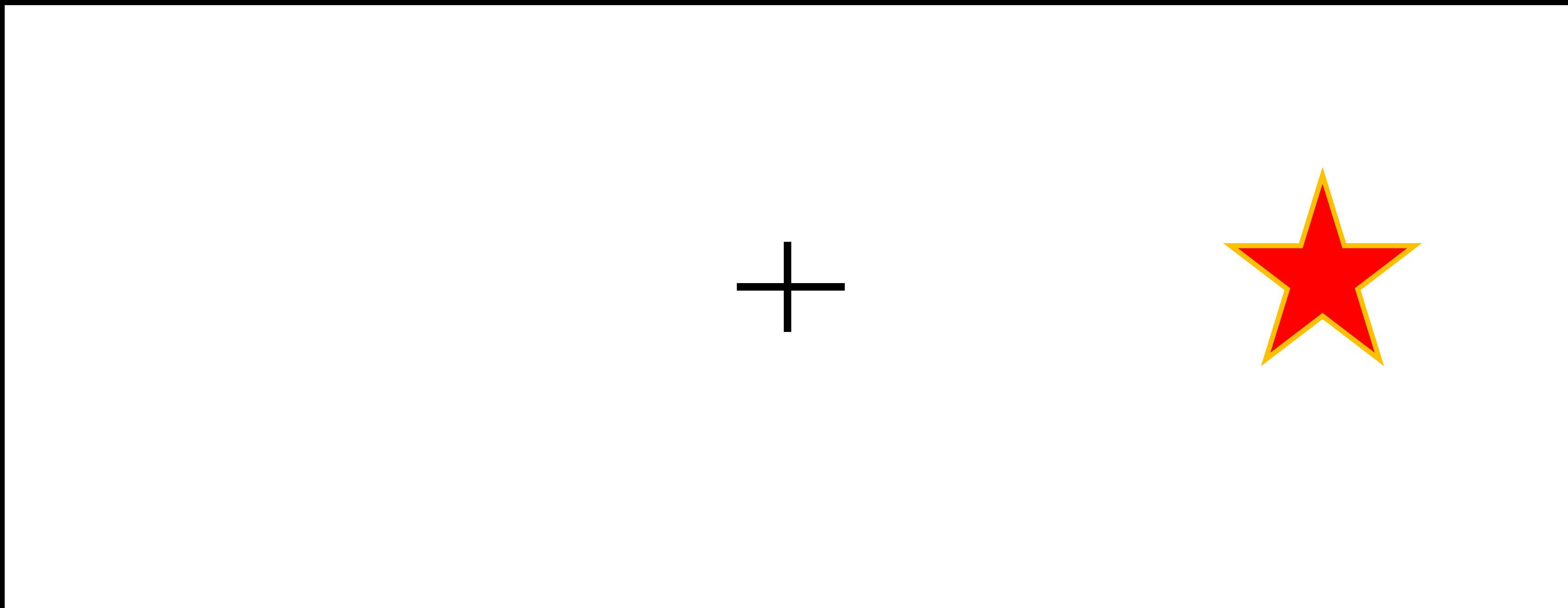
First, the easy

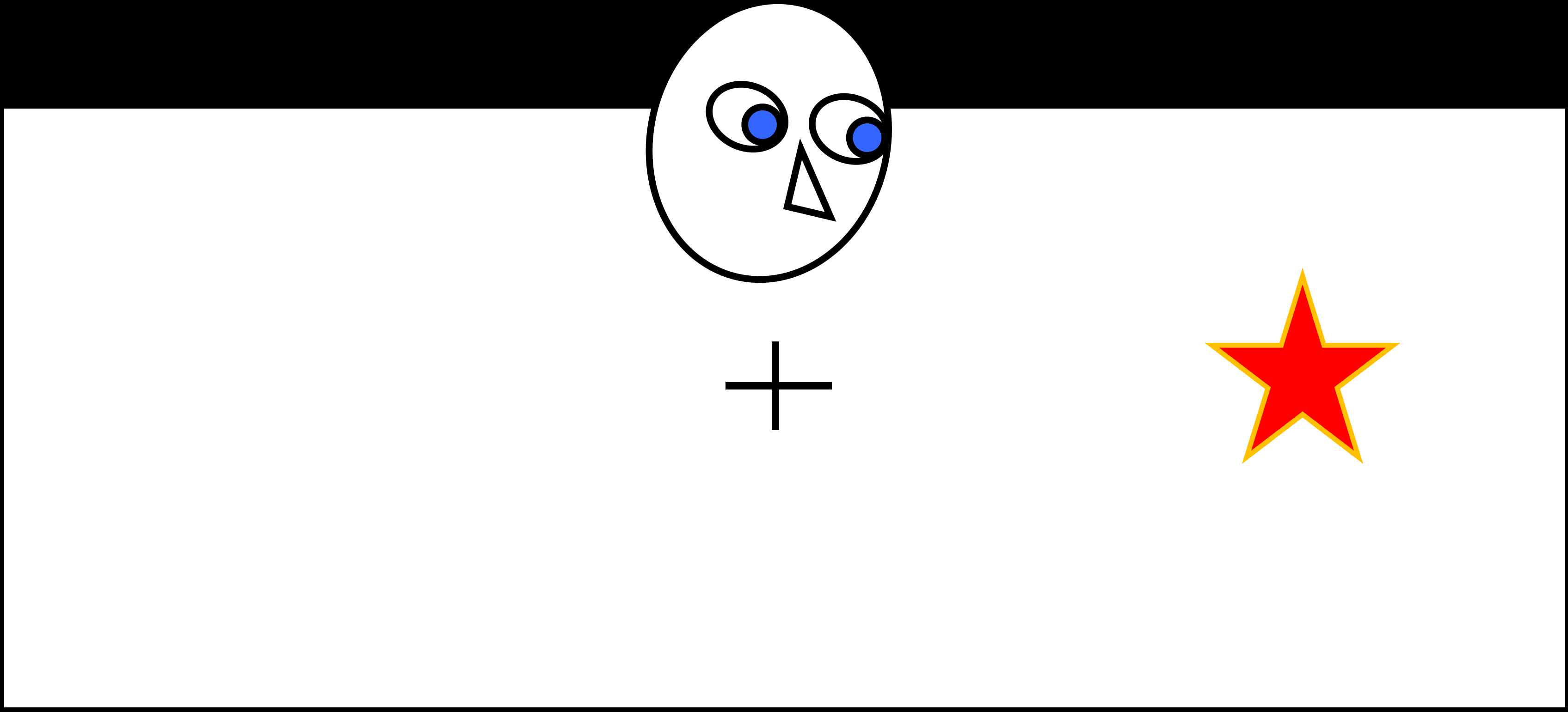
Pro-Saccade Block.

Look at the target as

fast as possible.

+

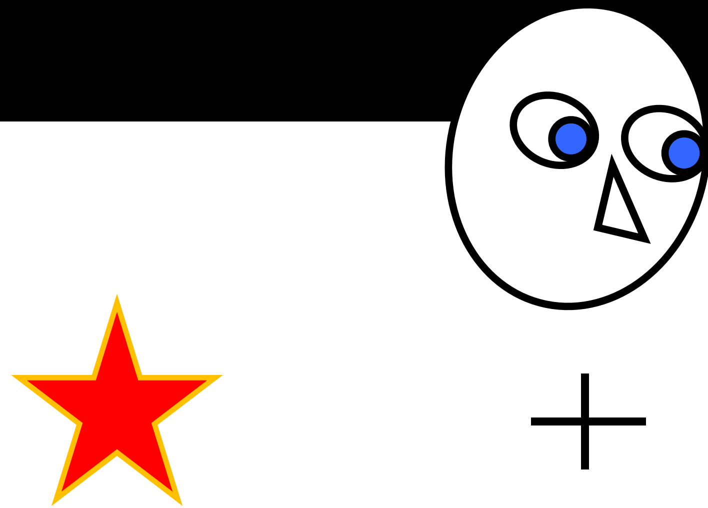




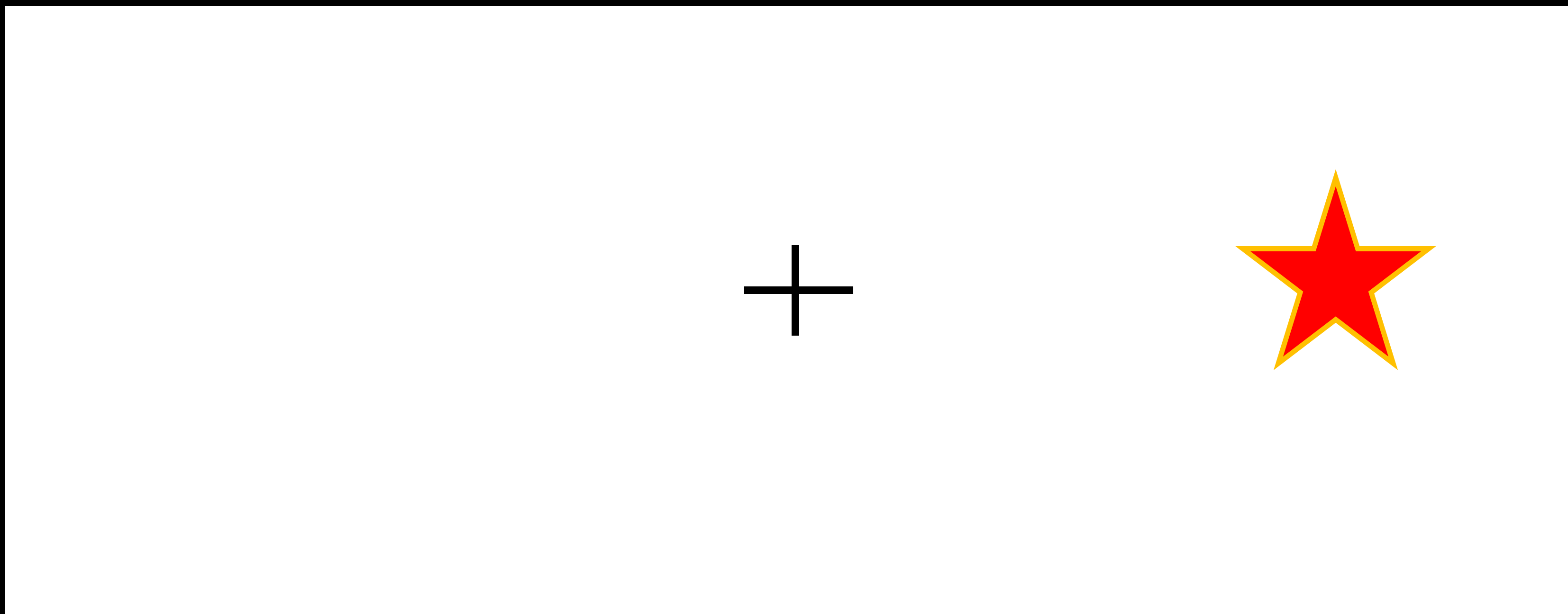
Now, the Anti-Saccade Block.

