Utilizing Targeted Cognitive Training To Enhance Working Memory Capacity in College Students

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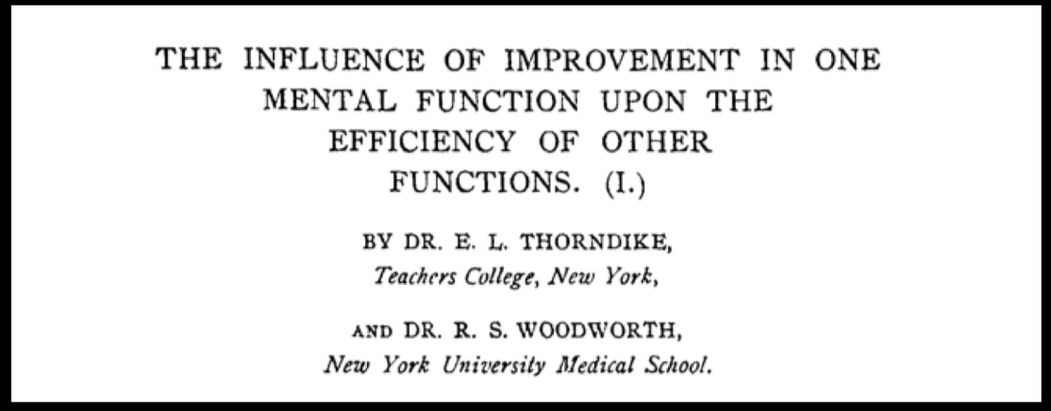
Cognitive Training

- Interventions designed to improve one's cognitive abilities
  - Will improvement on one task affect performance on another task?
  - Referred to as transfer effects

- Research on cognitive training is not new
  - Thorndike and Woodworth (1901, *Psychological Review*)



THE INFLUENCE OF IMPROVEMENT IN ONE MENTAL FUNCTION UPON THE EFFICIENCY OF OTHER FUNCTIONS. (I.)

BY DR. E. L. THORNDIKE,
Teachers College, New York,

AND DR. R. S. WOODWORTH,
New York University Medical School.

- Inexpensive computers, tablets, and smart phones have made training programs much more accessible

- There are now numerous commercial cognitive training programs that are available

lumosity

Fit Brains
by Rosetta Stone®

COGMED

mindsparke
think. work. feel. better.

BrainTrain
CHANGING THE WAY PEOPLE THINK

Jungle Memory™
Train your child's brain!

PositScience®
Brain HQ

Cognitive Training

- Programs claim to improve any number of cognitive abilities
- From Lumosity's Website:

"Based on extensive research, Lumosity improves **memory**, **attention**, **processing speed**, and **problem-solving skills** so you can feel more confident in your abilities."

- Present study focused on working memory training and potential transfer to general fluid intelligence (Gf) in college students

Short-term Memory vs. Working Memory

- Short-term memory: The amount of information a person can simply retain or a brief interval of time
  - Measured by simple span tasks
  - Longest list of verbal or visuo-spatial items that a person can recall in serial order

- Working memory: Central component of general cognition; involves both the storage and processing of information

- Working Memory Capacity (WMC): The efficacy with which working memory functions
    - Measured by complex span tasks
    - Predictor of cognitive ability (Daneman & Merikle, 1996; Unsworth & Engle, 2007)
    - Related to the ability to reason with novel information (Gf)

Short-term Memory vs. Working Memory

- Working Memory Capacity (WMC) - cont.
    - Related to attentional control (Engle, 2002), particularly when prepotent responses must be overcome in the face of an unsupportive environment (Shipstead et al., 2013)
    - Complex span tasks “measure a dynamic working memory system that involves both the storage and processing of information, in contrast to simple span tasks, which measure a short-term memory capacity that involves storage only.” (Redick et al., 2012, p. 164)

Evidence for WM Training?

- Review paper recently by published by Shipstead et al. (2012) in *Psychological Bulletin*

- Thirteen published studies that have examined WM training in young adults

- Overall: Little evidence that training programs based on simple/complex span tasks change the WM of young adults

- Very little (if any) evidence of far transfer to Gf

- Shipstead et al. identified four general concerns with these studies:

    1. **Inadequate measurement of abilities**: In most studies, abilities are measured via a single task

2. **Conflation of working memory and short-term memory**: In many studies, transfer to WM is measured via simple span tasks

3. **No control group or wrong type of control group**: Several WM training studies have been conducted without a control group, or a “no-contact” control group
   - 9 no-contact control group;1 no control group
   - others compared healthy adults to an ADHD-diagnosed control group from a separate experiment
   - No control over Hawthorne/placebo effects
   - Recommend using an adaptive control group

4. **Use of subjective measures**: Many studies use subjective measures to assess transfer.
   - Participants may expect to improve; such expectations can have a powerful effect
   - People are generally poor at assessing their own cognitive processes

Redick et al. (2013)

- Examined WM training in young adults using an approach that addressed the methodological and theoretical concerns identified by Shipstead et al. (2013)

- Used multiple measures of cognitive abilities that represent the theoretical constructs of interest

- Used an adaptive control group and a no-contact control group

- Although improvement was found in the training task, there was no evidence of transfer to any of the ability measures

- Despite no evidence of objective change, participants reported subjective improvements on various aspects of cognition

Present Study

- Purpose of the present study was to examine the effectiveness of WM training in college students who possess relatively low WMC, using placebo controlled, randomized design

- Rationale

  - Some of the strongest evidence for effective WM training comes from studies that have focused on children with WMC deficits

  - Eugene Wong's lab has found evidence of positive transfer using children with various forms of learning disabilities

  - There have been very few studies, if any, that have examined WM training in college students who possess low WMC

  - Present study involved three phases: Pretest, Training, Posttest

Pretest Phase

Participants

- 108 CSUSB students
- Recruited through the psychology department research management system (SONA)
- Participants received partial course credit for their participation
- Mean age = 24.2 years (*SD* = 5.6; 18 - 50 years)
- 100 females, 8 males
- 67% Hispanic, 9% Caucasian, 10% Asian, 7% African-American, 6% Other, 1% Unidentified
- 6 Freshman, 12 Sophomores, 37 Juniors, 53 Seniors
- Mean GPA = 2.92

