

# IMPACT OF LIGHTING COLOR TEMPERATURE ON COGNITIVE PROCESSES FOR AUTISTIC SUBJECTS

Cherif Amor, Ph.D; Ghizlane Bendriss, Ph.D;  
Haitham El Hammali, PhD; Ryad Ghanam, PhD;  
Edward Boone, PhD; Staci Carr, Ph.D; &  
Gawahar El-Khattib (RA).

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**vcuarts**  
QATAR

# RESEARCH TEAM: MULTIDISCIPLINARY PARADIGM

- **Architecture & Environmental Design (PI)**  
Cherif Amor—VCUarts Qatar
- **Cognitive Neuroscientist (Co-PI)**  
Dr. Bendriss, Weill Cornell
- **Cognitive Psychologist (collaborator)**  
Dr. Stacy Carr, VCU Center on Transition Innovations
- **VR Immersive Environment specialist (Co IS)**  
Dr. Haitham El-hammali VCUarts Qatar
- **Statistical and Data experts (collaborators)**  
Drs. Ryad Ghanem + Ed Boone, VCUarts Qatar + VCU Statistical Sciences
- **Research Assistant (RA)**  
Weill Cornell Jawahar El-Kattib

Multidisciplinary: Art/Design + Neuroscience + Cognitive Sciences + Immersive Environments + Data Science

# Environment, Behavior & Neuroscience Paradigm

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- **Environmental-related activities** (macro scale)  
wayfinding, proxemics, perception, cognition, etc.



- **Indoor environmental variables** (micro scale)  
(lighting, noise, ambient temperature, humidity, and air quality)



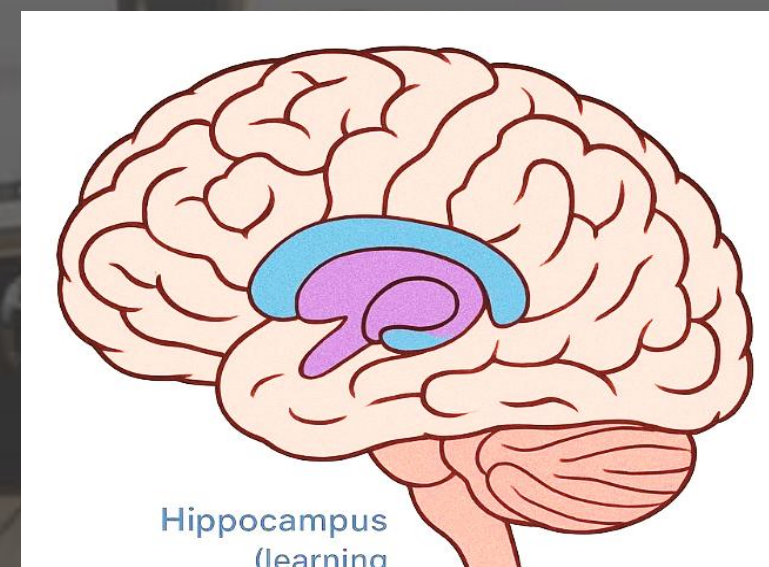
- **Behavioral & physiological consequences**  
(stress, anxiety, happiness, satisfaction, etc.)  
(increased heart rate, hypertension, high blood pressure)

# Precedents...

- **Behavioral Sciences:** Autistic subjects face challenges with the IEC (light, color, noise, proxemics, etc.) which generates stress, and subsequently weak cognitive skills (Elis & Yi, 2023; Karol & Smith 2019; Gaines, et. Al, 2014).
- **Neuroscience:** functional neuroimaging suggests increased neural activity of the brain areas associated with the visual cortex, and decreased neural activity in areas associated with cognitive processing (Bolton & Freta, 2020; Ludlow, Heaton, & Franklin, 2014).



Frontal Cortex--Cognition



Hippocampus (learning)  
Cingulate Cortex--Stress



Occipital Cortex--Vision

# Knowledge Gap

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- While behavioral precedents underscore that Autistic subjects face challenges with the IEC, little is known about the specifics of the color temperature and its lighting correlates.
- Neuroscience precedents indicate that seeing color activates the visual cortex but little is known about the neural activity under different Correlated Color Temperature— CCT.