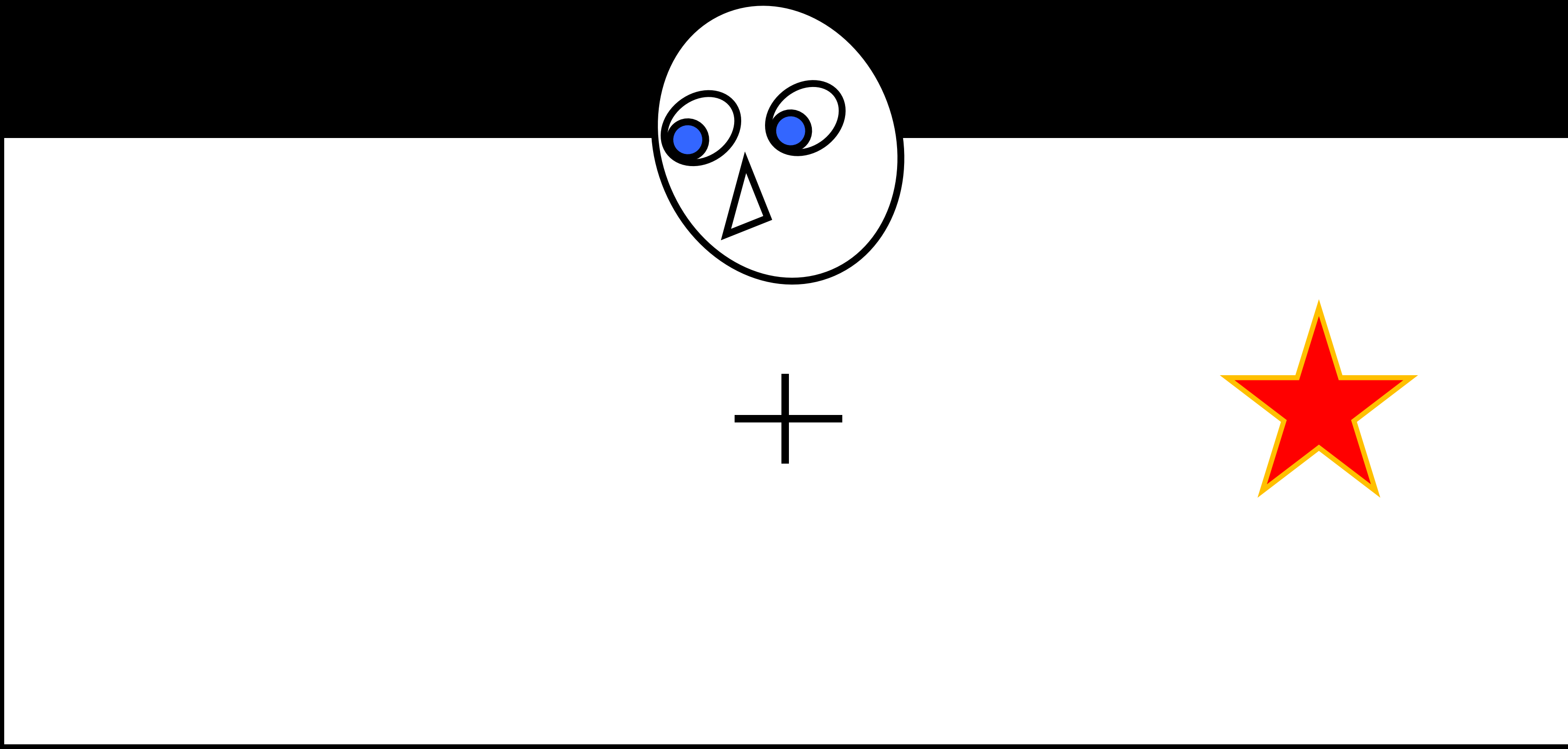
Look in the direction opposite to where the target appears as fast as possible.

+



+





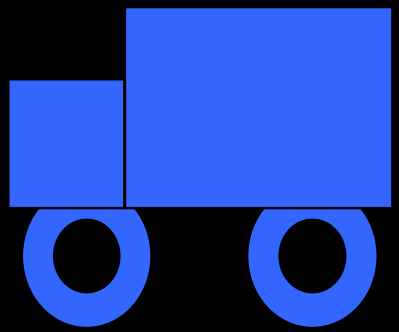
Dimensional Change Card Sort

(Zelazo, Frye, & Rapus, 1996)

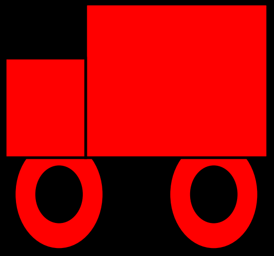
Holding two rules in mind, and inhibiting the tendency to continue sorting by the first dimension

When sorting by COLOR, Correct Response is the Blue Star.

Card to be sorted:

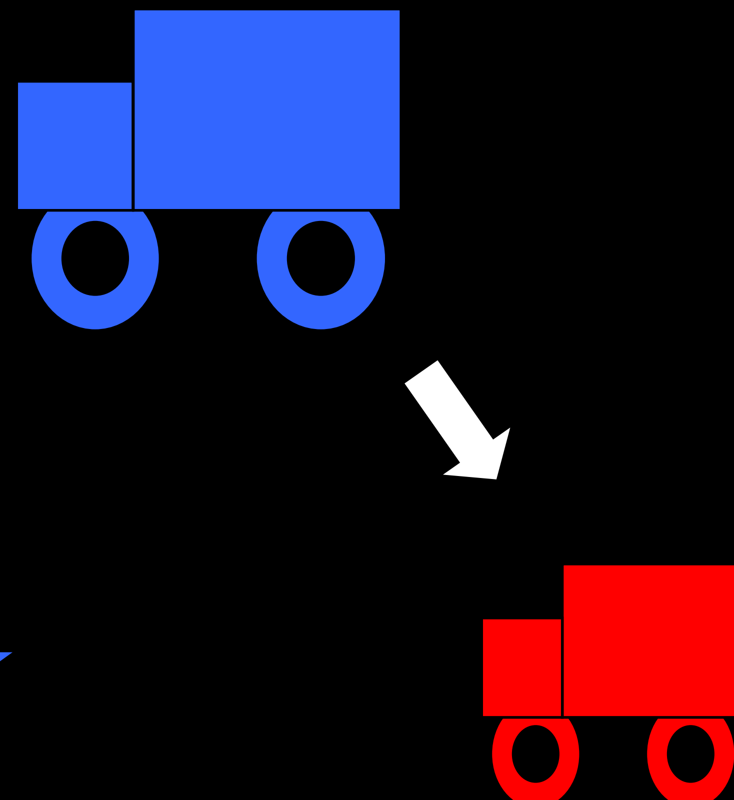


Model Cards:

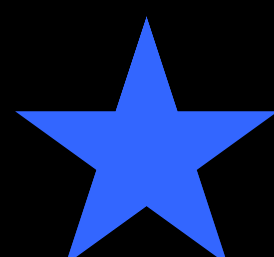


When sorting by SHAPE,
Correct Response is the Red Truck.

Card to be sorted:



Model Cards:

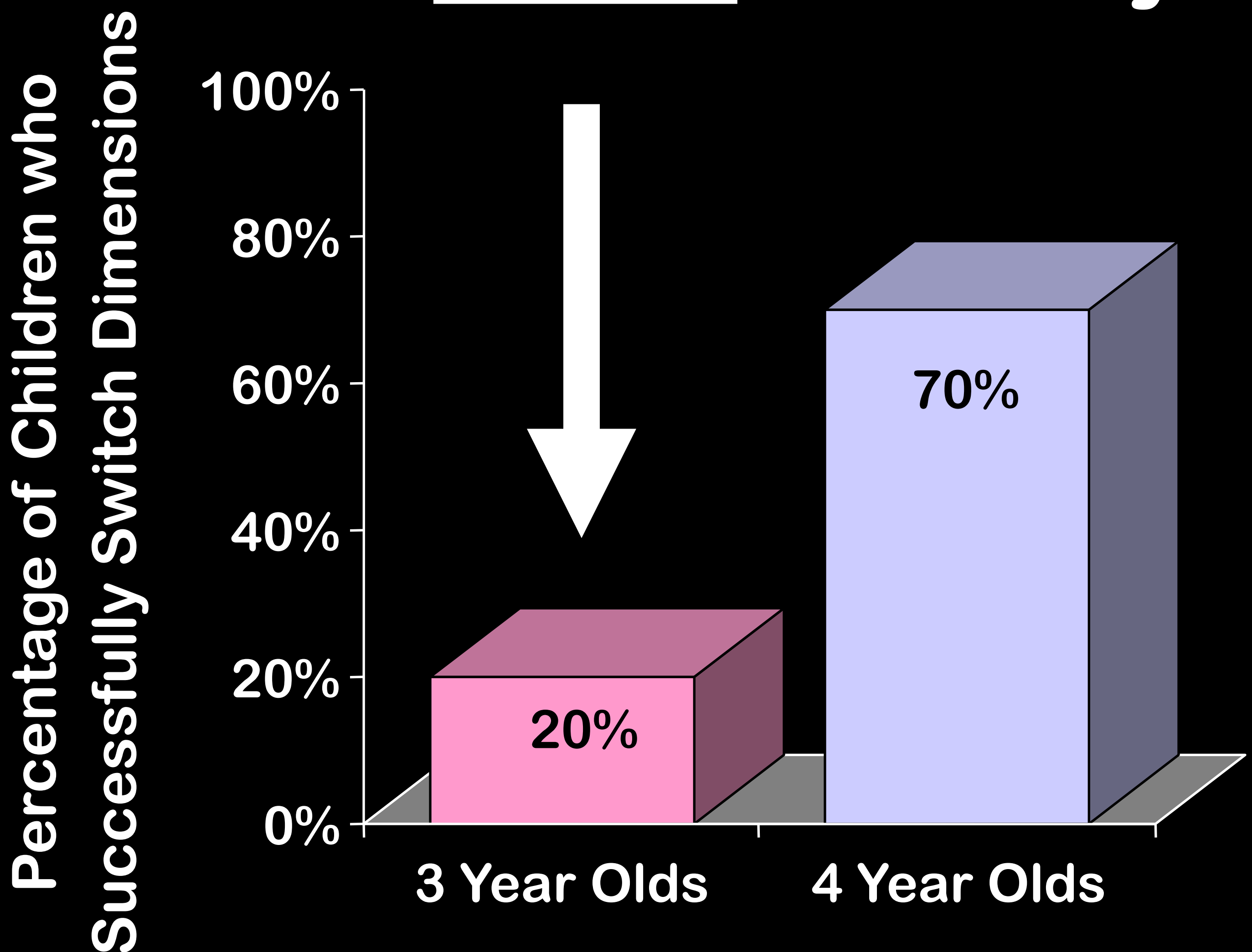


3-year-olds sort the cards perfectly

by either

color or shape

but, very few 3-yr-olds can <u>switch</u> how they sort



See VIDEO of child starting with sorting by Shape at:

www.devcogneuro.com/videos/cardsort.mpg

See VIDEO of child starting with sorting by Color at:

www.devcogneuro.com/videos/cardsort_failedswitch.wmv

The child has clearly in mind what the new sorting criterion is and the appropriate rules for that dimension.

BEFORE the stimulus appears the child is all set to perform correctly.

Then a stimulus appears that is relevant to both tasks, in incompatible ways.

That <u>CREATES</u> a problem, triggering the mindset the child is trying to inhibit.

The core problem for 3-year-olds in switching appears to be:

Attentional Inertia

Once they have focused their attention on a dimension, their attention gets STUCK there. They need to disengage from, or inhibit, their previous way of thinking about the stimuli.

It is not enough to know something and remember it;

you must get that knowledge into your behavior.

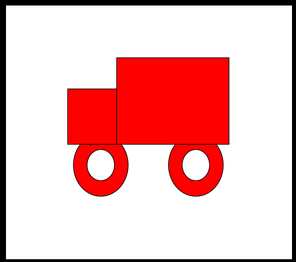
A child may know

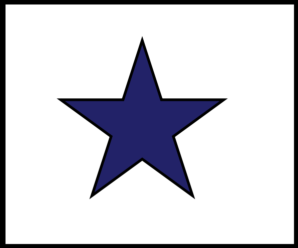
what he or she should do,

and want to do that, but still not

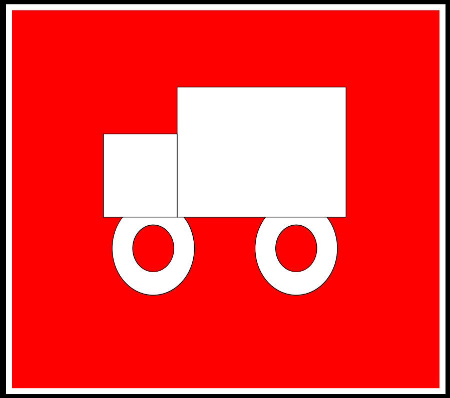
be able to act accordingly.

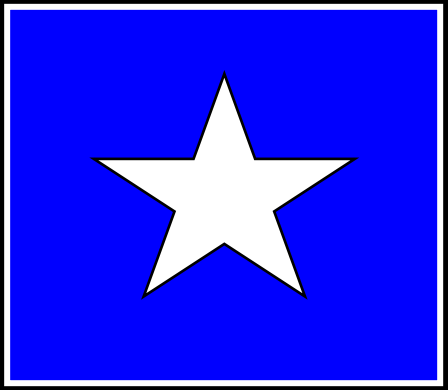
Each dimension is an intrinsic part of the stimulus object.