Pre-Test Schedule of Tasks

- Two, 1-hour sessions

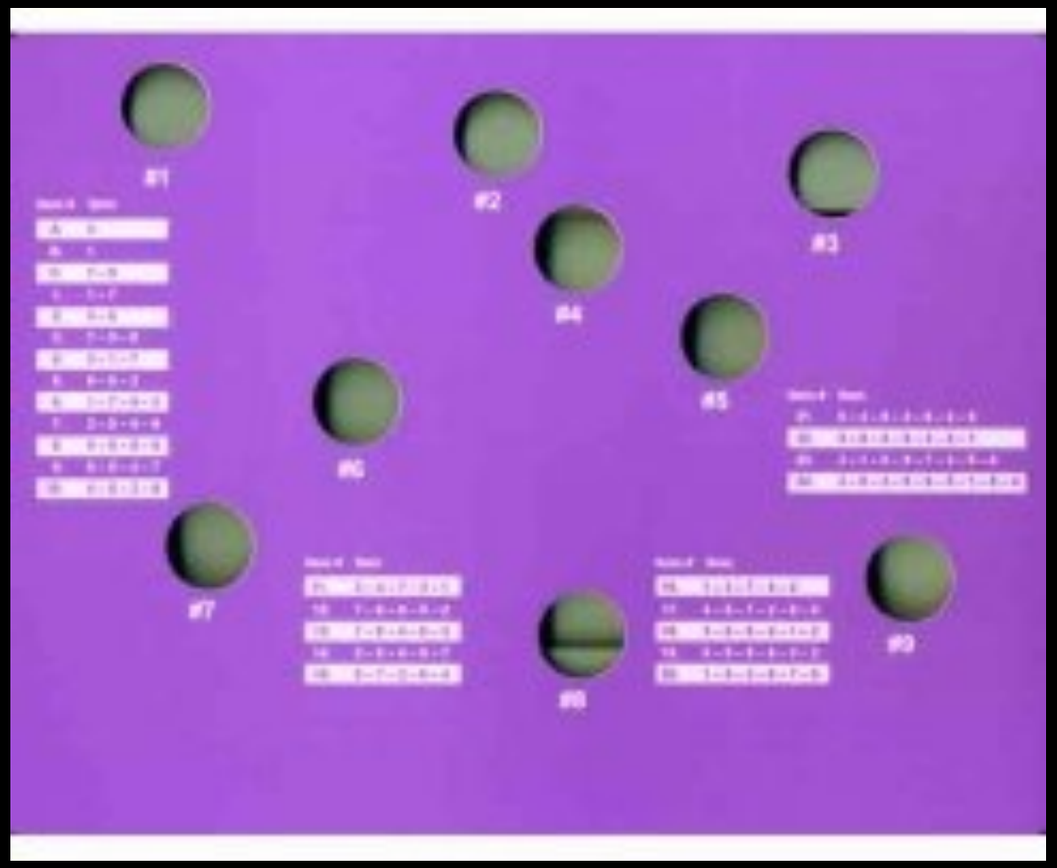
Session 1 (60 min)	**Session 2** (56 min)
1. Questionnaire (5 min)	1. Symmetry Span (15 min)
2. O-Span (25 min)	2. WRAML Number Letter (10 min)
3. WRAML Finger Windows (10 min)	3. WRAML Symbolic Working Memory (10 min)
4. WRAML Verbal Working Memory (10 min)	4. Inferences (9 min)
5. Letter Sets (10 min)	5. Raven (12 min)

WRAML Subtests

- Wide Range Assessment of Memory and Learning
- Standardized test
- The WRAML is normed for individuals ages 5–90 years
- Measures both immediate and delayed memory ability and the ability to learn new information
- We used four memory subtests:
  - Finger Windows
  - Number Letter
  - Verbal Working Memory
  - Symbolic Working Memory

WRAML Finger Windows

- Simple spatial WM task
- Participant must repeat a spatial pattern using their finger
- 1 item/second
- 24 items
- Examiner: 7-4-2-8-4-5-3



WRAML Number Letters

- Simple verbal WM task
- Participant is verbally presented with a sequence of numbers and letters and must verbally repeat the sequence back in the same order
- 1 item/second

  Examiner: 7-C-2-8-B-5-3
- 25 items

WRAML Verbal Working Memory

- Complex WM task
- Participants are verbally presented a list of animals and non-animals

  Examiner:
  "nail, elephant, lake, crab, kangaroo"

- Repeat animals first, small to large, then non-animals small to large

  Participant:
  "crab, kangaroo, elephant, nail, lake"