# Statement of Need/Precedents

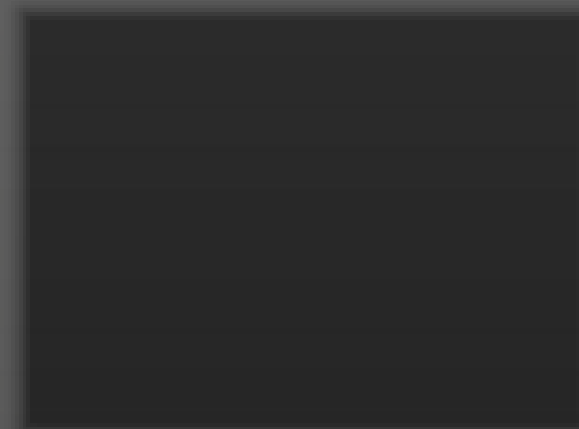
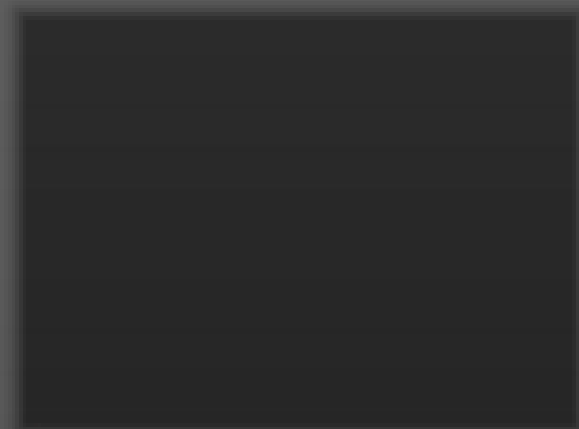
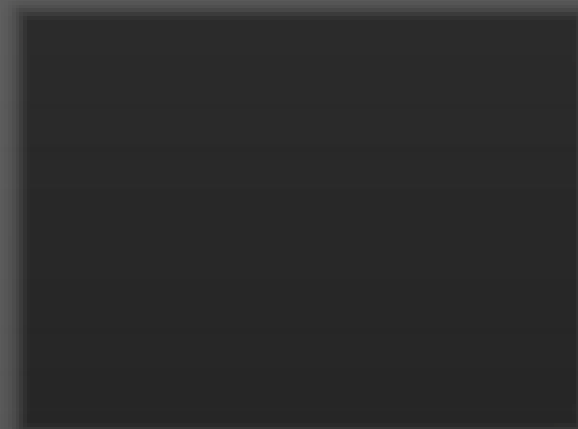
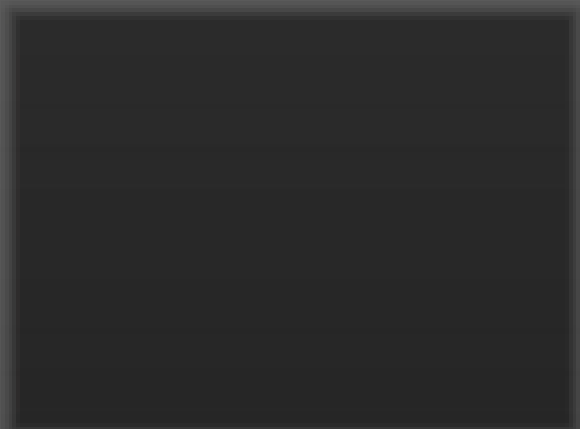
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- This line of inquiry finds justification in the fact that approximately **15-20% of the global population exhibits some form of neurodivergence**, which includes conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), dyslexia, dyspraxia, and dyscalculia (World Economic Forum, 2022).
- The Centers for Disease Control and Prevention (CDC) reports that about **1 in 36 children in the U.S. is diagnosed with ASD as of 2023**. This is a significant increase from previous years; the total number of people with autism is **estimated at 9.3 million** (US Government Accountability Office).
- The cost of autism in the United States is substantial and rising. In 2020, the total base cost was estimated to be around \$223 billion. **By 2026, it is expected to reach approximately \$589 billion annually**, and it is projected to exceed **\$1 trillion per year by 2040** (Journal of Autism and Developmental Disorders).

# Research Questions

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- Does lighting **color temperature** impact the activation of **the cognitive processes**, specifically the pre-frontal cortex (PFC)?
- Which **color temperature** is conducive to **favorable autistic learning environments**?
- Does **less favorable** lighting color temperature induce **stress**, which could inhibit **cognition** for autistic subjects?

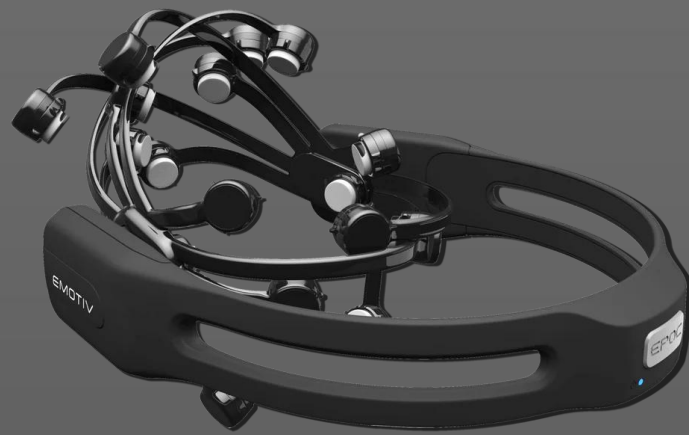


# Purpose

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Using a combination of Electroencephalogram EEG procedure and a VR immersive environment, the purpose of this study revolves around:

- Explore the **behavioral and neural** responses of three autistic subjects when exposed to 4 color themes (3 chromatic + 1 achromatic) and 3 test applications (numerical, problem solving, & reading).
- Examine the correlation between **color themes**, the activation of the **visual cortex**, and the **Pre-Frontal Cortex** and the resulting **behavioral & physiological** consequences (stress, anxiety, satisfaction, happiness, etc.).



