

# Enhancing Elderly Health and Well-being through Lighting Design



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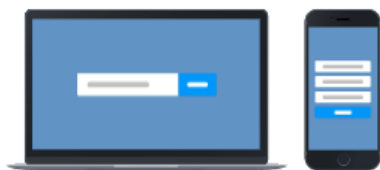
[Nasrin.Golshany@csun.edu](mailto:Nasrin.Golshany@csun.edu)



David Alan Harve, source: <https://davidalanharvey.tumblr.com/post/68205071854/while-steve-mccurry-and-i-are-literally-designing>

# Polling: How to Join?

## Join by Web



- 1 Go to **PollEv.com**
- 2 Enter **nasringolshany437**
- 3 Respond to activity

## Join by QR Scan



## Join by Text



- 1 Text **NASRINGOLSHANY437**  
to **+49 157 3598 1046**
- 2 Text in your message



# Impacts of Spatial Light Patterns on Older Adults' Cognitive Performance

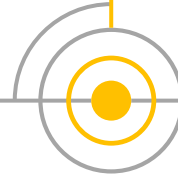
## *An Experimental Study*

### Research Background



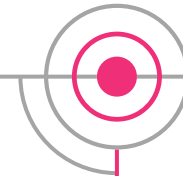
Problem Statement  
Significance of Study  
Literature Review  
Specific Aims and Hypothesis

### Proposed Experiment



2×2 factorial design  
Experiment design  
Findings

### Summary



Summary  
Application  
Limitation

## Background

## Why are older adults important?

- Older adults' cognitive performance

- Today, about **one in every seven** Americans is over the age of 65, and by 2040 that number will swell to **one in five** (Gabriel, 2018)
- Cognitive impairment increases exponentially with age (Paganini-Hill et al., 2016)

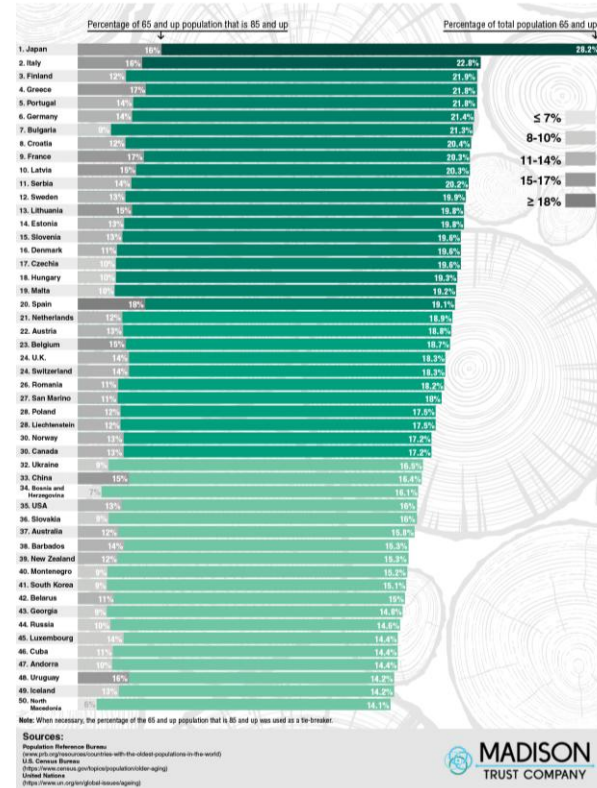
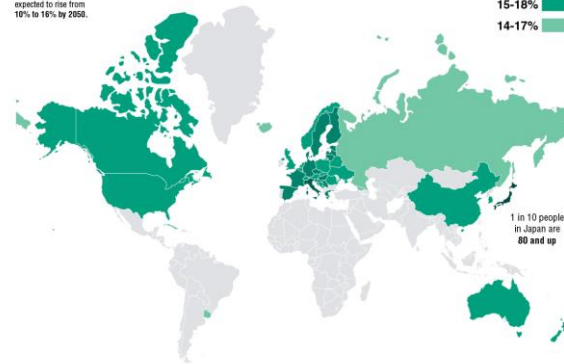
### Top 50 Countries With the Largest Percentage of Population Aged 65 and Up

The proportion of people aged 65 and up is rising at a faster rate than those below that range. The percentage of the global population aged 65 and up is expected to rise from 10% to 16% by 2050.