- 14 items

WRAML Symbolic Working Memory

- A series of numbers and letters are presented

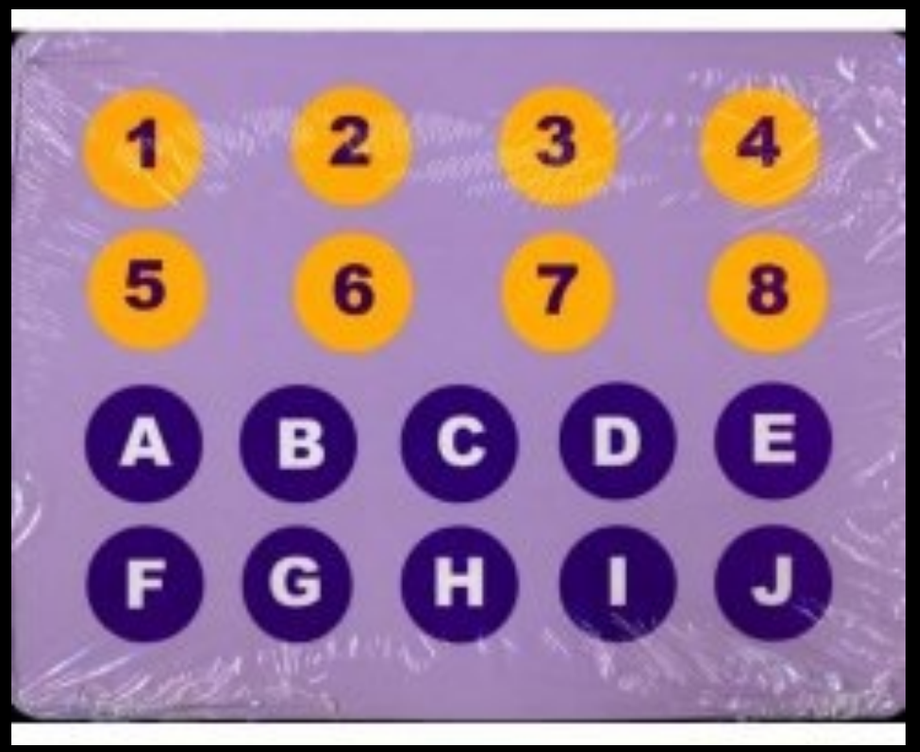
- Auditory input, non-verbal response

  Examiner:
  "3-B-D-7-A-4-1"

- Participant must point to numbers first, small to large, then letters in alphabetical order

- Complex span task???

- 28 items



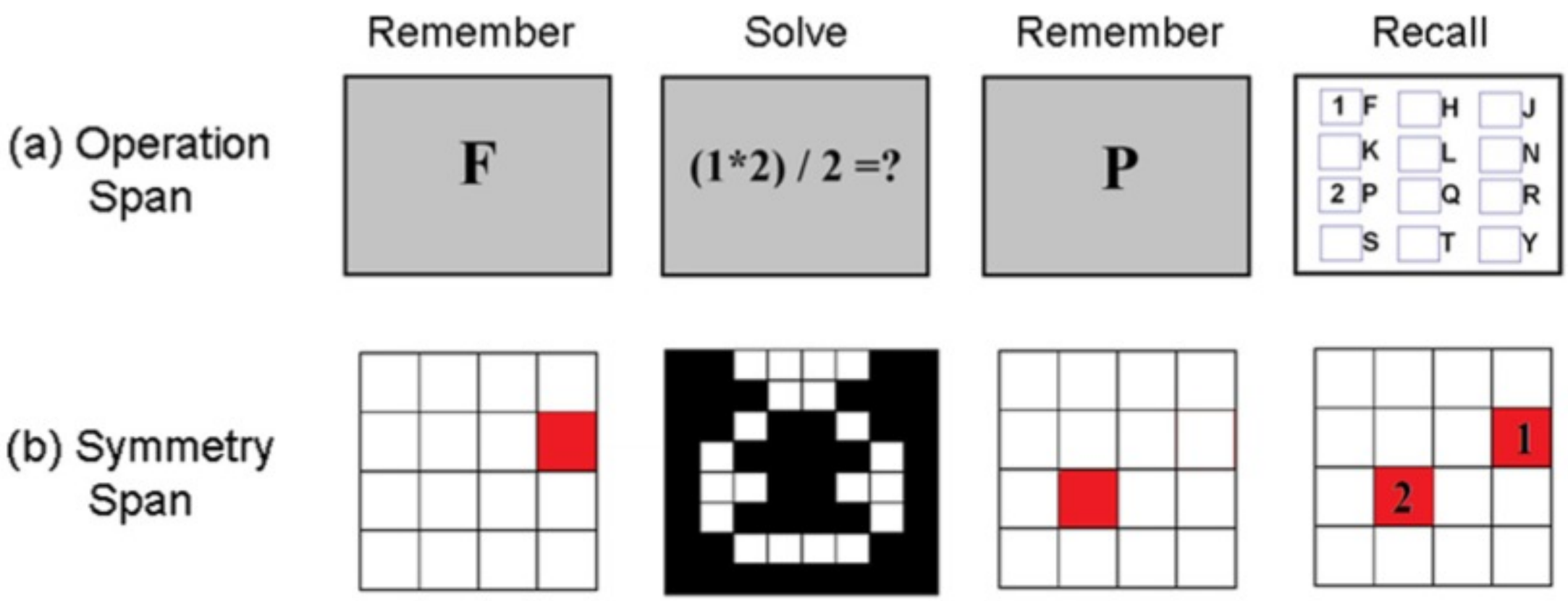
Complex Span Tasks

- Measure working memory capacity, i.e., involves *both* the storage and processing (manipulation) of information

- Tasks reflect the ability to temporarily maintain goal-relevant information in primary memory and to retrieve information from secondary memory

- Information must be protected from interference

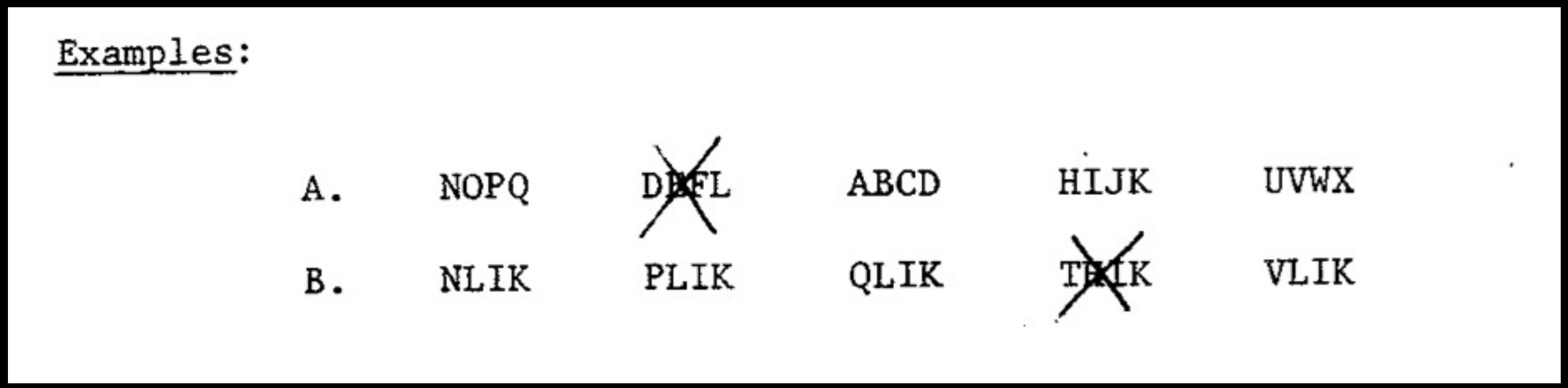
- We used two:
  - Verbal CST: Operation Span Task (OSPAN)
  - Spatial CST: Symmetry Span Task (SSPAN)