EEG Emotiv EPOC+



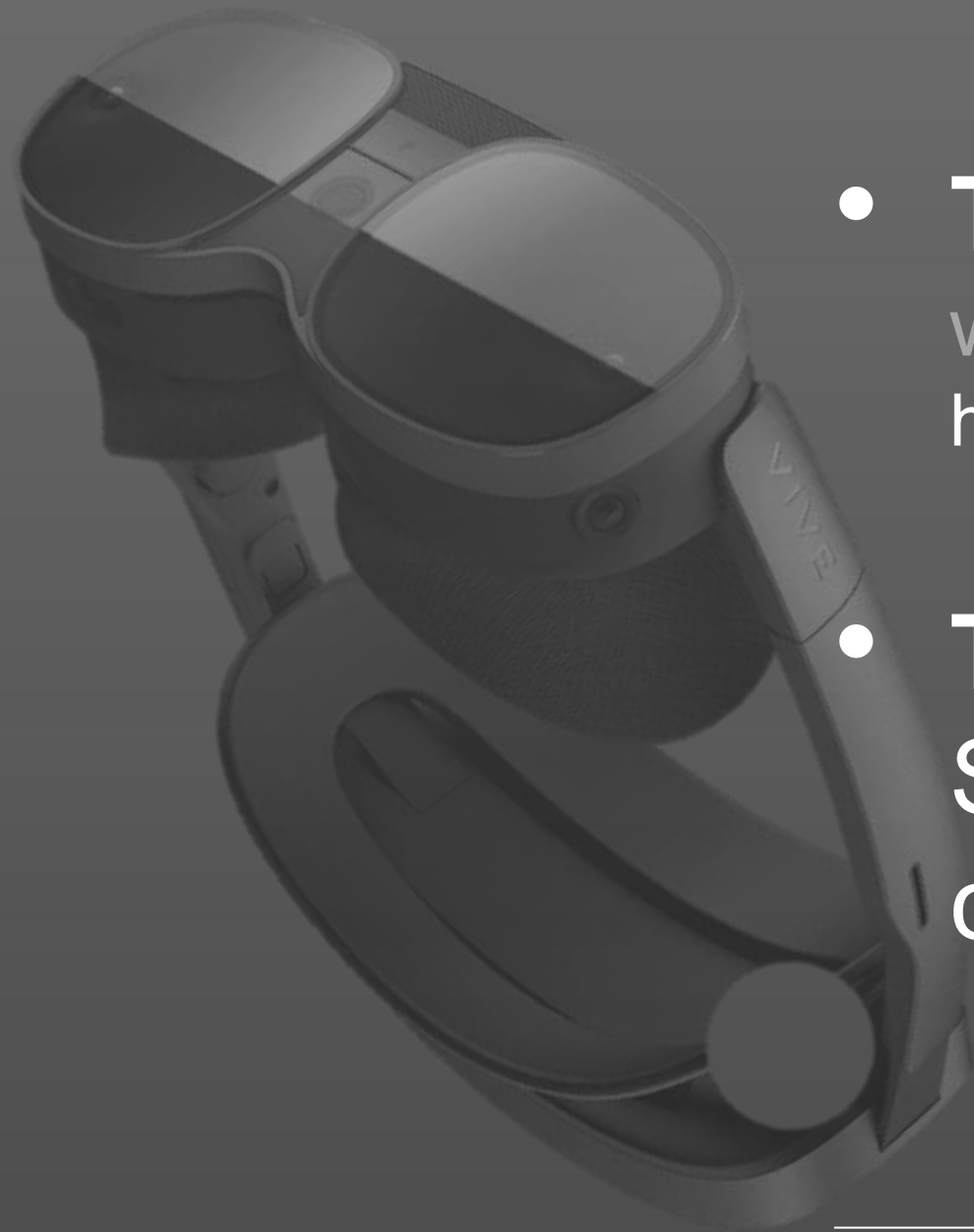
VR Headset: HTC ViVE Focus 3

# Mixed Research Methods

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- **The Quantitative Approach (Neural data set)**— wave oscillations-- EMOTIV EPOC+ (14-channel wireless EEG headset).
- **The Qualitative Approach (Behavioral data)** Satisfaction' survey administered right after the conclusion of the neural experiment.

- Every minute of EEG experiment generates 15,000 data points @ 250 Hz.
- Stats streamlined the data analysis enabling rapid interpretation of thousands of data points through advanced AI algorithms.



# Experiment

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The neural and behavioral experiment included **12 conditions**:

- **4 CCT's** (three chromatic colors and one achromatic) and
- **3 cognitive** test applications— numerical reasoning, reading comprehension, and problem solving.
- 12 picture stimuli that necessitated **12 minutes experiment** for every subject, **one minute test** for each stimulus.
- The experiment included an additional **6 minutes for the collection of the behavioral data**, i.e., 30 seconds for each stimulus.
- The experiment setup necessitated an additional **15 minutes for a mockup training** with VR immersive environment and the EEG equipment to eliminate confounding wave brain activations.

# Experiment

Correlated Color Temp (K)	Cognitive Test Type	Stimulus Condition ID
2700K (Warm White)	Numerical	C1
2700K (Warm White)	Problem Solving	C2
2700K (Warm White)	Reading Comprehension	C3
4100K (Cool White)	Numerical	C4
4100K (Cool White)	Problem Solving	C5
4100K (Cool White)	Reading Comprehension	C6
5500K (Daylight)	Numerical	C7
5500K (Daylight)	Problem Solving	C8
5500K (Daylight)	Reading Comprehension	C9
Achromatic	Numerical	C10
Achromatic	Problem Solving	C11
Achromatic	Reading Comprehension	C12

# Experiment

1. EXPERIMENTAL SESSION	
<b>Setup Phase (EEG + VR preparation)</b>	
<b>15 minutes</b>	EEG headset (EMOTIV EPOC +) and VR headset (HTC VIVE Focus 3) were fitted and calibrated. Participants completed a short familiarization session to reduce novelty-related brainwave artifacts.
<b>Task Phase (cognitive + EEG recording)</b>	
<b>12 minutes</b>	Participants performed 12 one-minute cognitive tasks (math, reading, and problem-solving) under four lighting conditions—Warm White (2700 K), Cool Light (4100 K), Daylight (5500 K), and Achromatic—each followed by a 30-second satisfaction rating.
2. BEHAVIORAL ASSESSMENT	
<b>Satisfaction Rating Survey</b>	
<b>6 minutes</b>	Participants completed post-exposure behavioral ratings 12 images assessing comfort, focus, and rated their satisfaction level for each image using a uniform 7-point Likert scale under each lighting condition.

