Artificial Synesthesia as a Cognitive Scaffold

Effects on Attention and Memory Across ADHD and Autism Traits

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PSY 499: Senior Thesis in Psychology

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Overview

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Digital Learning Environments

- Digital learning accelerated post-COVID-19 and educational technology is now central to universities
- Standard platforms rely on text-heavy, unisensory content that generates high extraneous cognitive load
- Cognitive Theory of Multimedia Learning shows that misaligned visual and auditory channels hinder encoding

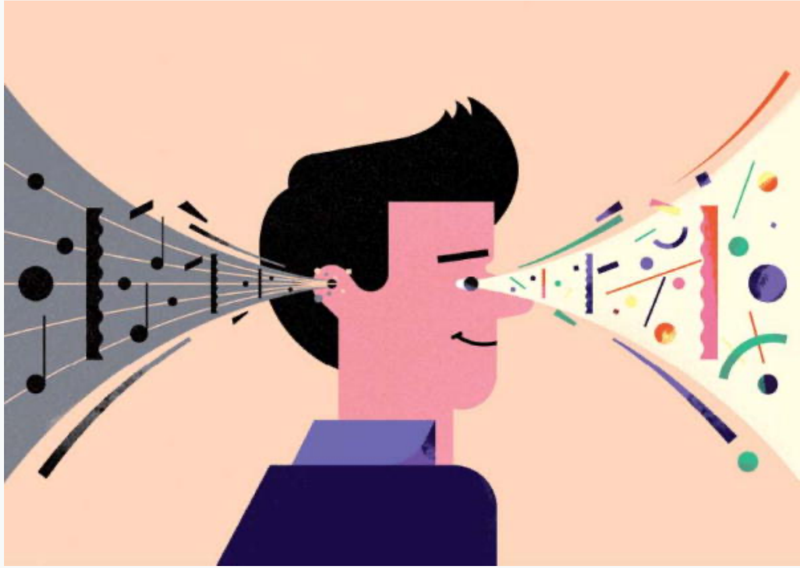
Key Concept

Extraneous Cognitive Load

The effort imposed by poor design that does not support learning. It depletes resources available for meaningful knowledge acquisition. (Sweller, 1988)

What is Synesthesia?

A neurological condition in which stimulation of one sense automatically triggers a perception in another.



Example: hearing a sound and automatically seeing a color

→ Stable, involuntary, and consistent over time

Theoretical Framework

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Synesthesia and Dual Coding

Grapheme-color synesthetes show superior memory via dual retrieval routes.

Cross-Modal Correspondences

Intuitive sound-color pairings produce faster and more accurate responses.

Multisensory Integration

Synchronous, congruent signals produce super-additive neural responses.

Neurodivergence as a Dimension

ADHD and autism traits measured continuously rather than categorically.

Research Question and Hypotheses

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Can artificial synesthesia based on cross-modal correspondences improve attention and memory performance, and how does this vary with individual ADHD and autism traits?

H1

Main Effect

The multisensory condition will produce significantly reduced Stroop interference and higher memory accuracy compared to the visual-only control.

H2

Differential Benefit

Synesthetic gain will positively correlate with ADHD and autism trait intensity, validating the intervention as a precision inclusion tool.

METHODS

Study Design and Procedure

- Within-subjects experimental design so that every participant served as their own control
- IV: Sensory condition
- DVs: Reaction time (rt) and accuracy (%)
- All sessions conducted on the researcher's laptop with calibrated headphones in a quiet room