- Each set has three to seven letters
- Partial storage score: The sum of items recalled in the correct serial position, regardless of whether the entire set was recalled correctly

Gf Intelligence - Letter Sets

“Each problem in this test has five sets of letters with four letters in each set. Four of the sets of letters are alike in some way. You are to find the rule that makes these four sets alike. The fifth letter set is different from them and will not fit this rule. Draw an X through the set of letters that is different.”



Examples:

A.	NOPQ	DEFL	ABCD	HIJK	UVWX
B.	NLIK	PLIK	QLIK	TRIK	VLIK

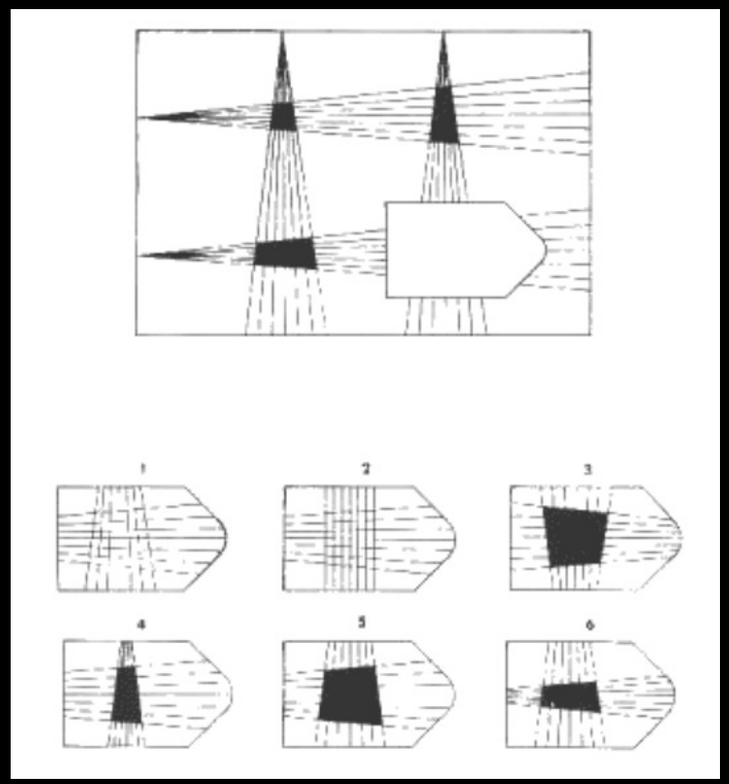
Gf Intelligence - Inferences

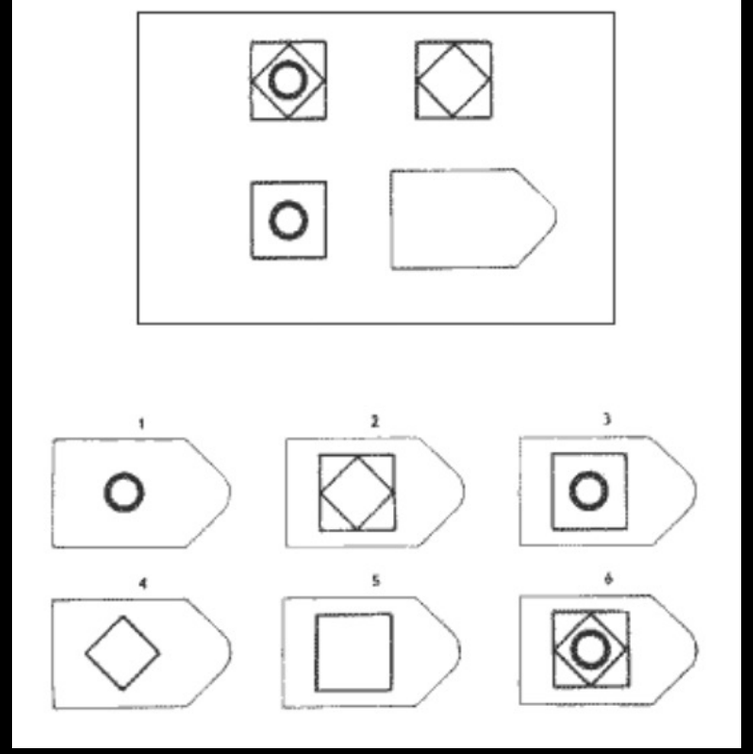
"In each item on this test you will be given one or two statements such as you might see in newspapers or popular magazines. The statements are followed by various conclusions which some people might draw from them. In each case, decide with conclusion can be drawn from the statement(s) without assuming anything in addition to the information given in the statement(s). There is only one correct conclusion."