#### Percentage of Total Population Aged 65 and Up

Global average: 10%

- 27-30%
- 23-26%
- 19-22%
- 15-18%
- 14-17%



Sources:  
Population Reference Bureau  
(<https://www.prb.org/resources/countries-with-the-oldest-populations-in-the-world/>)  
U.S. Census Bureau  
(<https://www.census.gov/hypoc/population/older-aging/>)  
United Nations  
(<https://www.un.org/en/global-issues/aging/>)



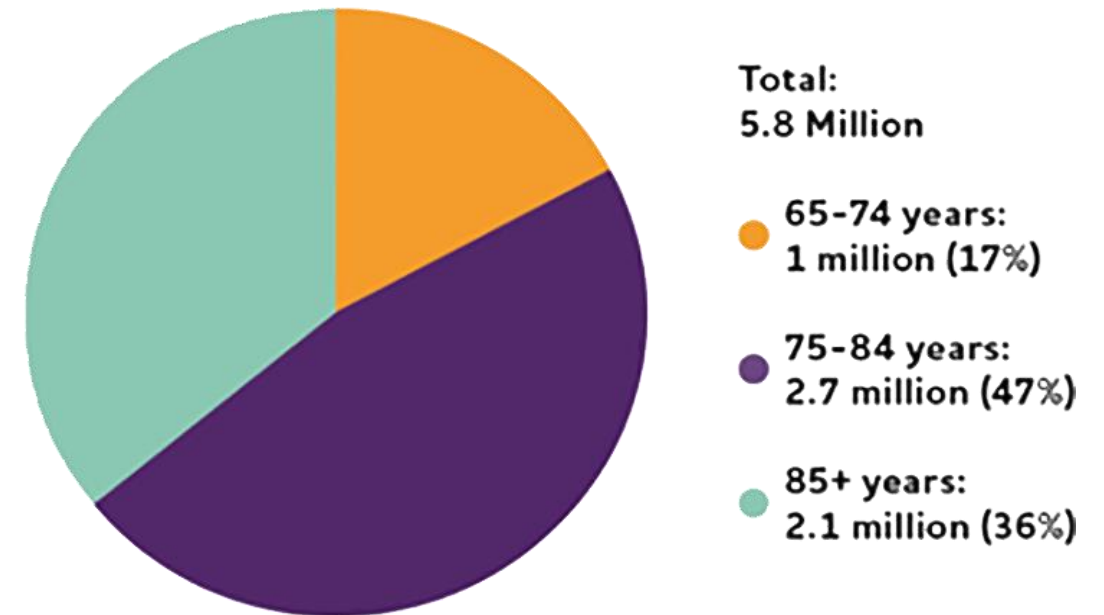
Credit: <https://www.belmarrahealth.com/alzheimers-disease-risk-elderly-due-mild-cognitive-impairment-increases-stress/>

## Background

# Why is cognitive performance important in older adults?

- Older adults' cognitive performance

- Sleep quality (McCurry et al., 2006)
- Behavioral disorders (Ancoli & Vitiello, 2006)
- Stress (Knez & Kers, 2000)
- Agitation (Burns et al., 2009)
- Fall and injuries (Shaw et al., 2003)