# Sampling

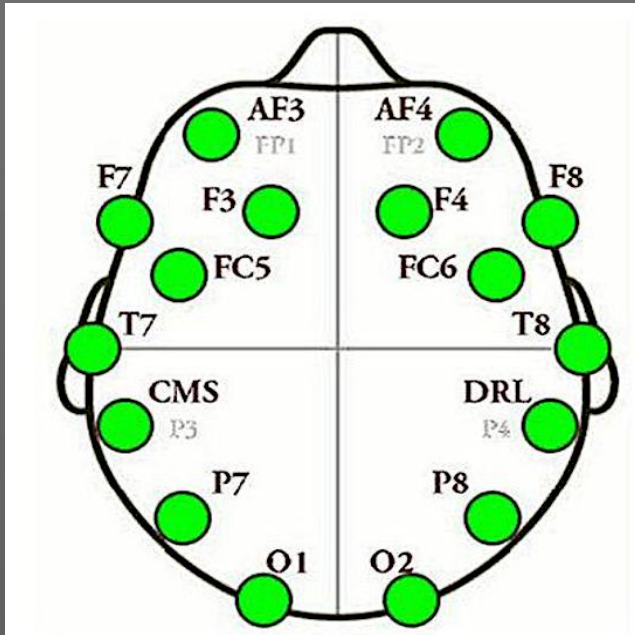
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- A purposive sampling strategy is used to identify **3 middle school participants**.
- The study is limited to **Level # 1 ASD subjects**, which is the mildest form of autism, as described the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5).
- The study is excluding color blind participants, epileptic subjects, and subjects suffering from illness or injury, to avoid any potential confounding wave brain effects.

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Level # 1 ASD subjects: Mildest form & requires less support than levels 2 & 3.  
Every minute of EEG experiment generates 15,000 data points @ 250 Hz

# Setting/Procedures



Map of Electrodes



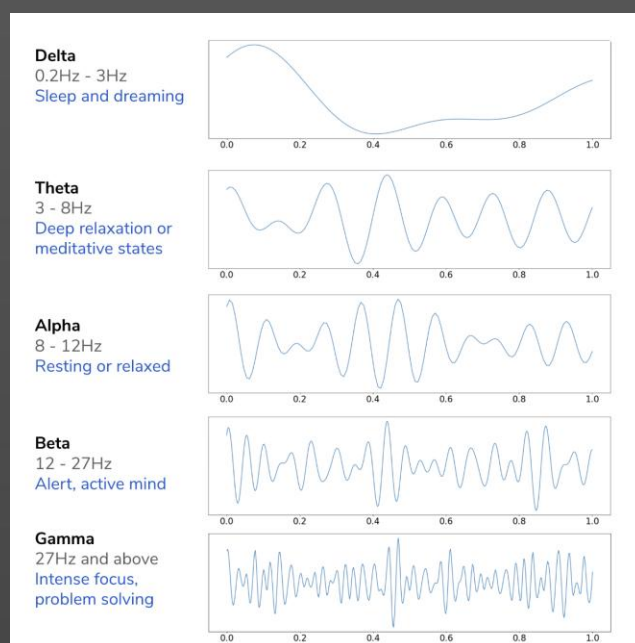
Combination of EEG + VR Immersive Experiment