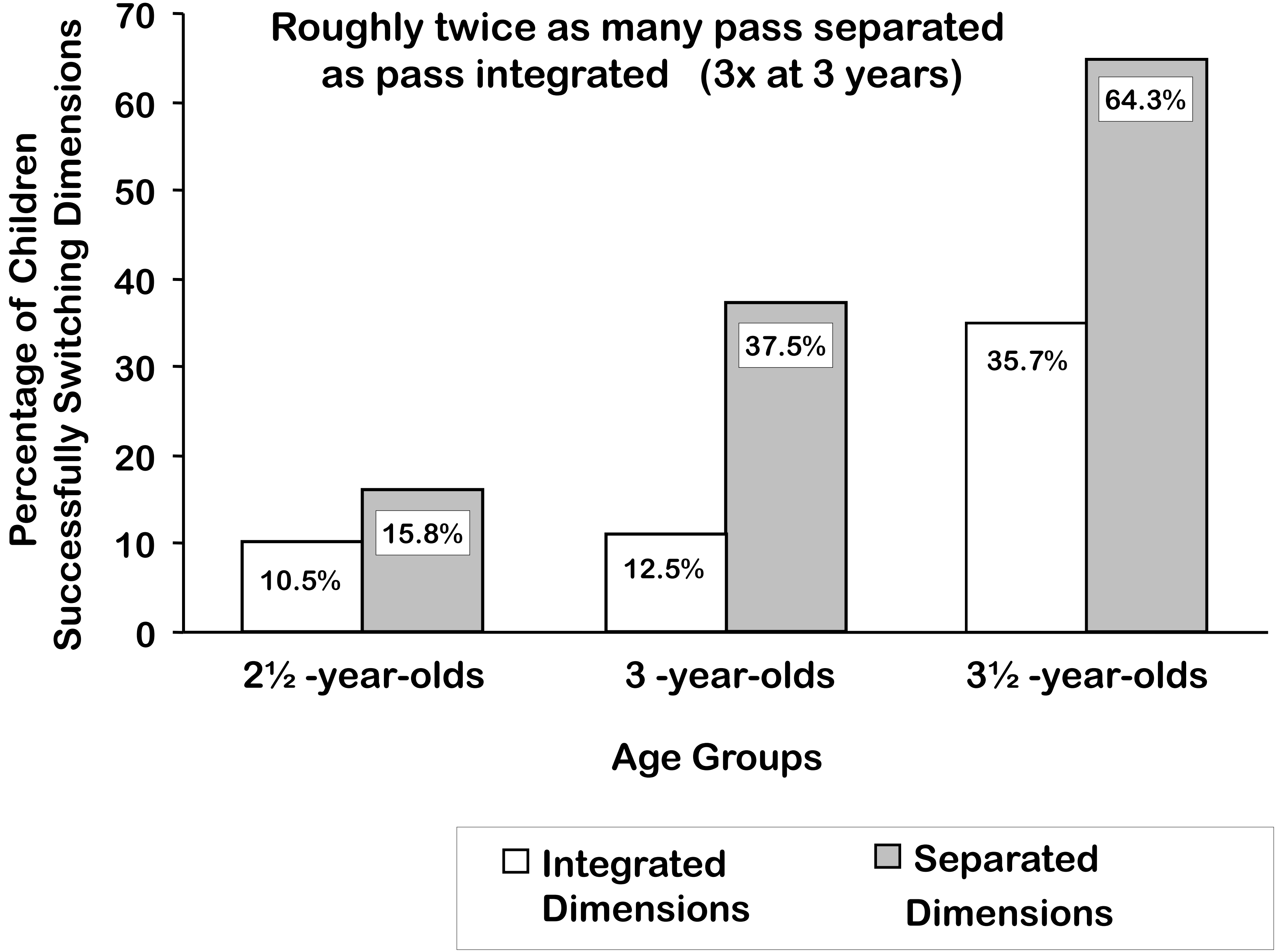


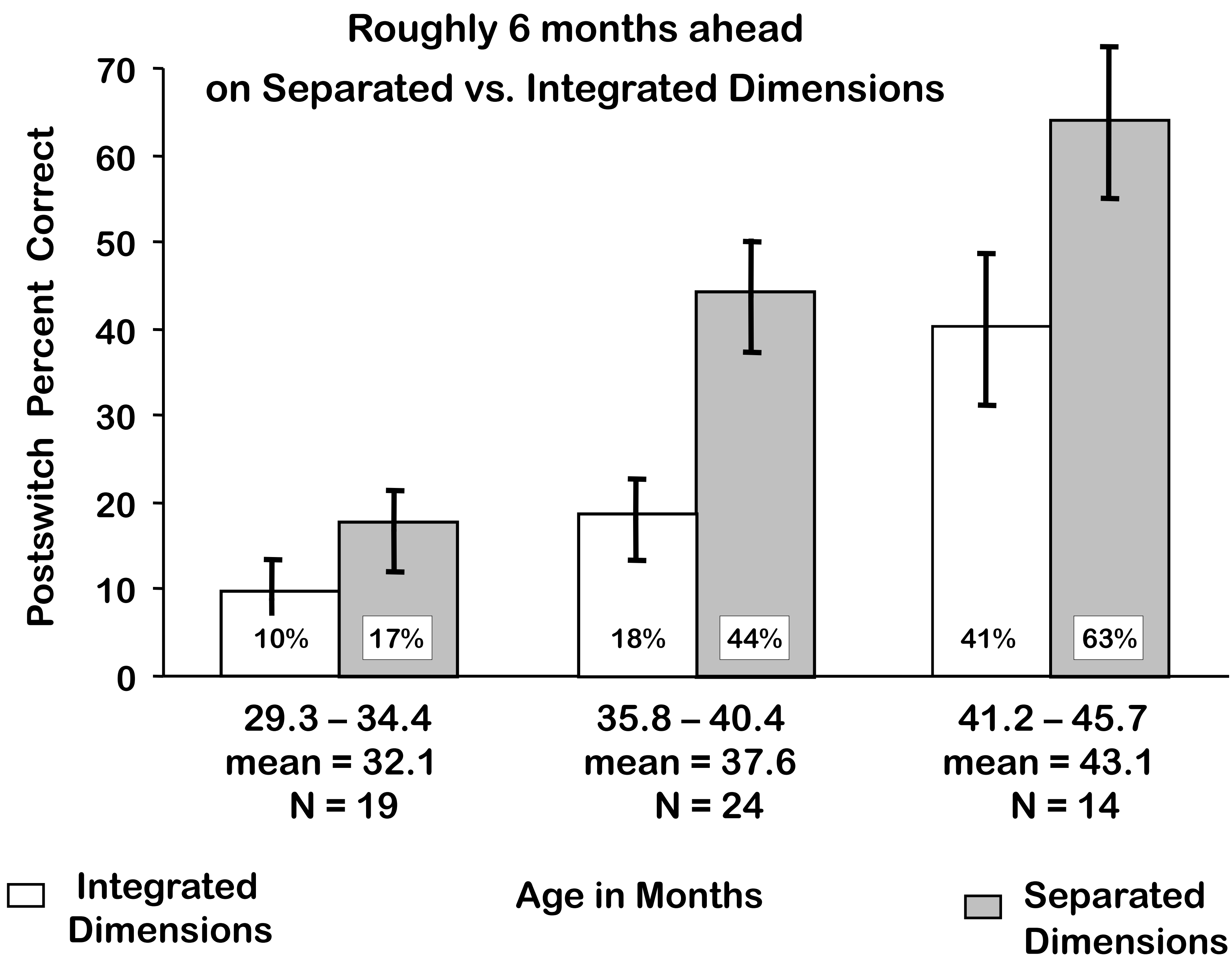


What if both dimensions are not properties of the stimulus?






Roughly twice as many pass separated
as pass integrated (3x at 3 years)
Percentage of Children
Successfully Switching Dimensions
70
60
50
40
30
20
10
0
10.5%
15.8%
12.5%
37.5%
35.7%
64.3%
2½ -year-olds
3 -year-olds
3½ -year-olds
Age Groups
Integrated
Dimensions
Separated
Dimensions


Roughly 6 months ahead
on Separated vs. Integrated Dimensions
Postswitch Percent Correct
70
60
50
40
30
20
10
0
10%
17%
18%
44%
41%
63%
29.3 – 34.4
mean = 32.1
N = 19
35.8 – 40.4
mean = 37.6
N = 24
41.2 – 45.7
mean = 43.1
N = 14
Integrated Dimensions
Age in Months
Separated Dimensions

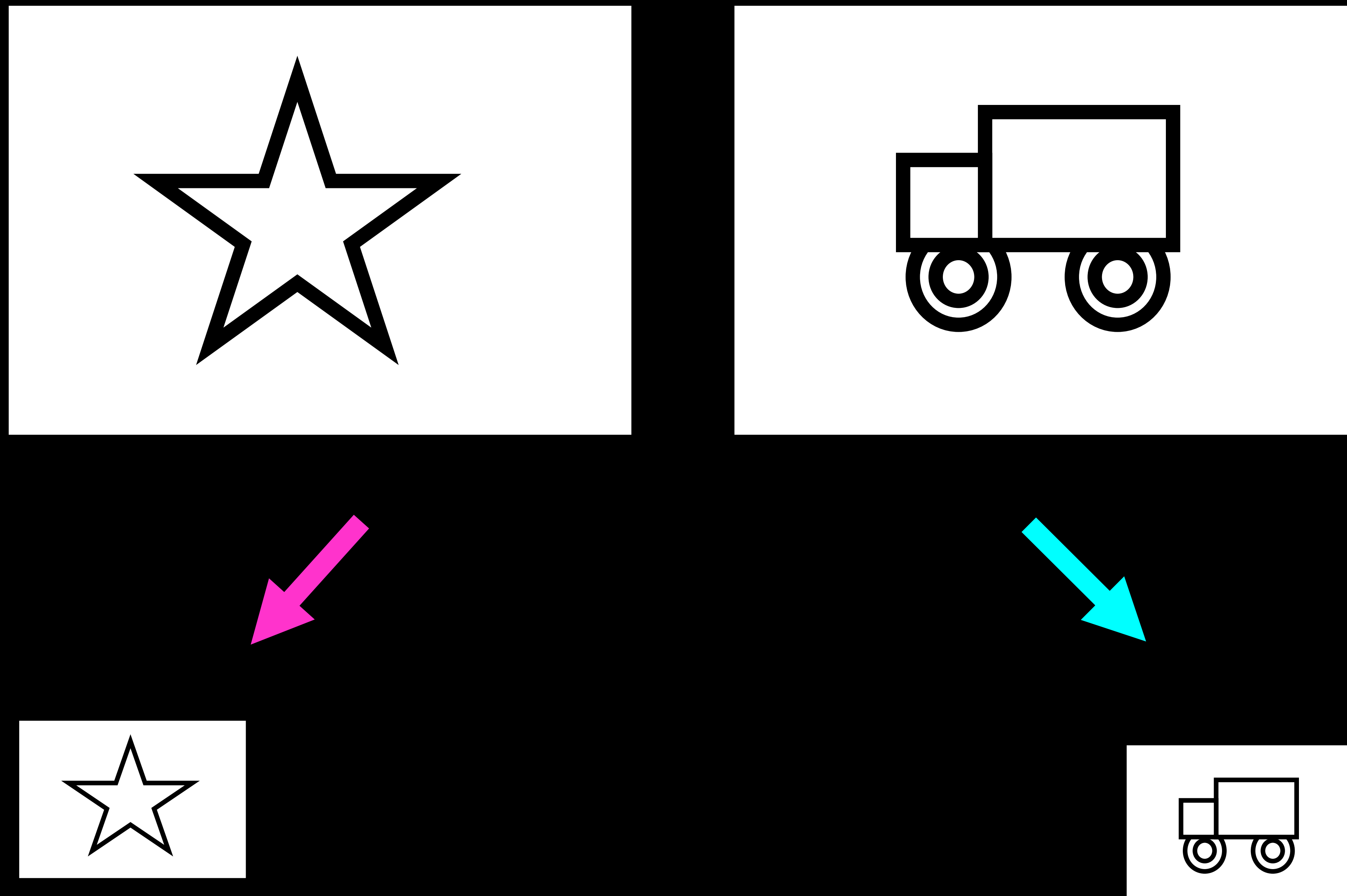
Children's performance on the dimensional change card sort task: Separation aids ability to switch dimensions

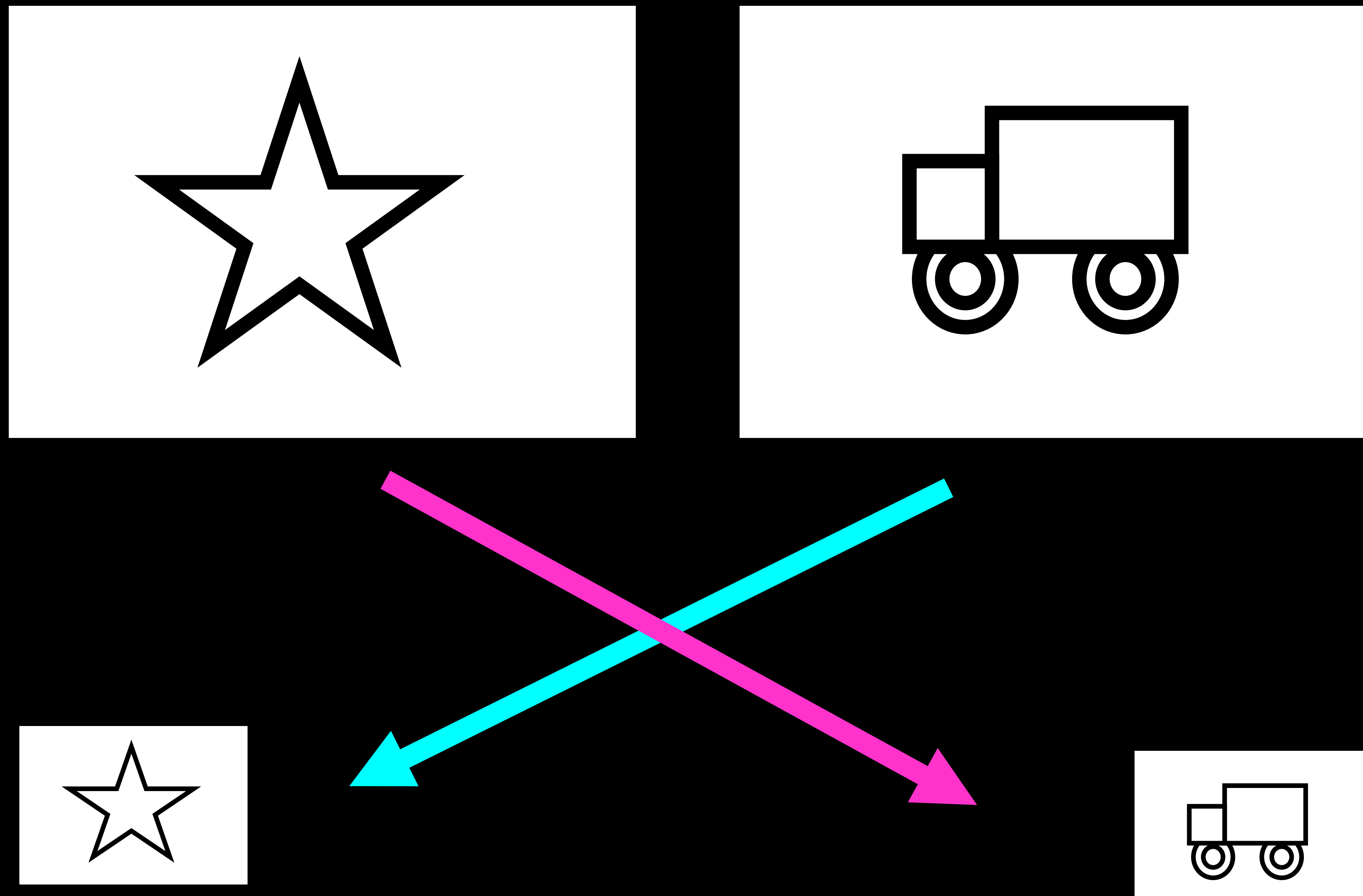
Adele Diamond,
Stephanie Carlson, & Danielle Beck