Participants
N = 26

Age range
18 to 25

Trait measures
AQ-10 and ASRS

Session duration
20 min average

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Experimental Tasks

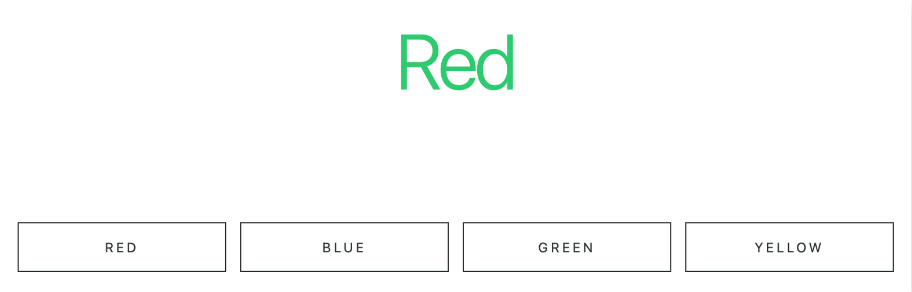
Stroop Color-Word Task

Purpose: Selective attention and interference control

Visual condition: Colored words only

Multisensory: Colored words paired with a congruent tone

Measures: Reaction time and accuracy



METHODS

Experimental Tasks

Paired-Associate Memory Task

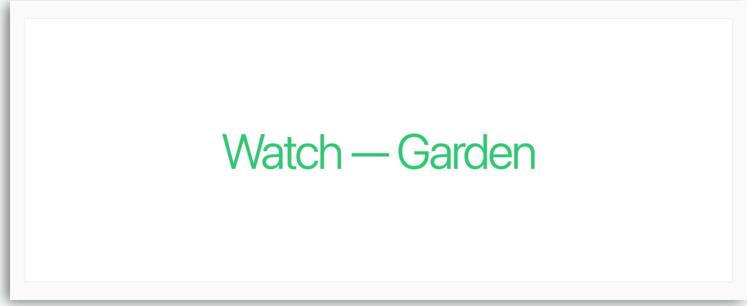
Purpose: Episodic memory and associative binding

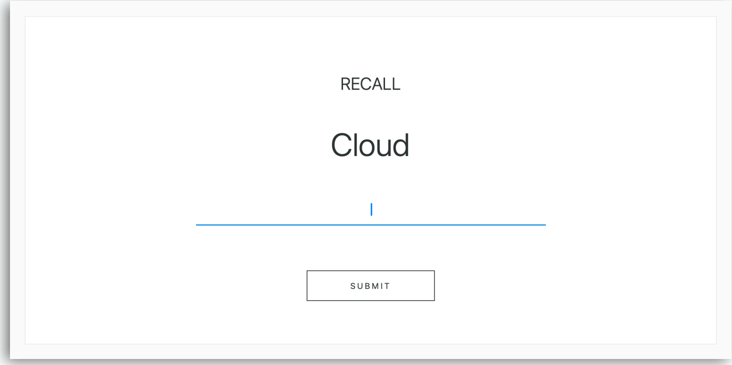
Encoding: Five unrelated word pairs

Multisensory: Colored words paired with a congruent tone

Retrieval: Cue word presented and participant types the paired word

Measures: Reaction time and accuracy





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RESULTS

Synesthetic Gain: Descriptive Overview (N = 26)

120 ms

Stroop RT change
(SD = 563 ms)

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Stroop RT change
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Stroop accuracy change (SD = 8.16%)

+525 ms

Memory RT change
(SD = 5,281 ms)

Synesthetic Gain: Descriptive Overview (N = 26)

120 ms	+1.15%	+525 ms	+8.46%
Stroop RT change (SD = 563 ms)	Stroop accuracy change (SD = 8.16%)	Memory RT change (SD = 5,281 ms)	Memory accuracy change (SD = 34.95%)

RESULTS

Synesthetic Gain: Descriptive Overview (N = 26)

120 ms	+1.15%	+525 ms	+8.46%
Stroop RT change (SD = 563 ms)	Stroop accuracy change (SD = 8.16%)	Memory RT change (SD = 5,281 ms)	Memory accuracy change (SD = 34.95%)

Key Takeaways from Descriptive Data

- Memory: extreme dispersion from -60% to +100% percent accuracy, meaning the intervention helped some and hindered others
- Memory task showed a speed-accuracy tradeoff: accuracy improved while reaction times increased
- No consistent group-level shift, suggesting the benefit is individualized rather than universal

RESULTS

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Inferential Statistics: One-Sample t-Tests vs. Zero

Variable	t	df	p-value
Stroop RT Change (ms)	1.09	25	**$p = .288$ n.s.**
Stroop Accuracy Change (%)	0.72	25	**$p = .478$ n.s.**
Memory RT Change (ms)	0.51	25	**$p = .617$ n.s.**
Memory Accuracy Change (%)	1.23	25	**$p = .229$ n.s.**

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H1 was not supported. No statistically significant main effects were found at the group level. The high variance points toward individual differences as the key driver.