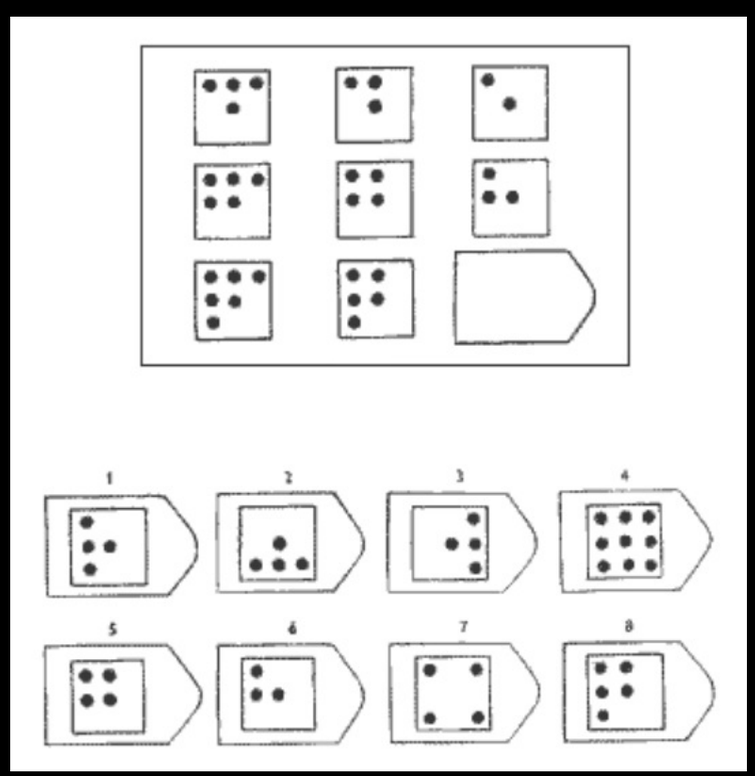
Bill, a member of the basketball team, is 6 feet, 2 inches tall and weighs 195 pounds. To qualify for the team, a person must be at least 5 feet, 10 inches tall.

1 - The larger a man is, the better basketball player he is.
2 - Basketball players are often underweight.
3 - Some players on the team are more than 6 feet tall.
4 - Bill is larger than the average man.
5 - The best basketball players come from the ranks of larger-than-average men.

Gf Intelligence - Raven Advanced Progressive Matrices







- “Your task is to select the piece that fits into the pattern cor

Pretest Results/Training Phase Selection

- Scores from each measure were calculated for each participant
- Selected participants who scored low on the pretest measures relative to others in the sample
- Composite scores calculated for each participant based on all the tasks
- Identified 54 participants who possessed relatively low working memory capacity as indicated by the OSPAN/SSPAN tasks and the WRAML Verbal WM and Symbolic WM tasks

Pretest Results/Training Phase Selection

- 54 participants invited to participate in the training phase, 34 participants volunteered
- 17 participants randomly assigned to and experimental condition (WM-based cognitive exercises)
- 17 randomly assigned to control condition (non-WM-based cognitive exercises)
- Exercises in both conditions were adaptive

Training Phase

Participants

- 34 CSUSB students
- Mean age = 23.8 years (*SD* = 5.8; 18 - 50 years)
- 31 females, 3 males
- 67% Hispanic, 7% Caucasian, 7% Asian, 9% African-American, 10% Other
- 1 Freshman, 6 Sophomores, 13 Juniors, 14 Seniors
- Mean GPA = 2.88

Training Phase

- Began the second week of the Winter 2014 quarter
- Nine weeks, 18, 1 hr 15 min sessions (2/week)
  - Total Training = 22.5 hours
- Each participant was assigned a computer that kept track of their training program (experimental or control) and progress
- Participants were trained in groups of four
- Groups were formed based on their availability so they were composed of both participants in the experimental and control conditions
- Training software:
  BrainTrain

- BrainTrain claims that 20 different cognitive skills can be trained using the MindPower Builder System:

Alternating Attention
Auditory Processing Speed
Central Processing Speed
Conceptual Reasoning
Divided Attention
Fine Motor Control
Fine Motor Speed
Focused Attention
General Attention
Immediate Memory
Response Inhibition
Selective Attention
Sustained Attention
Visuospatial Classification
Visuospatial Sequencing
Visual Perception
Visual Processing Speed
Visual Scanning
Visual Tracking
Working Memory

- BrainTrain uses a set of 50 different “games” or exercises in order to train the 20 cognitive skills

- On average, each exercise corresponds to approximately 5 cognitive skills

- **Ten** exercises that included a prominent working memory component
  - 5 trained auditory WM and 5 trained visual WM
  - Experimental condition

- **Ten** exercises that did not include a working memory component
  - 3 Conceptual Reasoning; 1 Logic Skills; 4 Visual Motor Skill; 2 Visuospatial Processing Speed/Classification
  - Control condition

Experimental Exercises:	Control Exercises:
Working Memory	**--**
--	Alternating Attention
Auditory Processing Speed	--
Central Processing Speed	Central Processing Speed
Conceptual Reasoning	Conceptual Reasoning
--	Divided Attention
Fine Motor Control	Fine Motor Control
--	Fine Motor Speed
--	Focused Attention
General Attention	General Attention
--	Immediate Memory
--	Response Inhibition
--	Sustained Attention
Visual Perception	Visual Perception
--	Visual Processing Speed
Visual Scanning	Visual Scanning
--	Visual Tracking
--	Visuospatial Classification
--	Visuospatial Sequencing

Training Phase

- All exercises were adaptive - the difficulty increased as participants progressed through each stage
  - “Adult” track was used
  - Three levels of difficulty - Easy, Medium, Hard
  - 15 stages within each difficulty level

- All exercises in each condition began at the same level of difficulty - Easy, Stage 1

- Criterion for stage advancement was based on time or accuracy
  - “Must complete a task in under 3 minutes”
  - “Must maintain an accuracy rate of at least 85%”

- If a participant failed to meet the criterion on two consecutive attempts, they would revert back to the previous stage

Training Phase

- Within each training session, participants completed three, 24 minute training periods
- Enough time in each training session to complete approximately 24 total exercises
- Participants were paid $10/hour
- $250/participant total for their participation (including training and pre- and post-testing)