(2005)

Developmental Neuropsychology

vol 28, p.689-729





- Patricia Brooks, Julie B. Hanauer, Barbara Padowska, & Heidy Rosman (2003) The role of selective attention in preschoolers' rule use in a novel dimensional card sort. *Cognitive Development* **vol 117, p 1-21**

- Josef Perner & Birgit Lang (2002) What causes 3-year olds' difficulty on the dimensional change card sorting task? *Infant & Child Development* vol 11, p. 93-105

Developmental Progression

Succeed at…. **at Age**

Reversals (intra-dimensional shift) 2½

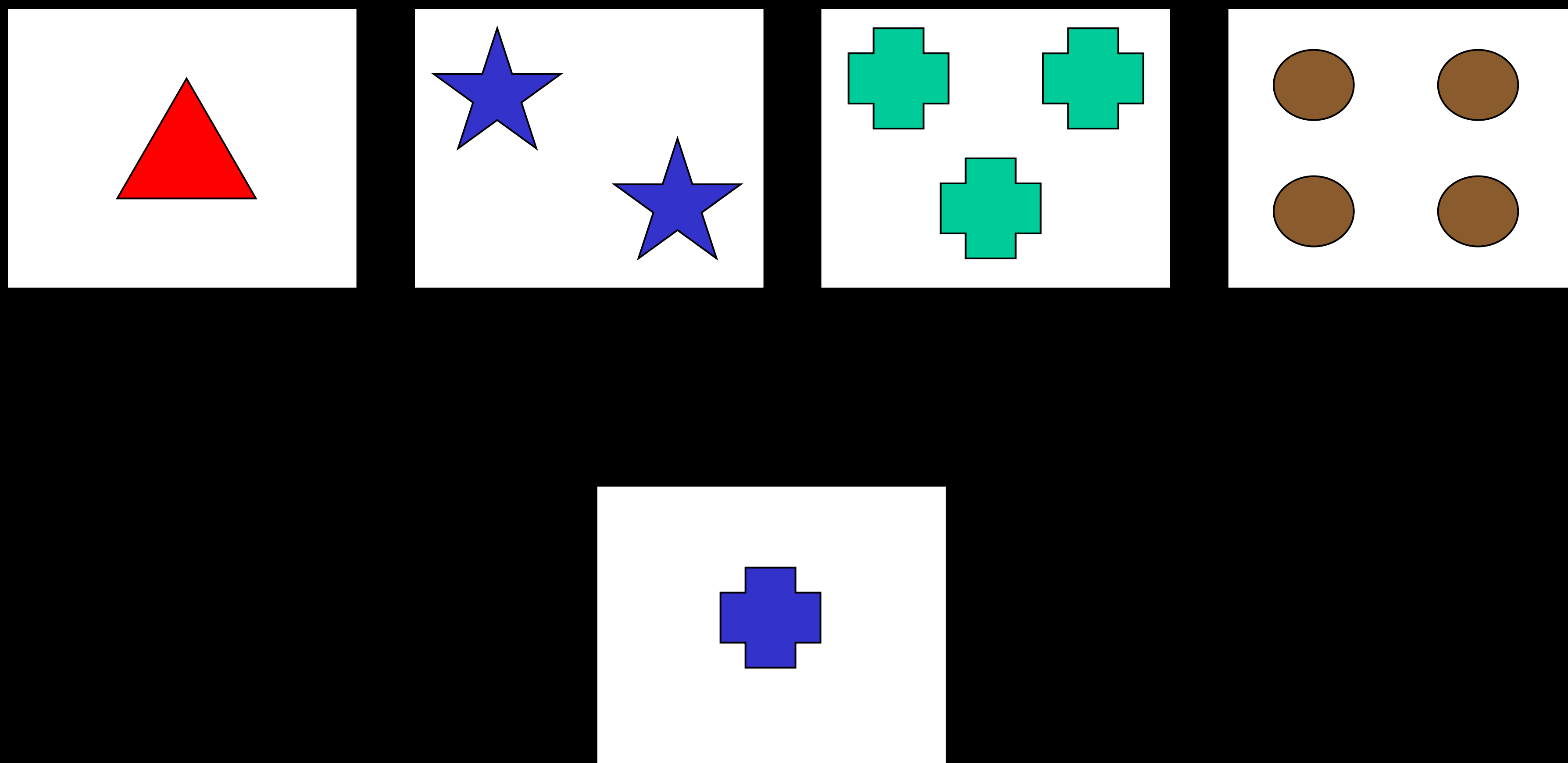
extra-dimensional switches (1 dimen. to another):

DCCS - Separated Dimensions 3½

DCCS (Standard) - Integ. Dimen. 4½

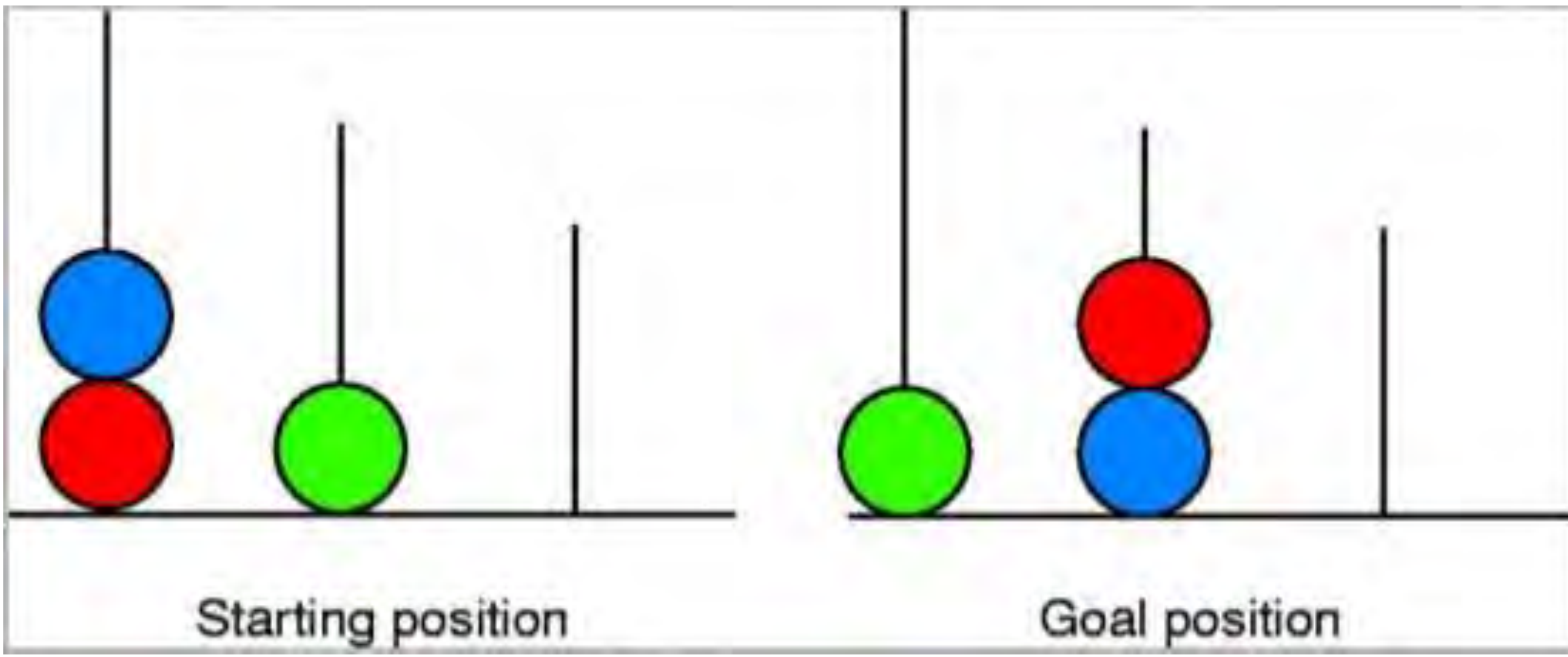
DCCS - Mixed Block………………… 7½

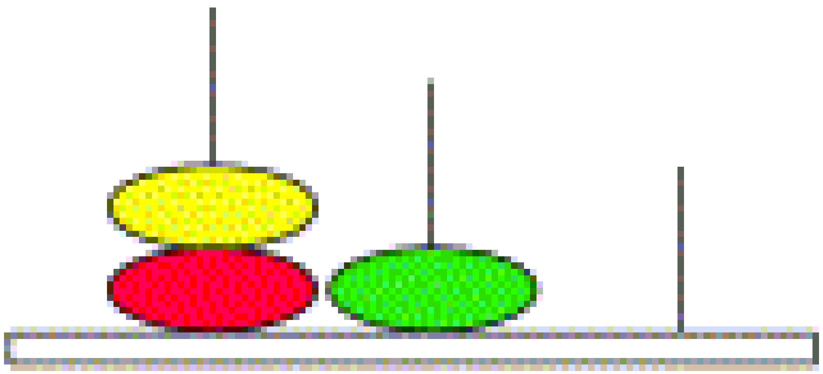
(switching dimensions randomly across trials)