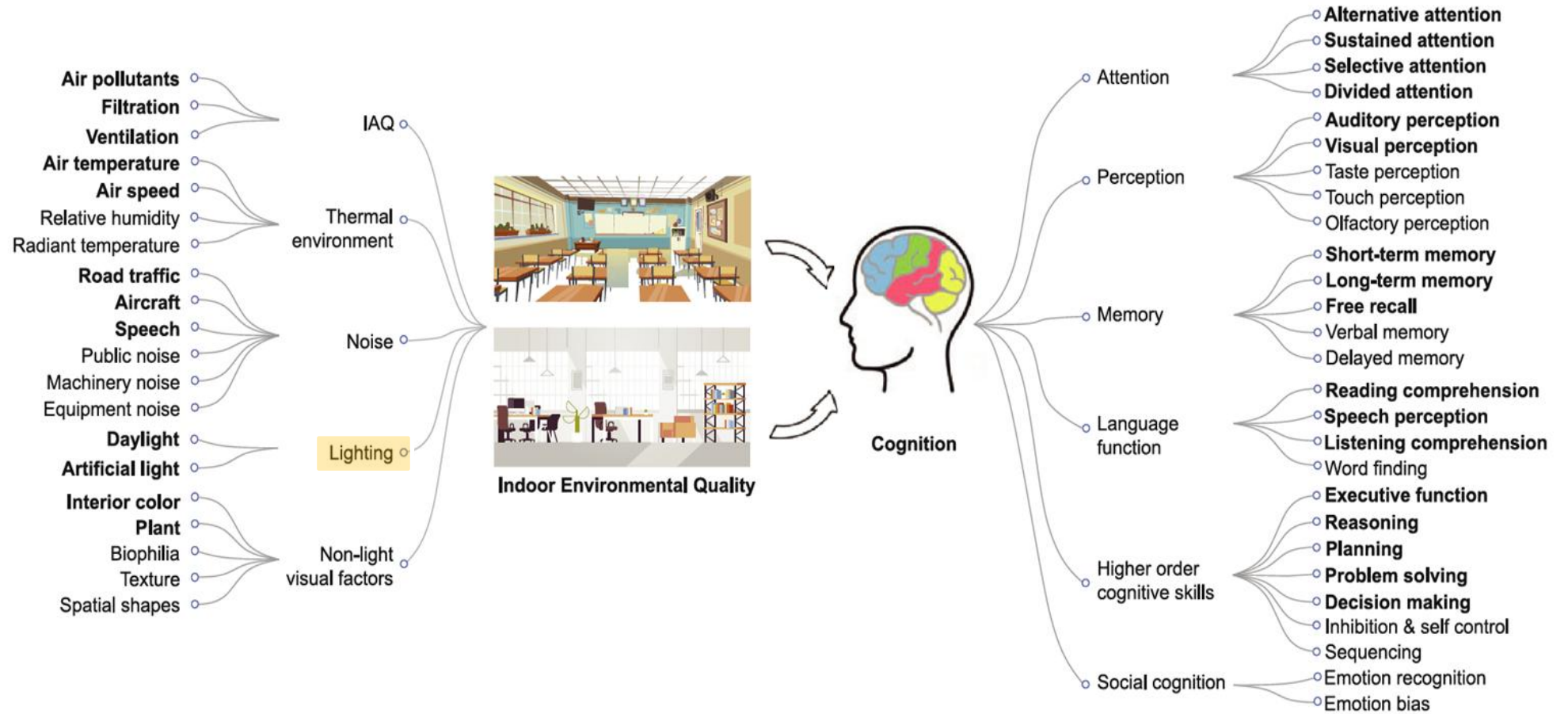


Number and ages of people 65 or older with Alzheimer's dementia, 2020. Created from data from Hebert et al.

## Background

# Indoor Environmental Quality and Cognitive Performance

- Older adults' cognitive performance
- Light, perception, and cognitive performance

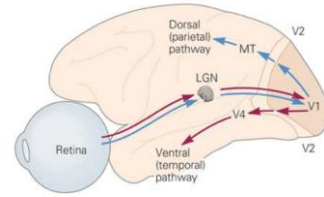


(Wang, Zhang, & Liu, 2020)

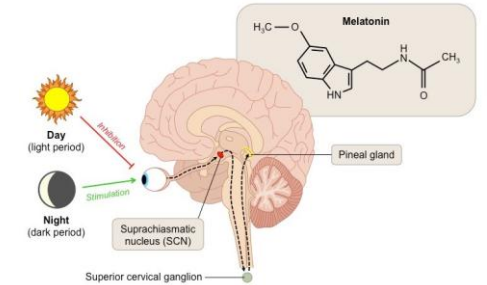
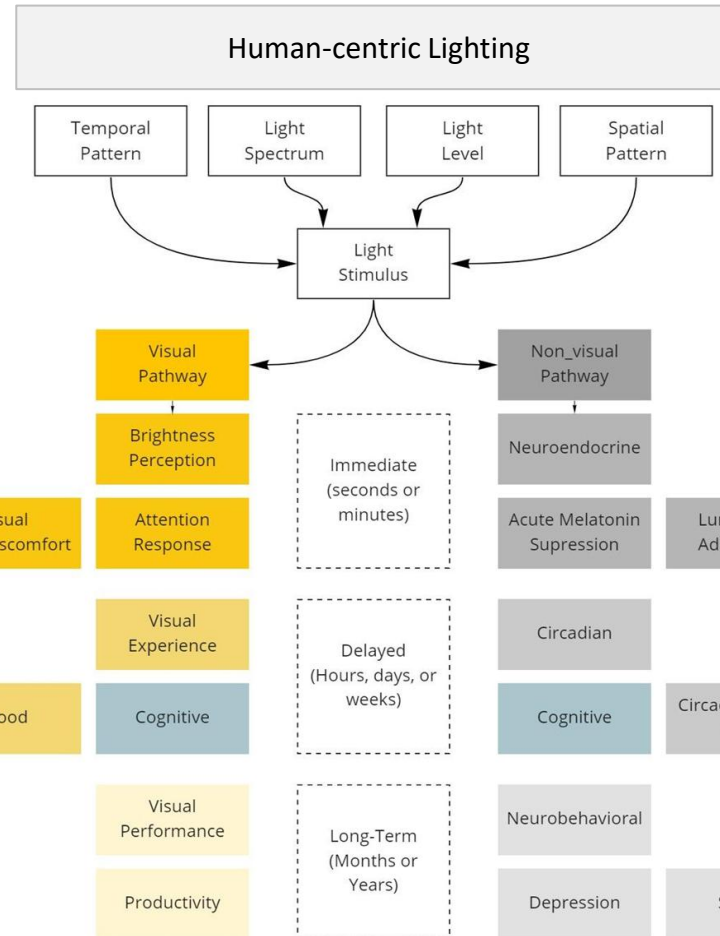
## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance