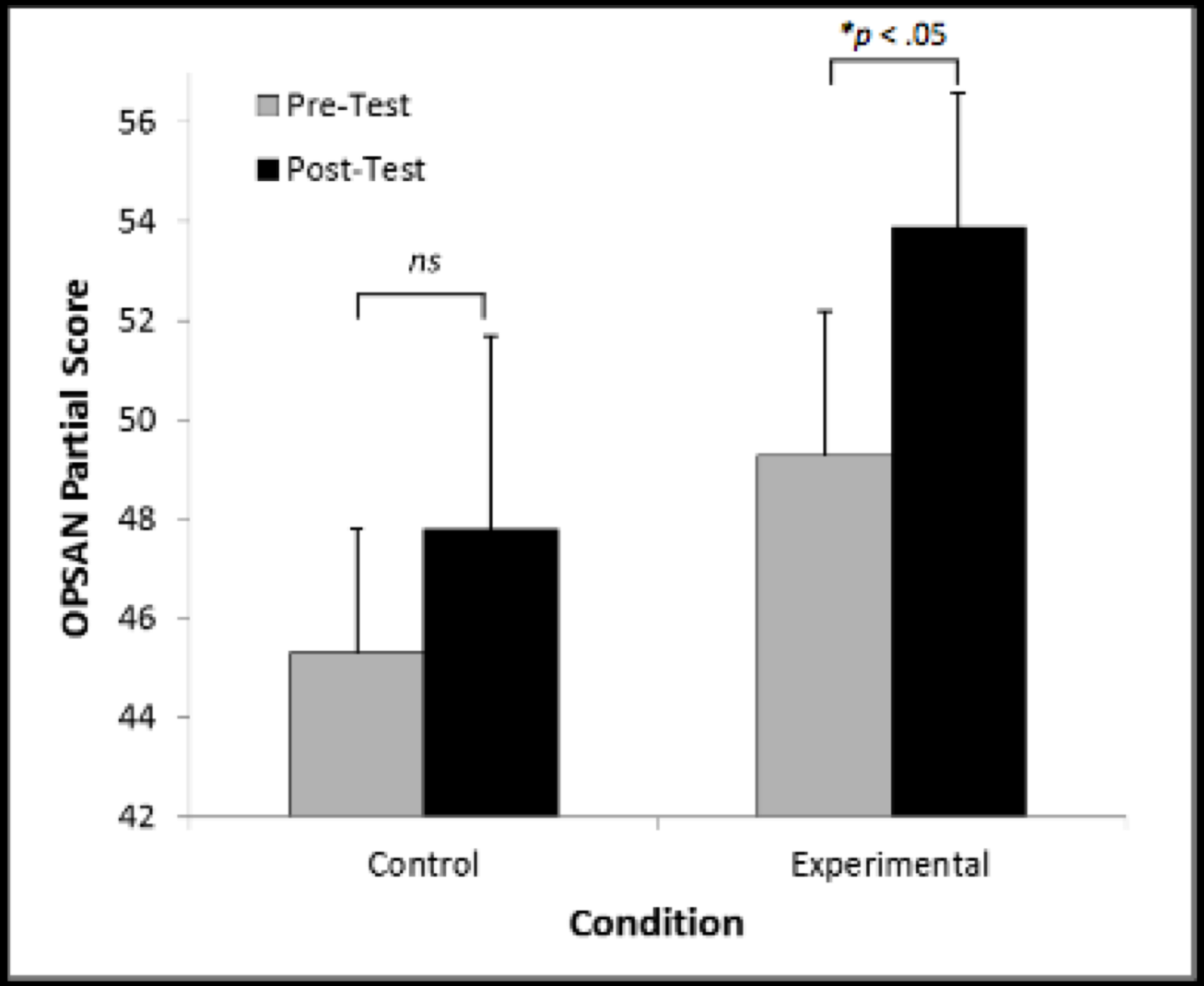
Posttest Phase

- Post-testing began after participants completed training
- Each participant completed the same pretest measures
- The average amount of time between the end of training and the first posttest session was 6.5 days (*SD* = 3.6)

- Experimental condition *N* = 16
  - 1 late posttest session (21 days)
- Control condition *N* = 13
  - 2 dropped out before training
  - 2 dropped out during training