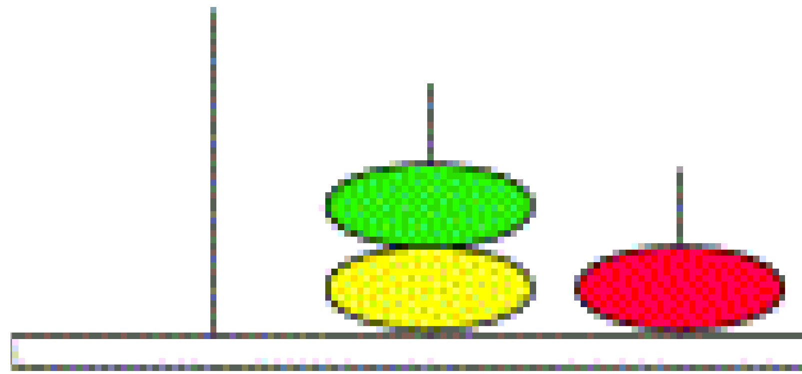
Wisconsin Card Sort Test

Tower of London

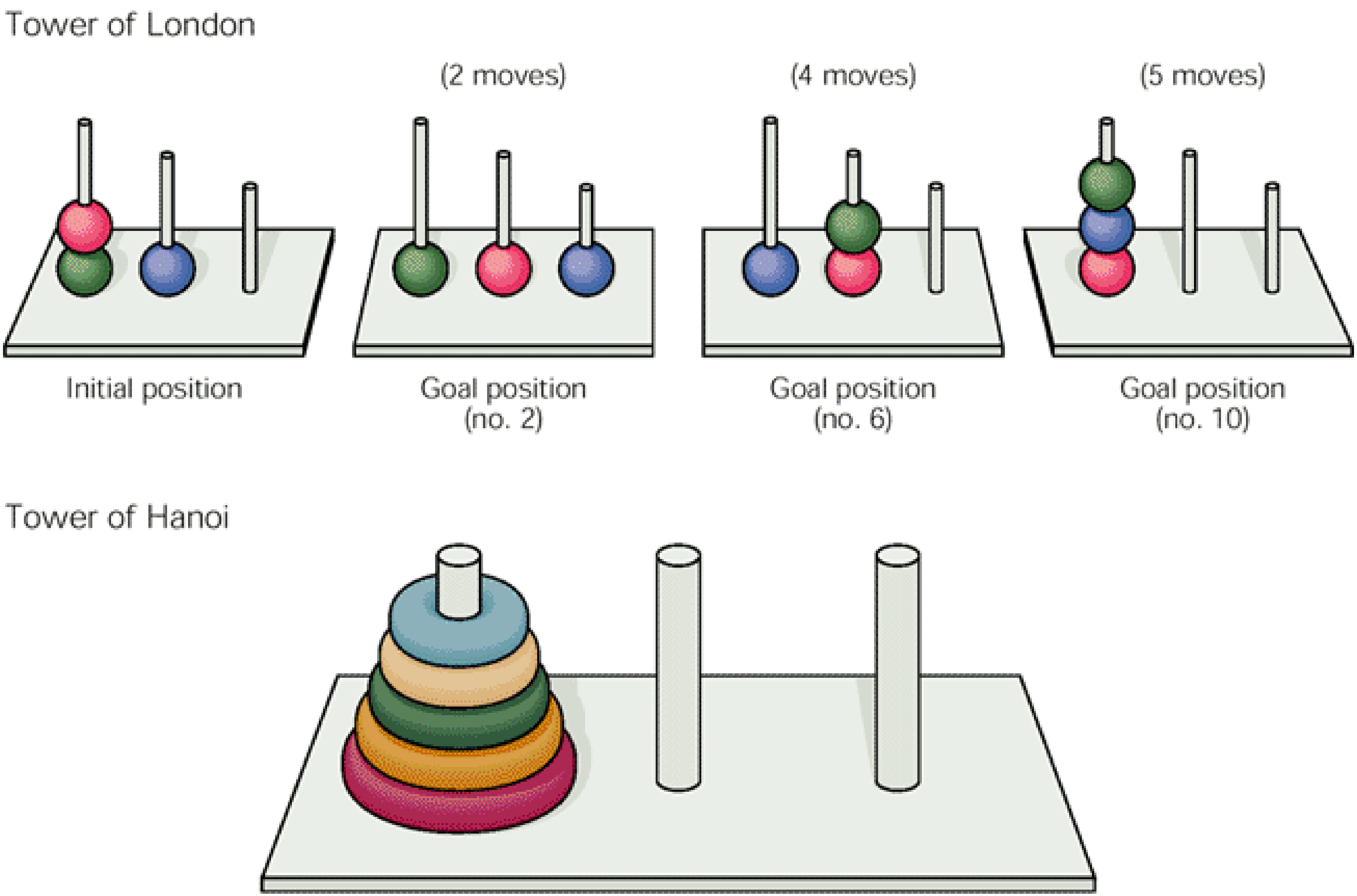




Start



Goal


Tower of London
(2 moves)
(4 moves)
(5 moves)
Initial position
Goal position
(no. 2)
Goal position
(no. 6)
Goal position
(no. 10)
Tower of Hanoi

Complex, multi-component measures

(such as complex-span tasks, Tower of London, or the Wisconsin Card Sort test)

which require multiple EF skills

are often best for distinguishing between groups,

but, because they require multiple EF skills they are not good for isolating which particular EF skill improved.

Say the color of the ink that each set of X's is printed in as fast as you can.

XXX XXX XXX XXX XXX

XXX XXX XXX XXX XXX

Read the words below as quickly as you can.

green blue green red blue

green blue red green green

Say the color of the ink in which each word is written as fast as you can.

red blue green green blue

blue red green red blue

Say the color of the ink in which each word is written as fast as you can EXCEPT when there is a box around the word. When there's a box around the word, read what the word says as fast as you can.

green $\boxed{\text{blue}}$ green red $\boxed{\text{blue}}$ $\boxed{\text{green}}$

blue $\boxed{\text{blue}}$ green $\boxed{\text{green}}$ $\boxed{\text{blue}}$ red

It matters critically HOW a task is done, e.g., whether trials were administered in single-task blocks or in mixed-task blocks.

If a study says they measured EFs or WM, do not take their word for it.

LOOK at what tasks they used & HOW those tasks were administered.

The devil is in the details, and people who say they used Task X may have administered very different tasks or critically different versions of X.

To see a full-blown Stroop Effect compare performance on color-naming trials in a mixed block to performance on word-reading trials in a single-task block

green $\boxed{\text{blue}}$ green

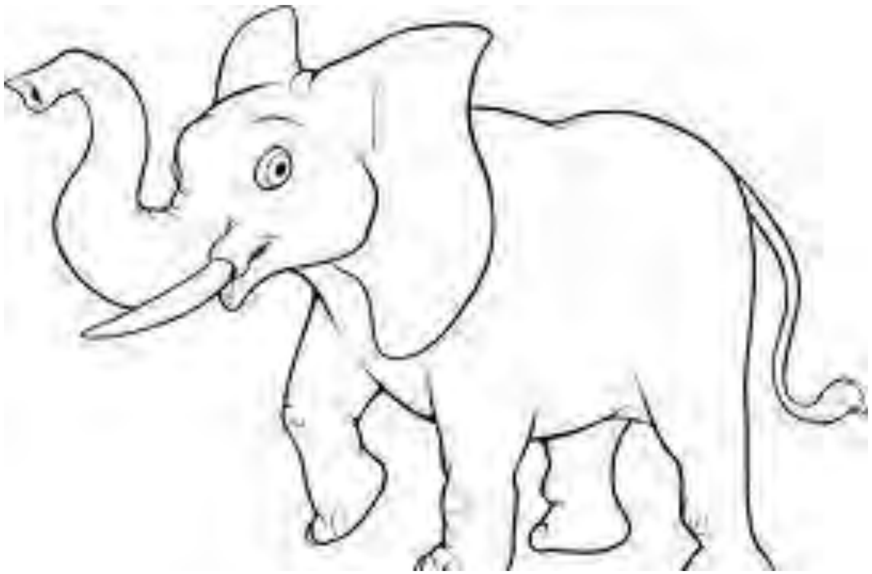
re: Delis-Kaplan battery

A kind of Stroop task.

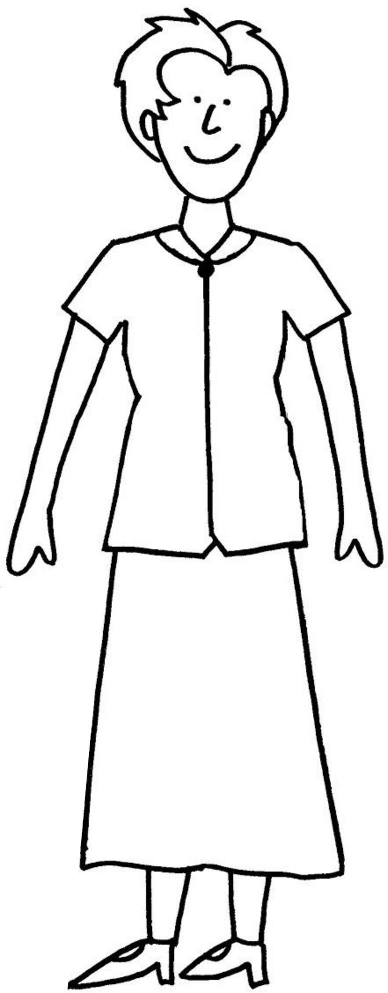
Which one is

BIGGER ?