# Human-centric Lighting and cognitive performance



Credit: (Wurtz & Kandel, 2000)



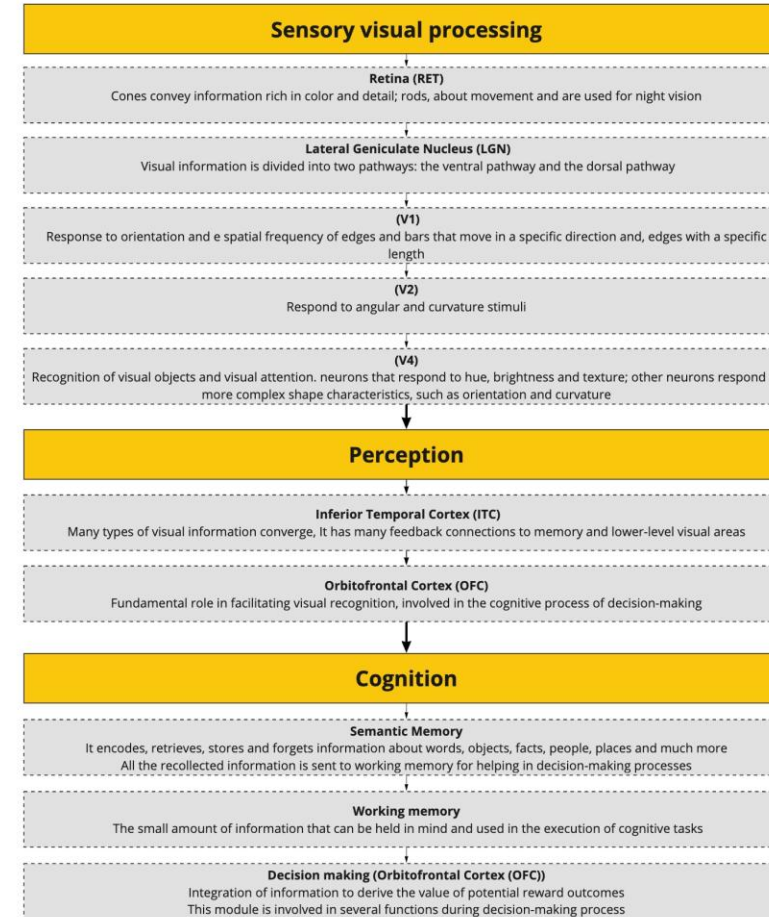
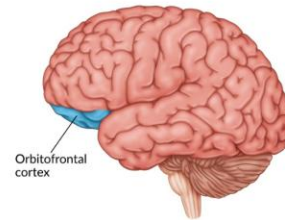
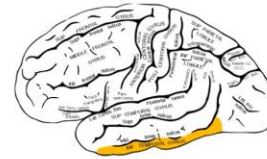
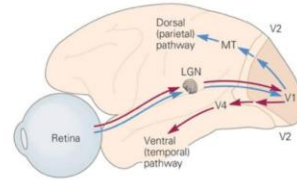
Credit: <https://ib.bioninja.com>

A schematic overview of different visual and non-visual responses of light based on three periods of time\_ figure inspired by Houser& Esposito (2021) and de Kort & Veitch (2014).