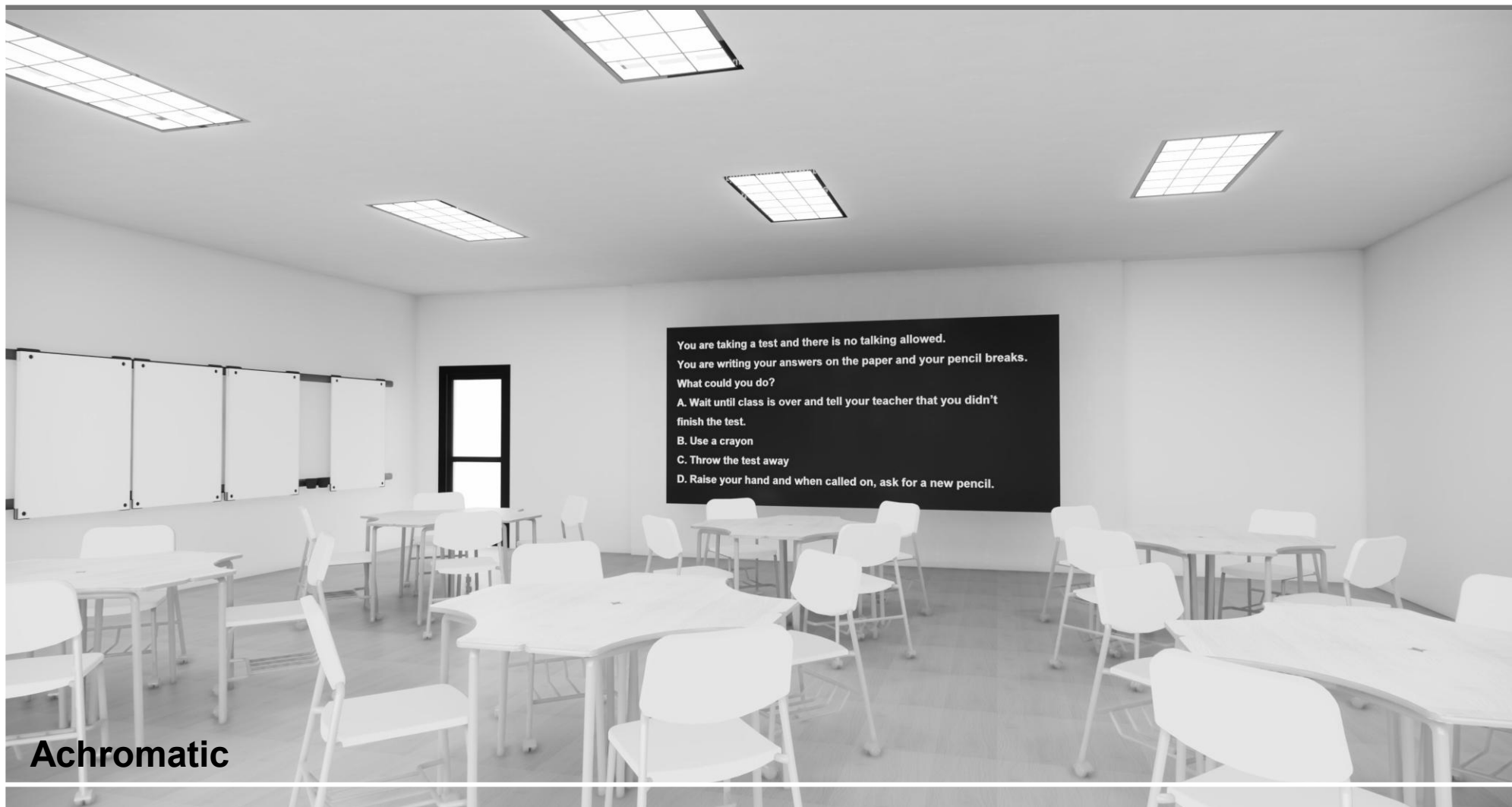
EEG Emotiv EPOC+



VR Headset: HTC Vive



Brain Waves



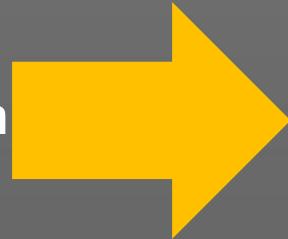
# Lighting Considerations

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- **Light Fixtures:** 2 x 4 ceiling mounted
- **Lumen output:** 5200 lumen per fixture
- **Correlated Color Temperature:** 2700K, 4100K, and 5500K
- **Color Rendering Index CRI:** 82
- **Light Reflectance Value LRVs:** 80/50/20
- **Unified Glare Rating (UGR):** < 19

# 5 Types of Brainwaves

High Level Concentration



Gamma Waves

30 - 100 HZ



INSIGHT  
PEAK EXPERIENCES  
SYNCHRONIZATION

Thinking + Concentration



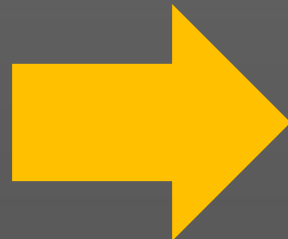
Beta Waves

12 - 30 HZ



ALERTNESS  
CONCENTRATION  
THINKING

Conscious visualization



Alpha Waves

8 - 12 HZ



MEDITATION  
CREATIVITY  
RELAXATION

Theta Waves

4 - 8 HZ



VISUALIZATION  
TRANCE  
DREAMING

Delta Waves

0.5 - 4 HZ



DEEP SLEEP  
TRANSCENDENCE  
RESTORATION

Gamma + Beta waves (cognition) & Alpha Waves (Conscious Visualization)