H2: Differential Benefit by Trait Profile

ADHD Traits (ASRS)

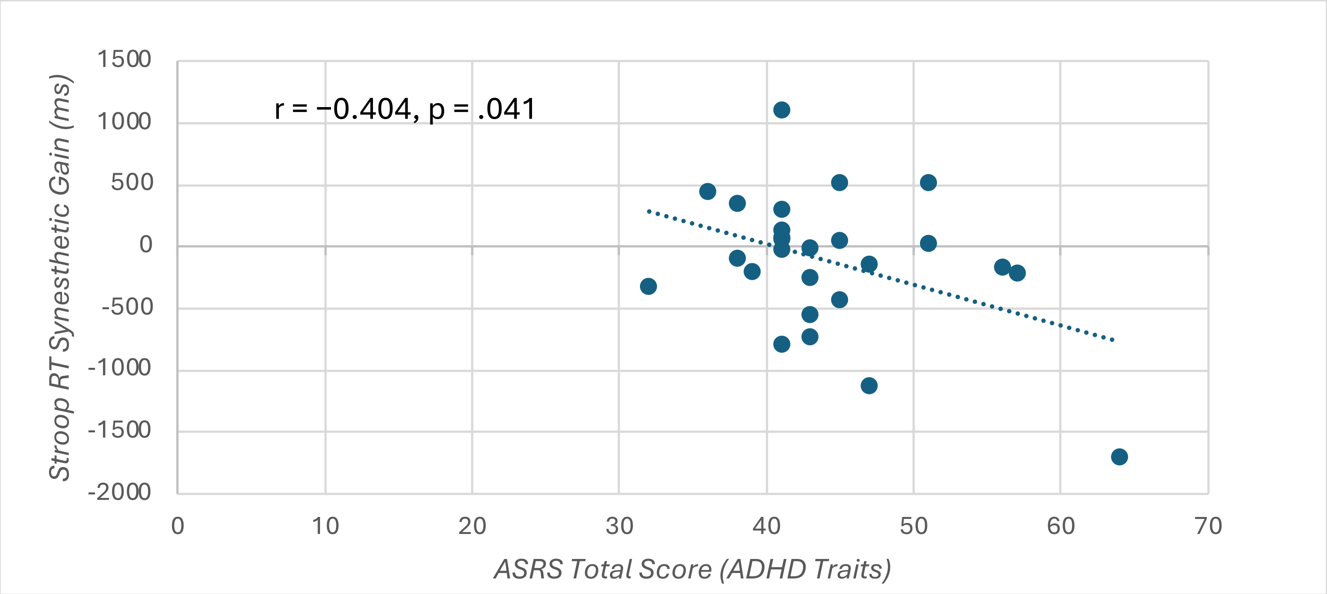
Significant correlation found

Higher ADHD trait scores predicted greater RT improvement on the Stroop task under multisensory conditions.

Interpretation: Congruent auditory signals act as external attentional stabilizers for systems with higher internal variability, which is consistent with arousal regulation models of ADHD (Barkley, 2012).

H2: Differential Benefit by Trait Profile

ADHD Traits (ASRS)



Discussion and Theoretical Implications

Not a universal enhancer

Artificial synesthesia does not uniformly boost performance.

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Arousal modulation over load reduction

Multisensory cues appear to regulate cognitive state rather than simply simplify content

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Speed-Accuracy Tradeoff in memory

Memory accuracy gains came at the cost of longer reaction times,

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Limitations

- Small sample of 26 participants limits statistical power
- Trait self-reports reflect subjective perception rather than clinical diagnosis
- Web-based delivery introduced some environmental variability despite researcher control
- A single participant with dyslexia could not be analyzed as an independent variable

Conclusions

1. Artificial synesthesia did not produce significant group-level effects on attention or memory tasks.
2. ADHD traits significantly moderated Stroop RT gain, which supports a precision-tool interpretation rather than a universal-enhancer one.
3. Autism traits showed no significant association, likely because enhanced local processing may limit cross-modal binding.
4. Speed-accuracy tradeoffs in the memory task suggest deeper and more deliberate encoding under multisensory conditions.
5. **Implication for EdTech: structured sensory cues should be deployed adaptively for learners with attentional vulnerabilities rather than applied broadly.**

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Thank You

Questions and Discussion

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Artificial synesthesia should be viewed not as a universal performance enhancer, but as a targeted compensatory mechanism for individuals with specific attentional vulnerabilities.