## Background

# Human-centric Lighting, perception, and cognitive performance

- Older adults' cognitive performance
- Light, perception, and cognitive performance

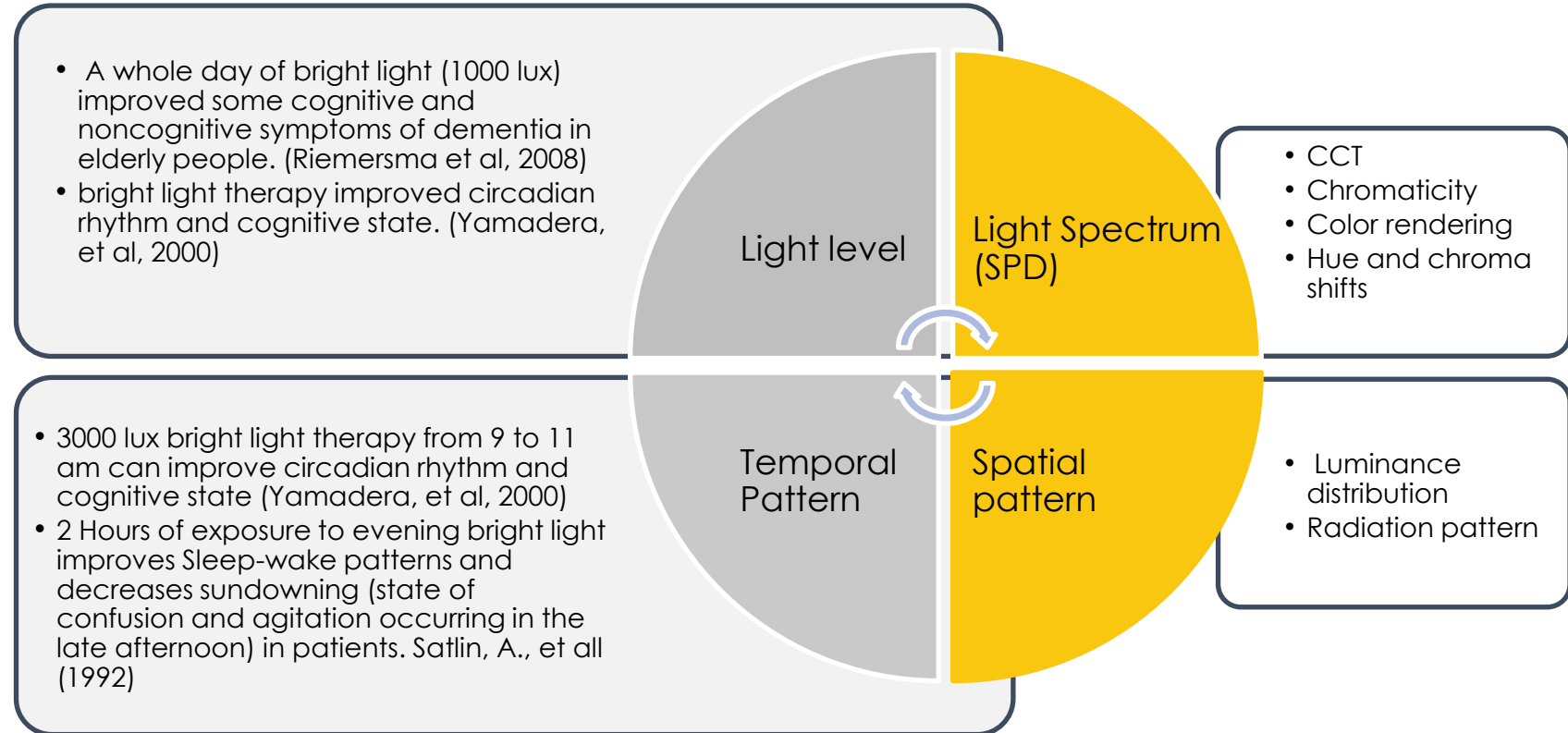


Different sequences of visual perception and cognition from eye receptors to brain processors according to (González-Casillas, et al, 2018)