# Cognitive Tests

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## Types of Tests

- Numerical Competency
- Problem Solving
- Reading Comprehension

## Multiple Choice Option: Test Taking Strategy

- 12 stimuli--1 min/each

## Tests Validation:

- Content Validity
- Construct Validity
- Criterion Validity



# Findings (Neural Data)

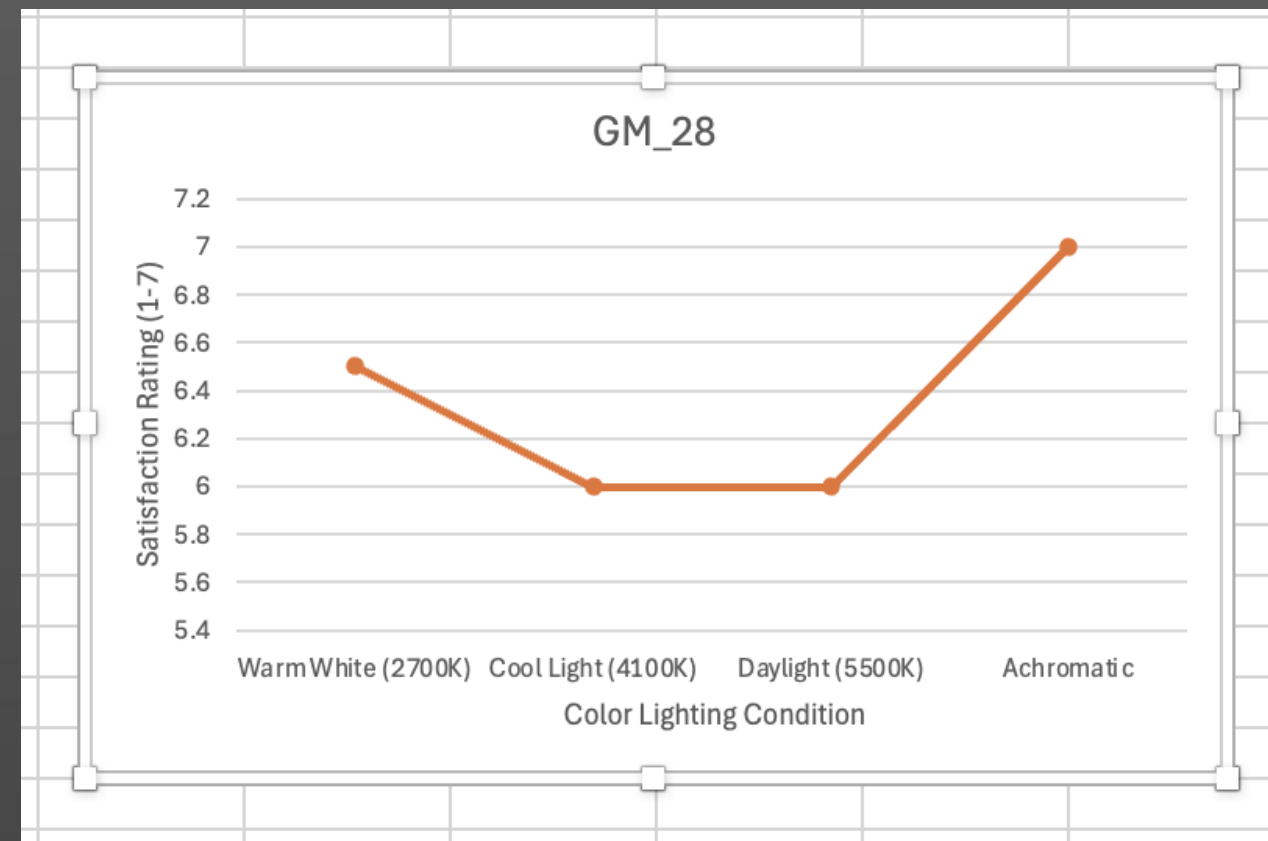
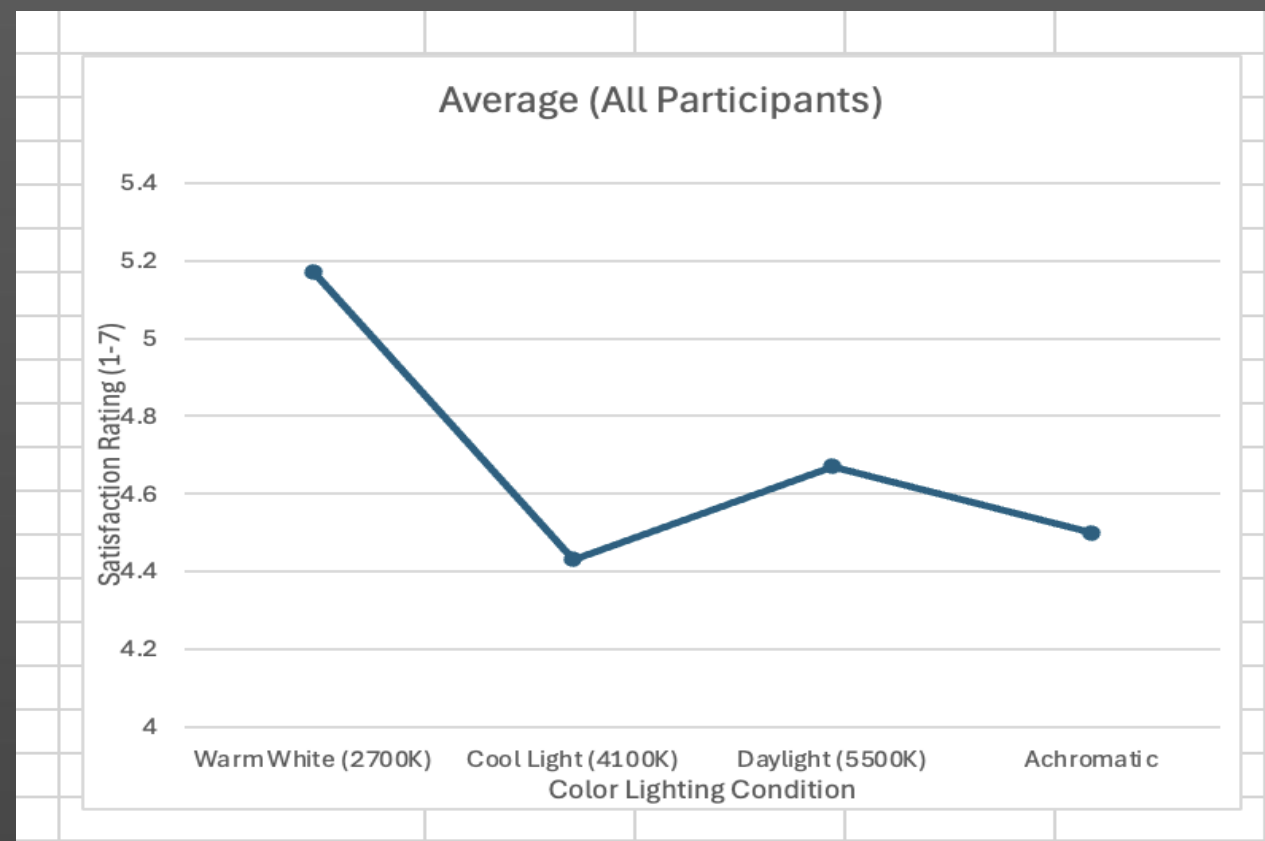
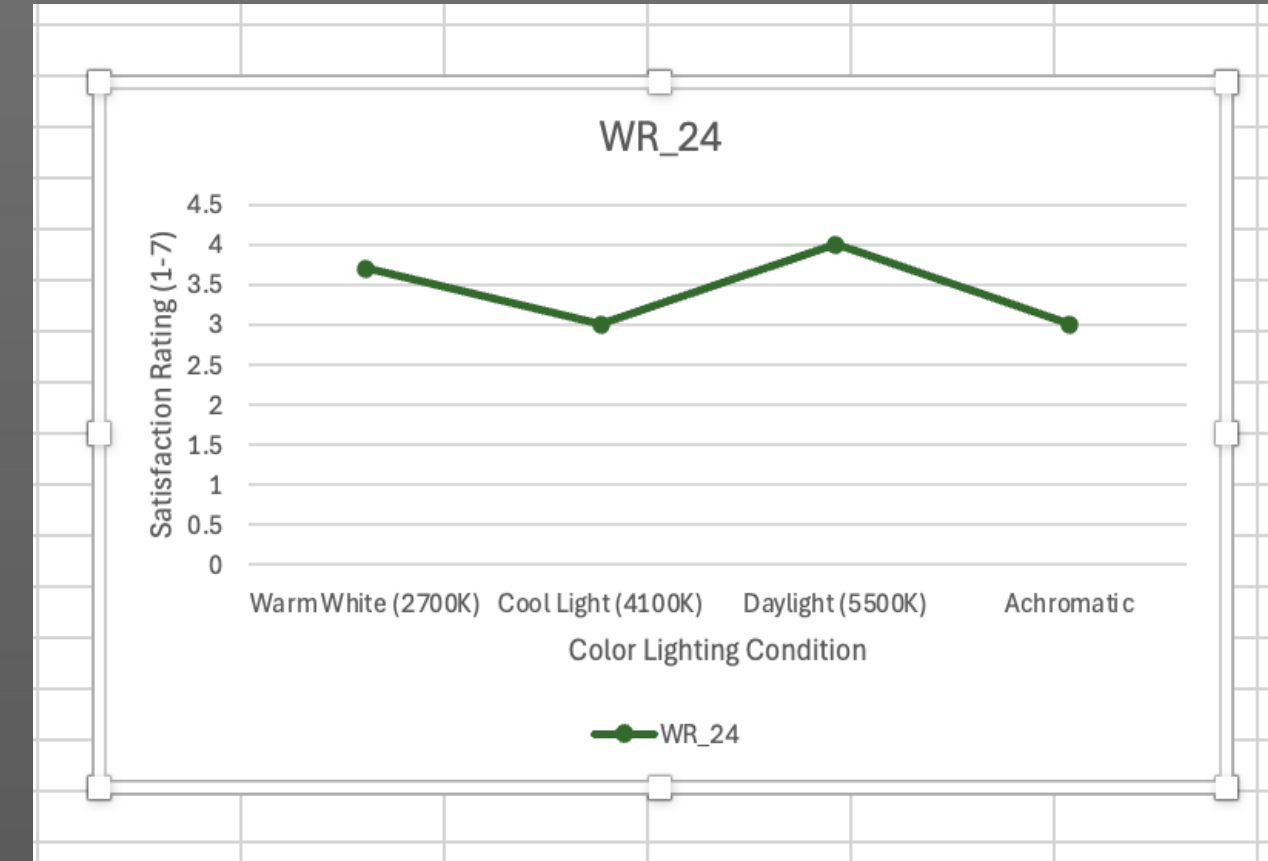
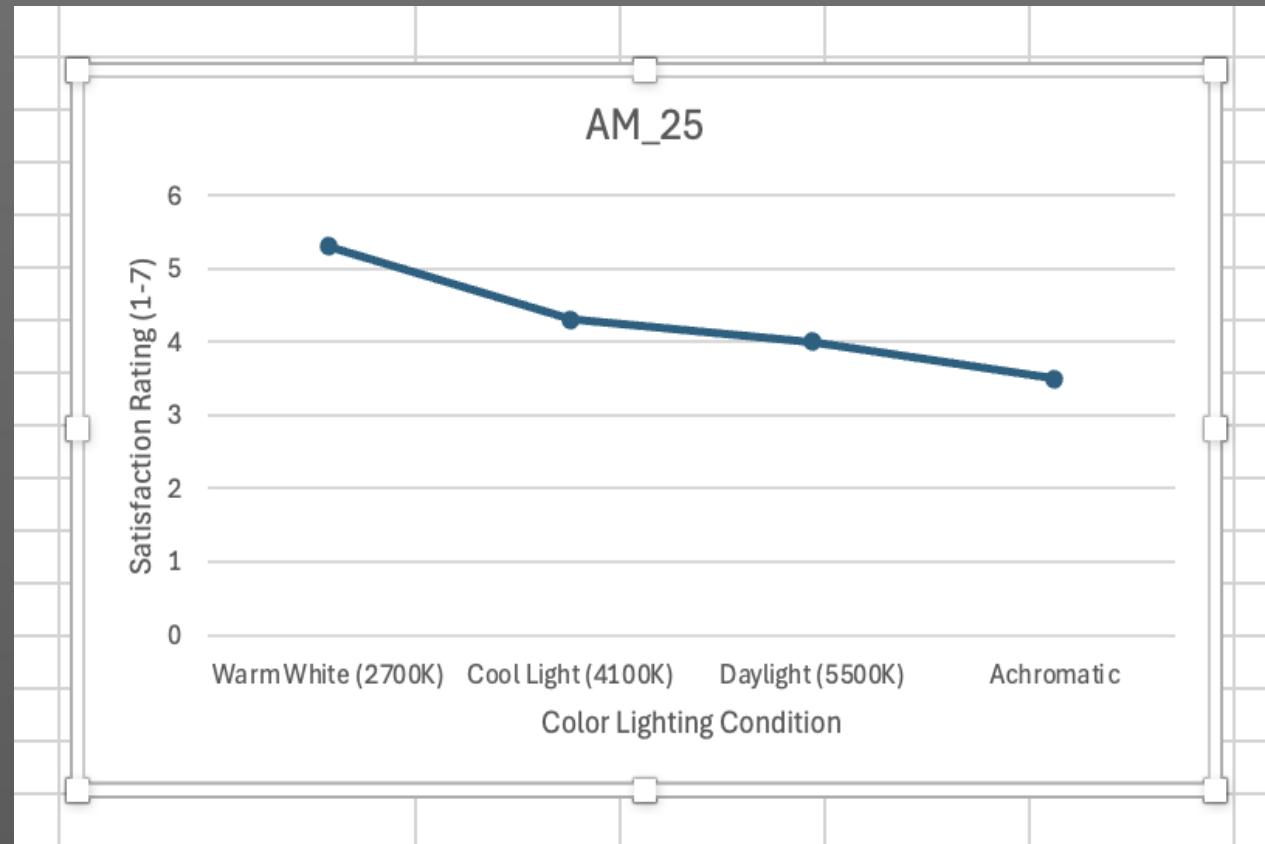
BRAINWAVE TYPE	LIGHTING CONDITION	INTERPRETATION
Gamma	CL (4100 K)	Highest activation observed at <b>AF4</b> and <b>F8</b> , indicating enhanced cognitive engagement and visual attention under cooler color temperature.
	WW (2700 K)	Moderate activity in <b>O1</b> and <b>F3</b> , suggesting a balanced state of comfort and mental relaxation.
	DL (5500 K)	Slightly lower activation across frontal regions, implying visual strain or overstimulation.
	Achromatic	Minimal activation; correlated with reduced alertness and engagement.
Beta High ( $\beta$ H)	CL (4100 K)	Marked increase in <b>AF4</b> and <b>F8</b> , consistent with heightened arousal and task-related alertness.
	WW (2700 K)	Moderate activation in <b>O1</b> , linked with relaxed focus during reading and reasoning tasks.
	DL (5500 K)	Decrease in <b>F3</b> and <b>O1</b> , possibly reflecting discomfort or visual fatigue.
	Achromatic	Lowest $\beta$ H activity, associated with decreased motivation and sensory engagement.
Beta Low ( $\beta$ L)	CL (4100 K)	Strongest response at <b>AF4</b> , showing increased sensory–motor readiness and sustained attention.
	WW (2700 K)	Moderate activation in <b>O1</b> , supporting steady concentration with visual comfort.
	DL (5500 K)	Lower $\beta$ L levels across frontal electrodes, indicating diminished attention control.
	Achromatic	Weakest $\beta$ L amplitude; linked with passive or resting cognitive states.