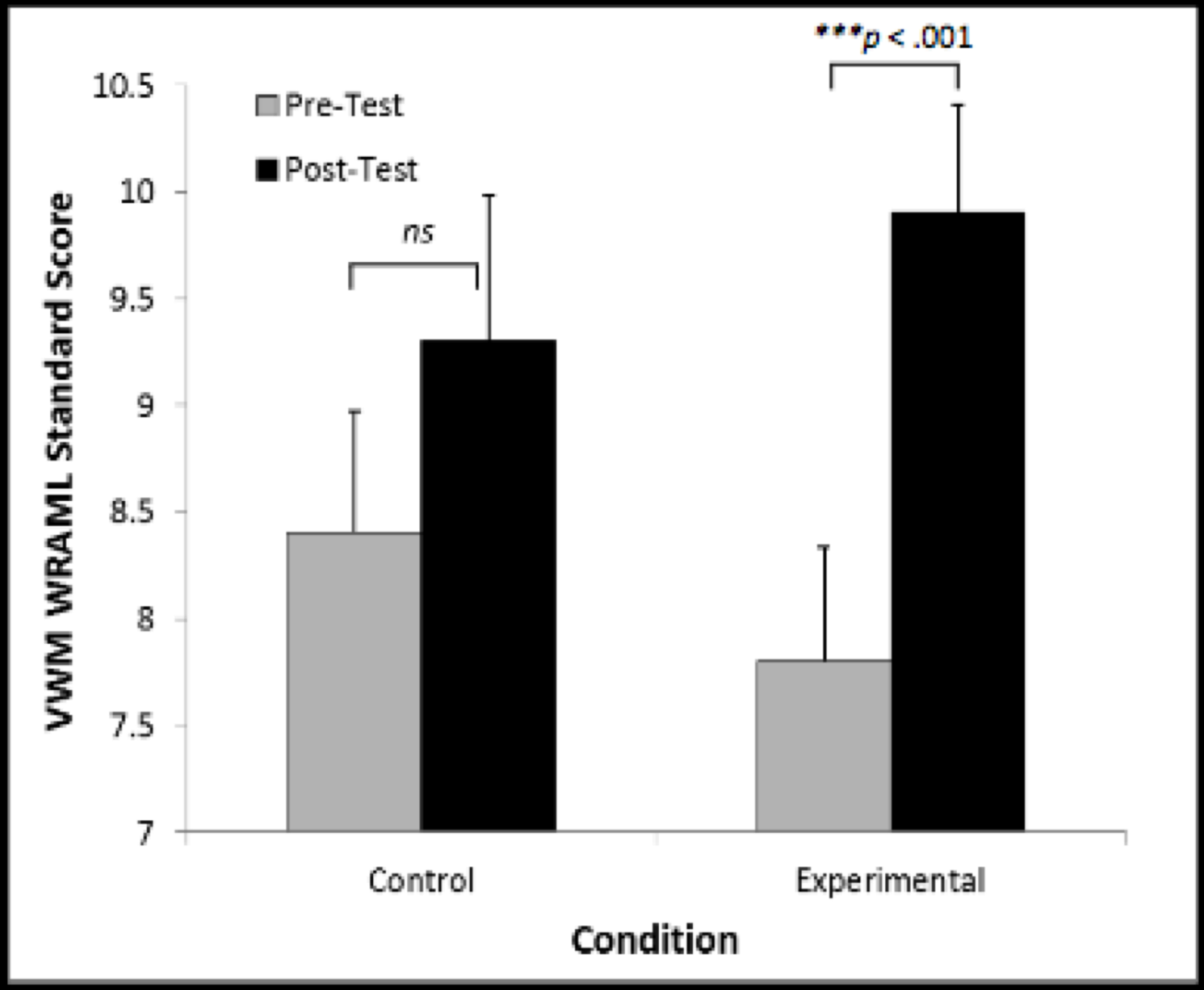
Results

- Calculated mean pre- and post-test scores for each participant in each condition across measures
- Compared the pre- and post-test scores of each measure separately for experimental and control conditions



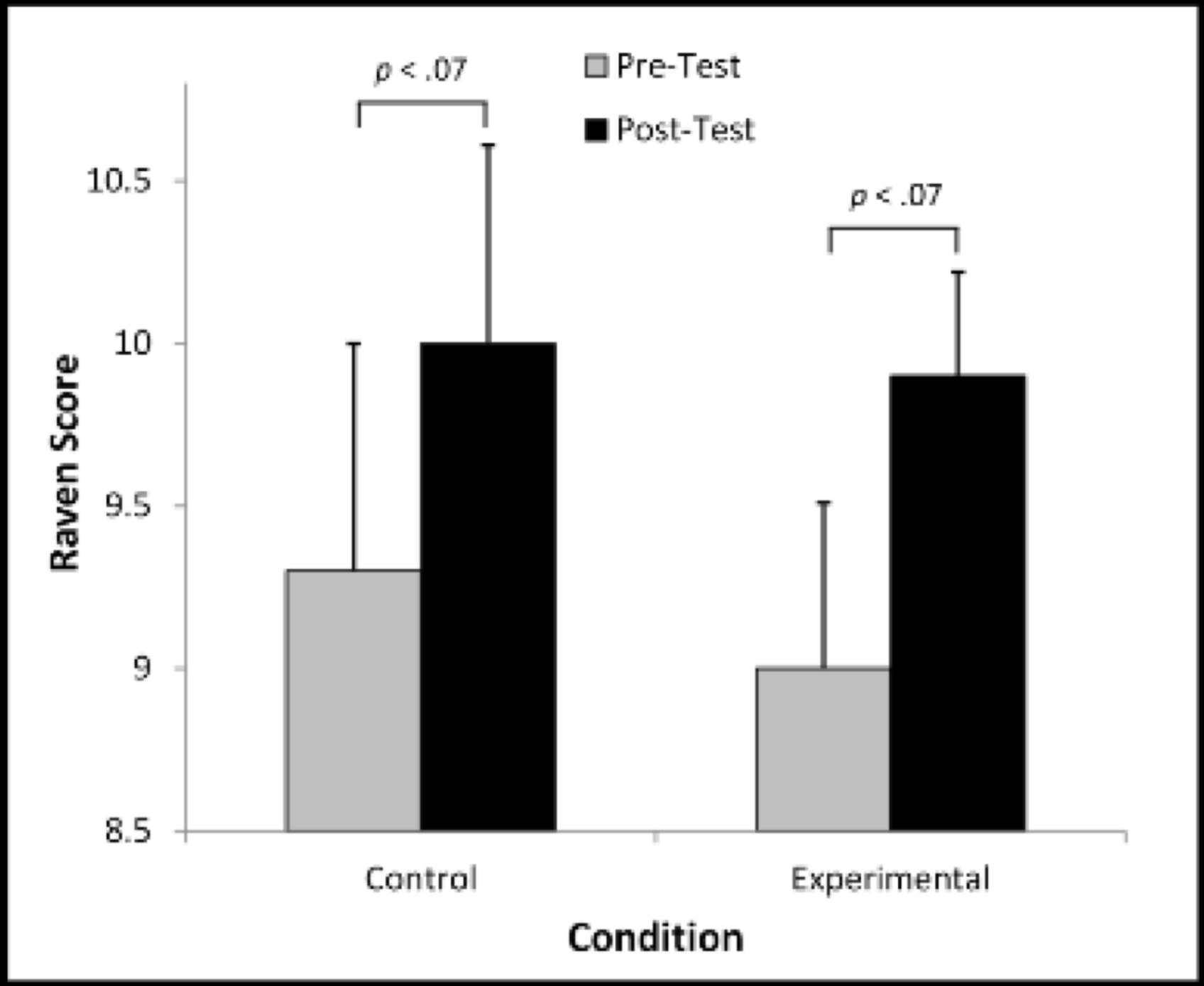
Experimental: $F(1,15) = 6.309$, $MSE = 27.13$, $p < .05$, $\eta_p^2 = .30$
Control: $F(1,12) = 1.057$, $MSE = 39.64$, $p = .32$, $\eta_p^2 = .08$