## Background

# Light and cognitive performance of older adults? (Literature Review)

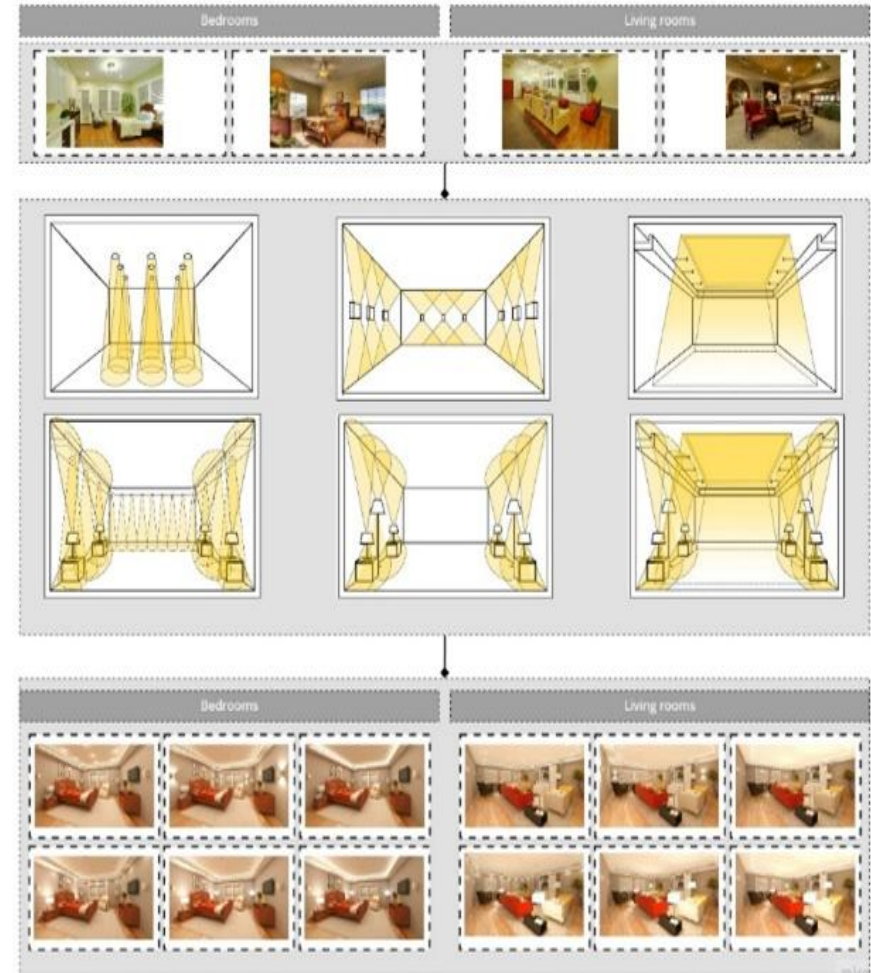
- Older adults' cognitive performance
- **Light, perception, and cognitive performance**



## Background

- Older adults' cognitive performance
- **Light, perception, and cognitive performance**

## Flynn's Theory



Spatial lighting patterns according to Flynn's theory of lighting and mood (Flynn, 1973).

## Background

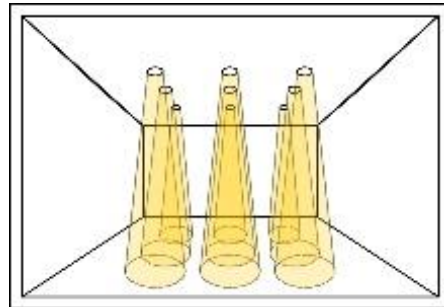
- Older adults' cognitive performance
- Light, perception, and cognitive performance