# Findings

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- Findings suggest that lighting color temperature significantly modulates the cognitive activity across brain regions.
- For autistic participants, this interpretation aligns with existing evidence of heightened sensory sensitivity to environmental stimuli.
- The cool light (CL) condition consistently produced higher BetaL and BetaH power at frontal and occipital sites (e.g., AF4, FC6, O1), while day Light (DL) and warm white (WW) lights showed markedly lower values.
- Because Beta activity is closely associated with focused attention, information processing, and cognitive control, the reduced Beta power under DL and WW conditions suggests a stress-related or inhibitory neural state.
- These differences are statistically significant across most sensor locations, indicating that less favorable color temperatures—particularly those with lower or warmer spectral energy—may induce sensory stress or discomfort, resulting in decreased cognitive activation.
- In summary, the EEG results support the hypothesis that less favorable color temperatures induce stress, which in turn may inhibit cognitive processing in autistic individuals, whereas cooler lighting conditions foster a more optimal state for attention and cognition.

# Findings (Behavioral Survey)



# Recommendations & Limitations

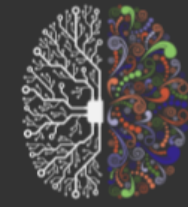
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This experimental pilot study **yielded valuable insights**, it also revealed specific **areas requiring additional focus**, such as:

- **VR immersive environment**  
VR settings, while realistic, are still simulations
- **Small sample size:**  
Larger sample inclusive of different cultures with specific color preferences
- **Demographics:**  
Inclusion of different age brackets, e.g., Childhood, adolescence, and adulthood
- **Control vs. experimental groups**  
Baseline for comparison and deduction
- **Use of fMRI rather than EEG**  
Emphasis on identifying where brain activity occurs rather than when it happens

# Presentations/publications

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**ANFA**

Academy of Neuroscience for Architecture

Academy of Neuroscience for Architecture  
September 18–20, 2025 La Jolla, California



**Weill Cornell  
Medicine-Qatar**

Medical & Health Humanities: Global Perspectives  
February 7-8.,2025



**Innovations**  
in Global **Health Professions  
Education**

Journal of Innovation in Global Health (progress)  
Published by Weill Cornell Medicine in Qatar

**Design  
& Health**  
International Academy for Design and Health

14<sup>th</sup> World Congress on Design & Health  
Singapore October 29—Nov. 2, 2025



International Conference on Neurology  
May 15-16, 2025, Dubai, UAE.

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This line of inquiry has led to four international conference presentations during the current academic year.

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# Thank you,

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