- Experimental group's performance was raised to average

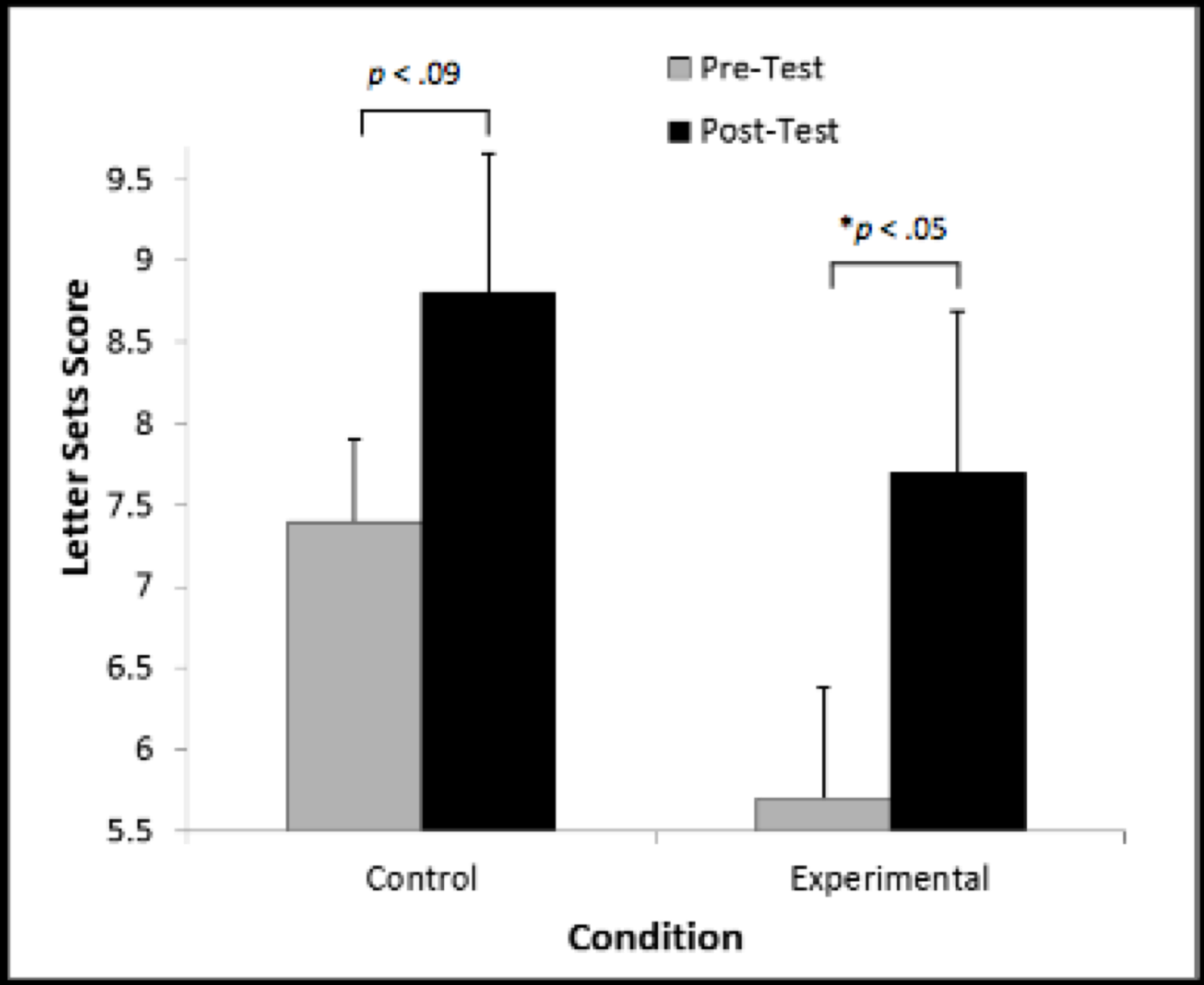


Experimental: $F(1,14) = 20.022$, $MSE = 1.705$, $p < .001$, $\eta_p^2 = .59$
Control: $F(1,11) = 1.244$, $MSE = 1.244$, $p = .29$, $\eta_p^2 = .10$

- Experimental group's performance was raised to average



Experimental: $F(1,15) = 3.840$, $MSE = 1.831$, $p < .07$, $\eta_p^2 = .20$
Control: $F(1,12) = 3.984$, $MSE = 0.782$, $p < .07$, $\eta_p^2 = .25$



Experimental: $F(1,15) = 6.920$, $MSE = 4.296$, $p < .05$, $\eta_p^2 = .32$
Control: $F(1,12) = 3.619$, $MSE = 3.598$, $p < .09$, $\eta_p^2 = .23$

Posttest Questionnaire Results

Likert-like scale was used:

1=Agree
2=Slightly Agree
3=Slightly Disagree
4=Disagree

	Control	Experimental
"I was focused and engaged during training"	*M* = 1.9	*M* = 1.5
"It was hard to stay engaged and focused during training"	*M* = 2.5	*M* = 2.7
"I enjoyed the games/training"	*M* = 2.3	*M* = 1.6*
"I gave my best effort during each training session"	*M* = 1.9	*M* = 1.6

Posttest Questionnaire Results

	Control	Experimental
<u>General Abilities</u>		
Ability to Remember Things	77%	81%
Perceptual Ability	77%	56%
Motor Skills	69%	44%
Ability to Process Information Faster	69%	75%
Ability to Reason	62%	69%
Ability to Pay Attention	62%	63%
Intelligence	46%	44%
<u>Academic Setting</u>		
“I feel smarter”	38%	25%
“Studying is easier”	54%	63%
“I feel more attentive”	46%	69%
“I started using strategies“	69%	81%

Conclusions

- One of the first studies to examine the effectiveness in college students with relatively low WMC
- Present study found evidence of strong positive transfer effects to WMC measures
- Mixed evidence of far transfer to Gf measures
- Results highlight the importance of using true control groups in pretest-posttest, training studies
- Caution should be used when using subjective measures. However, in conjunction with objective measure, they may be useful.

Future Directions

- Replicate with both psychology and non-psychology majors and include more males
- Examine the duration of the training effects
- Compare transfer effects in children, adolescents, and young adults in order to develop a longitudinal framework of WM training
- Compare students who possess low WMC with high WMC students
- Examine training effects in college students with diagnosed learning/attention-related disorders
- Examine the effects of WM training on academic performance - both GPA and academic achievement tests
- Explore how WMC relates to classroom instruction and learning

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