## Flynn's Theory

### The clearest pattern



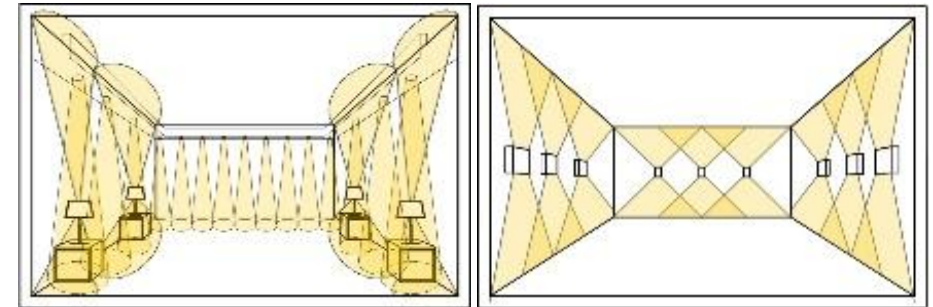
Uniform, Central, Direct



### Least stressful pattern



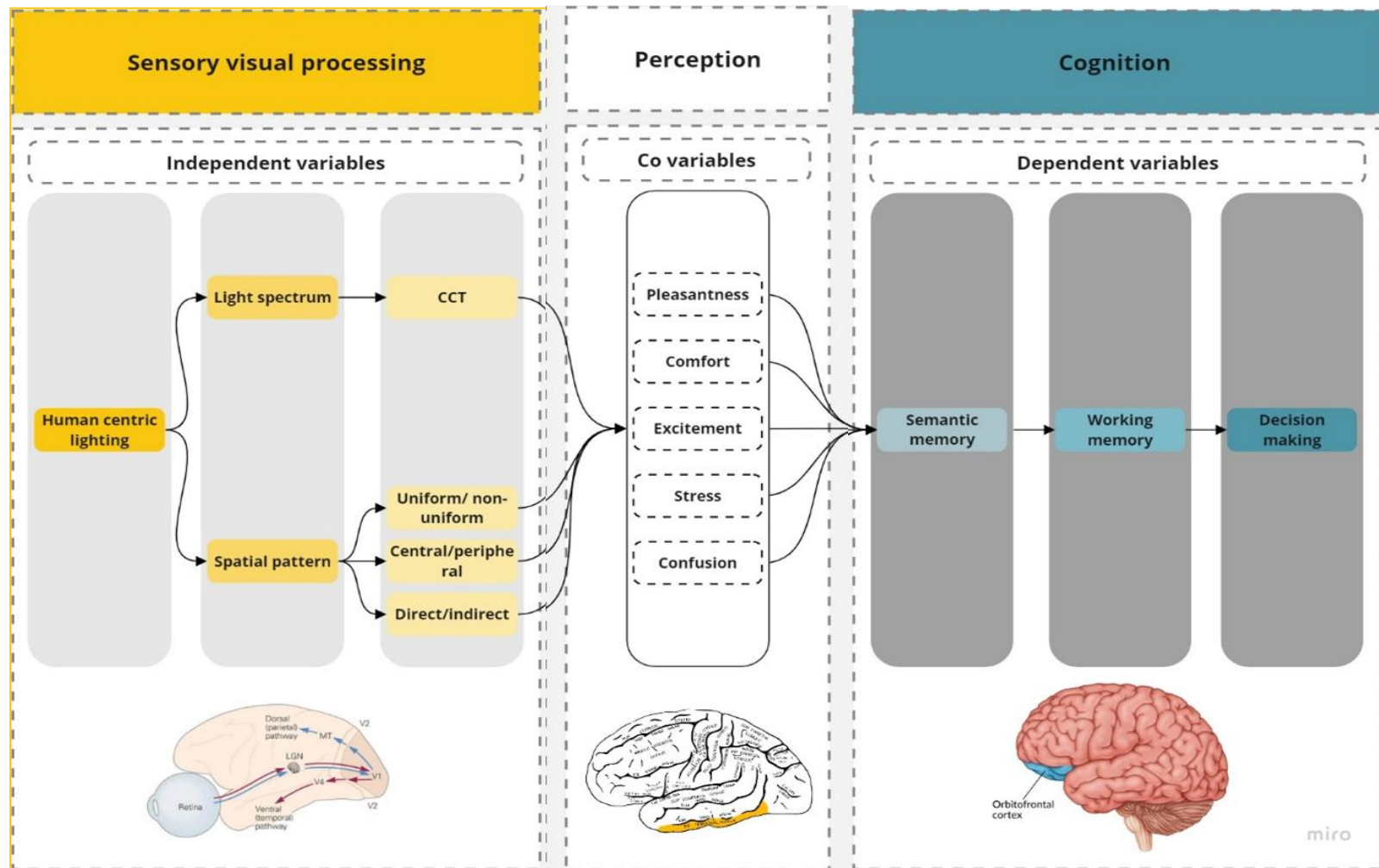
Nonuniform, peripheral, Direct/indirect



## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- **Aims and questions**

## Conceptual framework



## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- **Aims and questions**

## Research Aims and Questions

This study investigates the impact of spatial patterns and the light spectrum on older adults' perceptions and cognitive performance.