For example:



Another example:



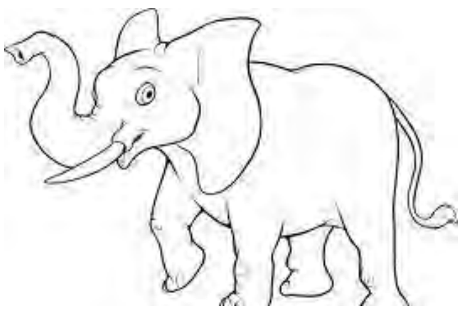
And another:

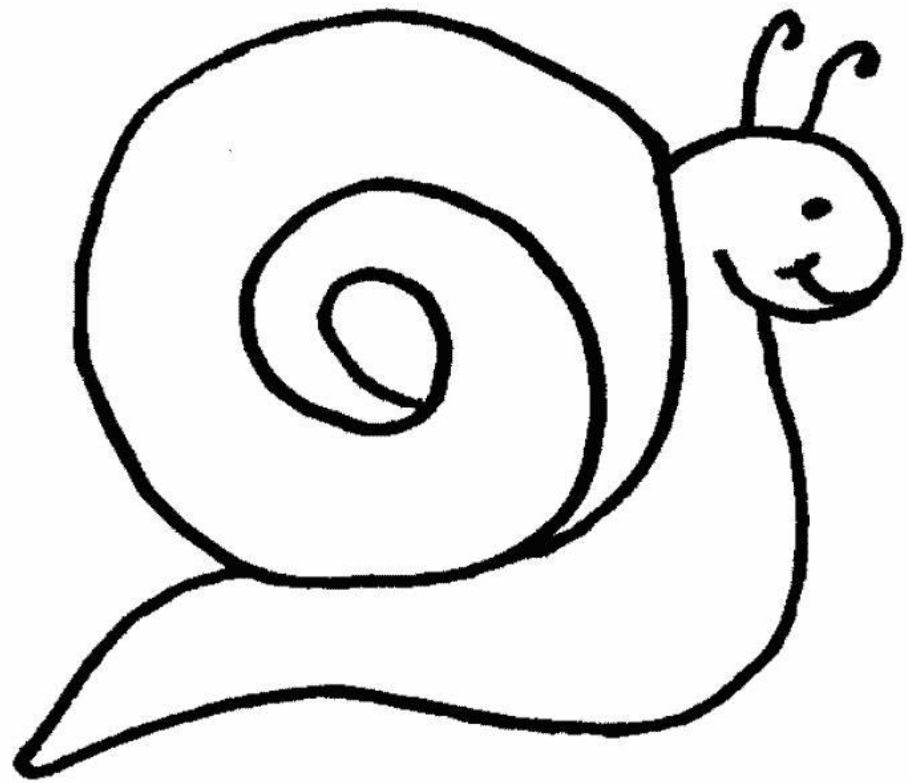
Now, you need to go by the objects REAL size,

NOT the size in the drawing.

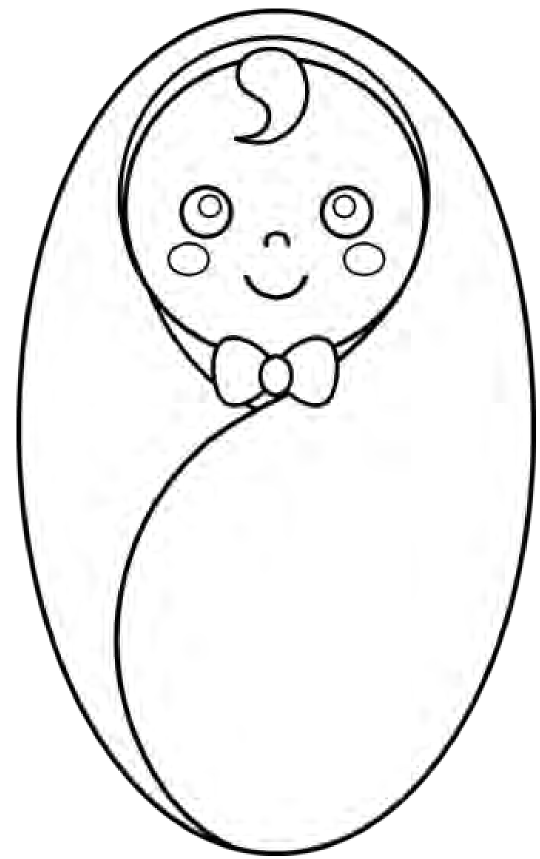
Show them examples:

For example:

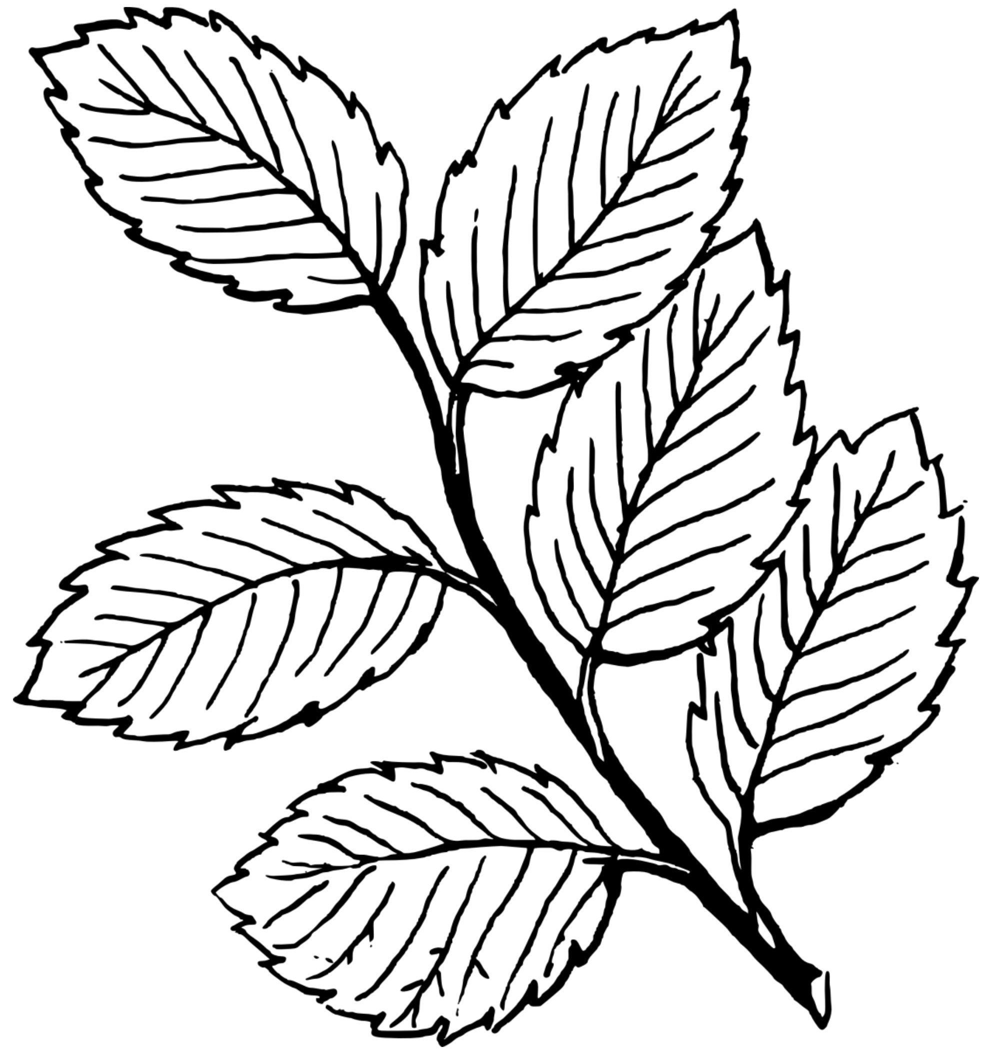




Another example:



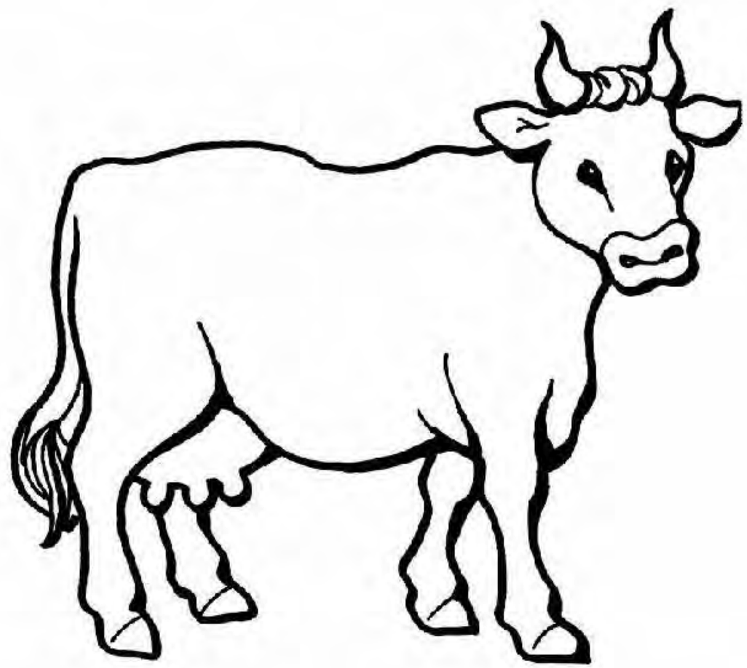
And another:

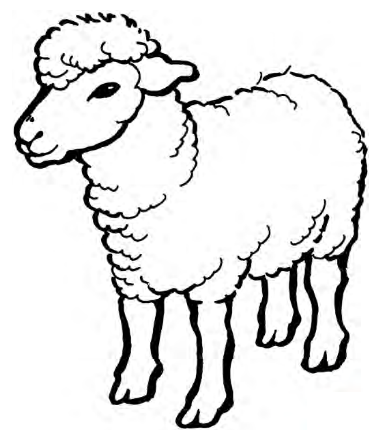


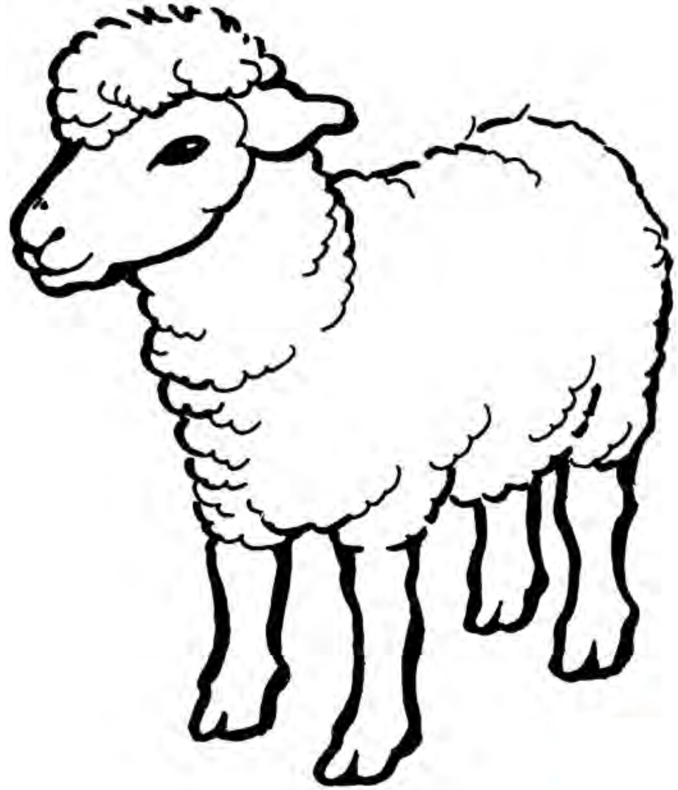
Then a Mixed Block.

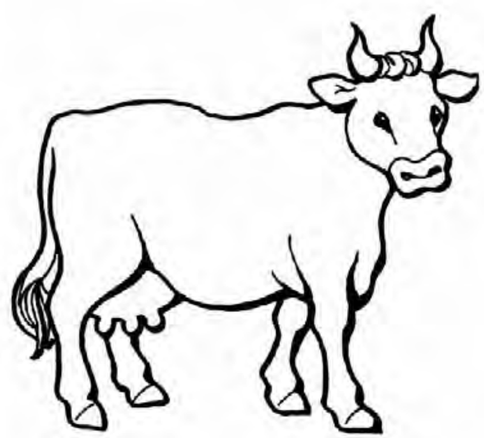
Some are the correct sizes

but some are opposite sizes.









NUMBER STROOP

Which number is the bigger numeral value?

2

6

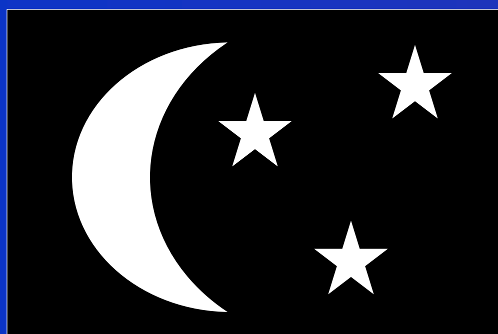
6

2

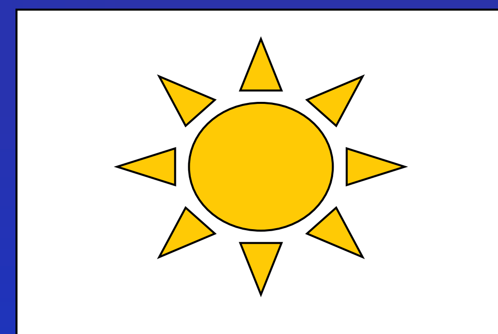
THE DAY-NIGHT TASK

(Gerstadt , Hong, & Diamond, 1994)

Semantically conflicting labels



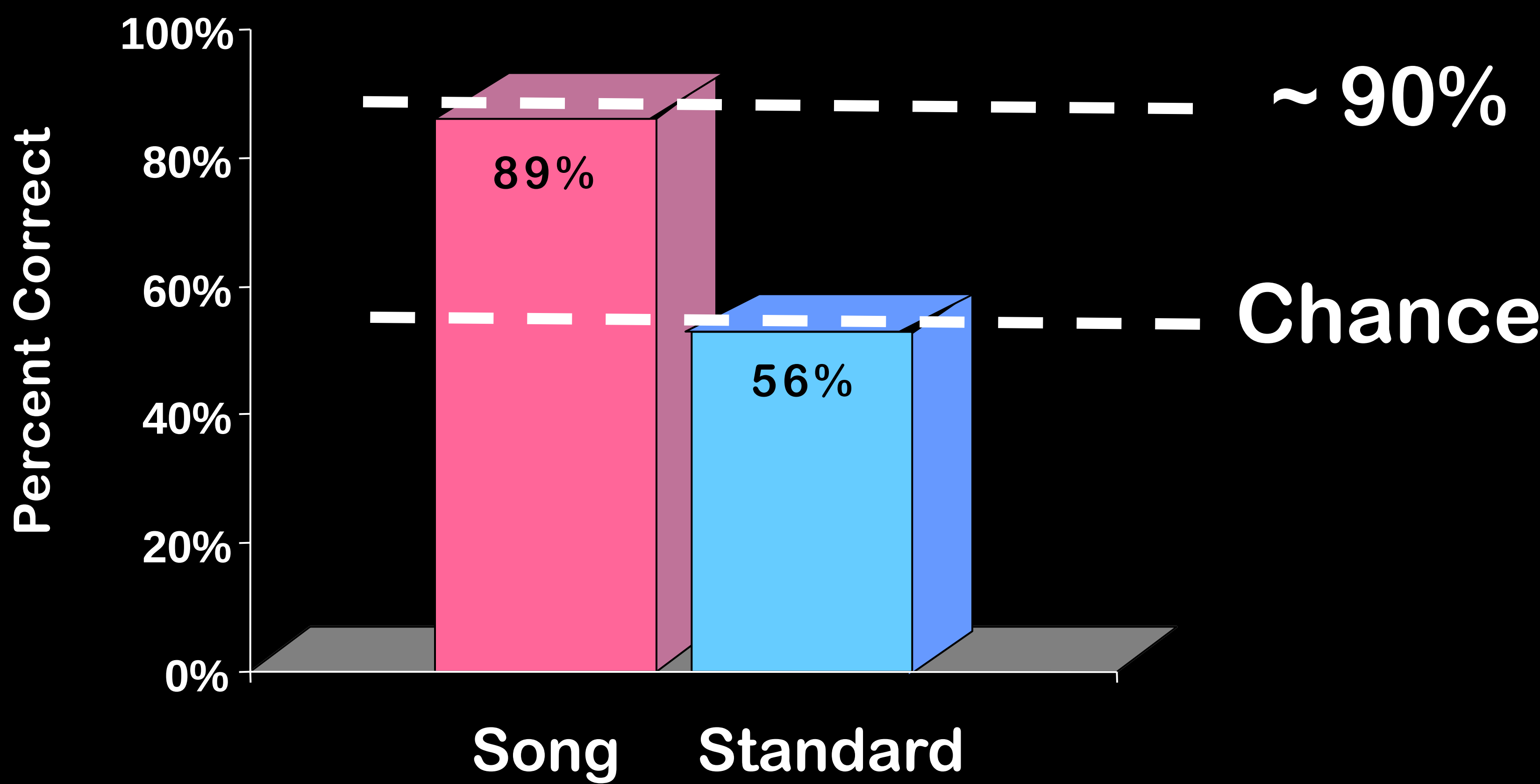
"Day"



"Night"

Requires holding 2 rules in mind, and inhibiting saying what the images really represent, saying the opposite instead.

Percentage of Correct Responses by 4-Year-Old Children on the Song and Standard Conditions of the Day-Night Task



See VIDEO at:

www.devcogneuro.com/

videos/daynight3.wmv

My thanks to the NIH (NIMH, NICHD, & NIDA), which has continuously funded our work since 1986, & to the Spencer Fdn, CFI, NSERC, & IES for recent support our work - and especially to all the members of my lab.

thank you so much for your attention

adele.diamond@ubc.ca

Jelena Obradovic

Children with better inhibitory control

(i.e., children who were more persistent, less impulsive, & had better attention regulation)

later as teenagers,

were LESS likely to

- **make risky choices,**
- **have unplanned pregnancies, or**
- **drop out of school**

and

and as adults 30 years later were found to have:

- better health
- higher incomes and better jobs
- fewer run-ins with the law
- a better quality of life (happier)

than those with worse inhibitory control as young children,

controlling for IQ, gender, social class, & home lives & family circumstances growing up across diverse measures of self control.

That's based on a study of 1,000 children born in the same city in the same year followed for 32 years with a 96% retention rate.

by Terrie Moffitt et al. (2011)

Proceedings of the Nat'l Academy of Sci.

Of 500 fraternal twin pairs, the twin with poorer self-control at age 5 was more likely to smoke, do poorly in school, and engage in aggressive or antisocial behavior at age 12, though each pair grew up together.

Wong et al. (2010) in *Epigenetics*

My thanks to the NIH (NIMH, NICHD, & NIDA), which has continuously funded our work since 1986, & to the Spencer Fdn, CFI, NSERC, & IES for recent support our work - and especially to all the members of my lab.