**Is there a difference in older adults' perception and cognitive performance under different spatial patterns and correlated color temperature (CCT) of light?**

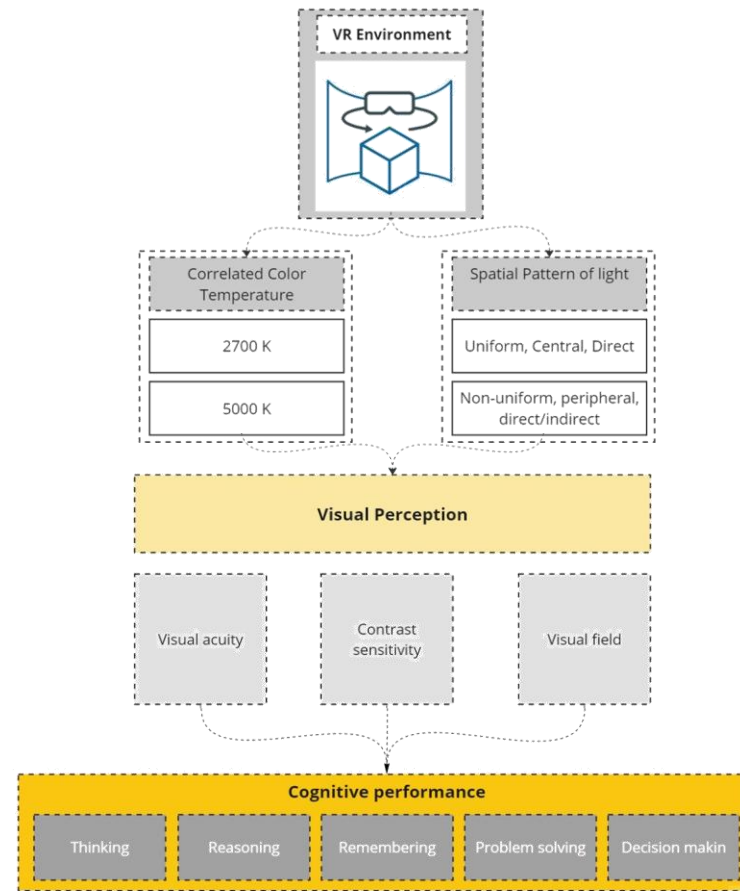


## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- **Aims and questions**

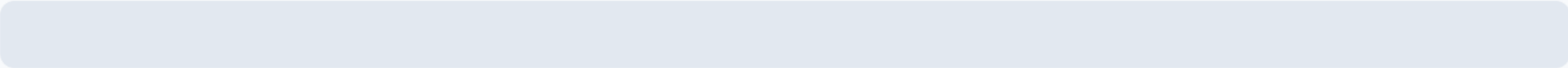
## Aim and hypothesis

Is there a difference in older adults' perception and cognitive performance under different spatial patterns and correlated color temperature (CCT) of light?



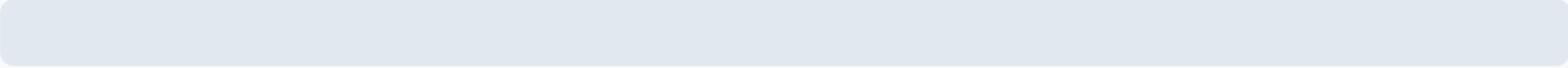
# Which Lighting Design Will Positively Impact Cognitive Performance of Older Adults?

(A) A



0%

(B) B

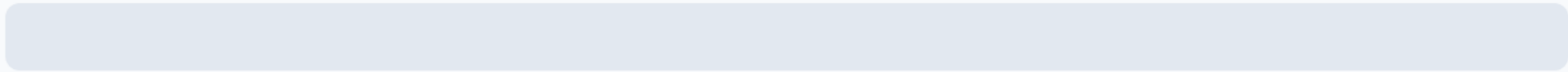


0%



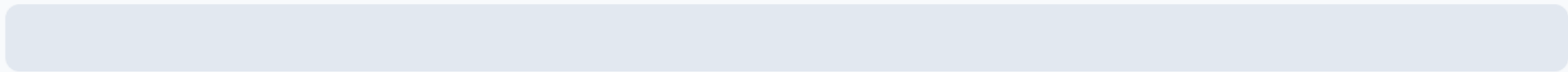
# Which Lighting CCT is Perceived to be More Stressful?

A



0%

B



0%



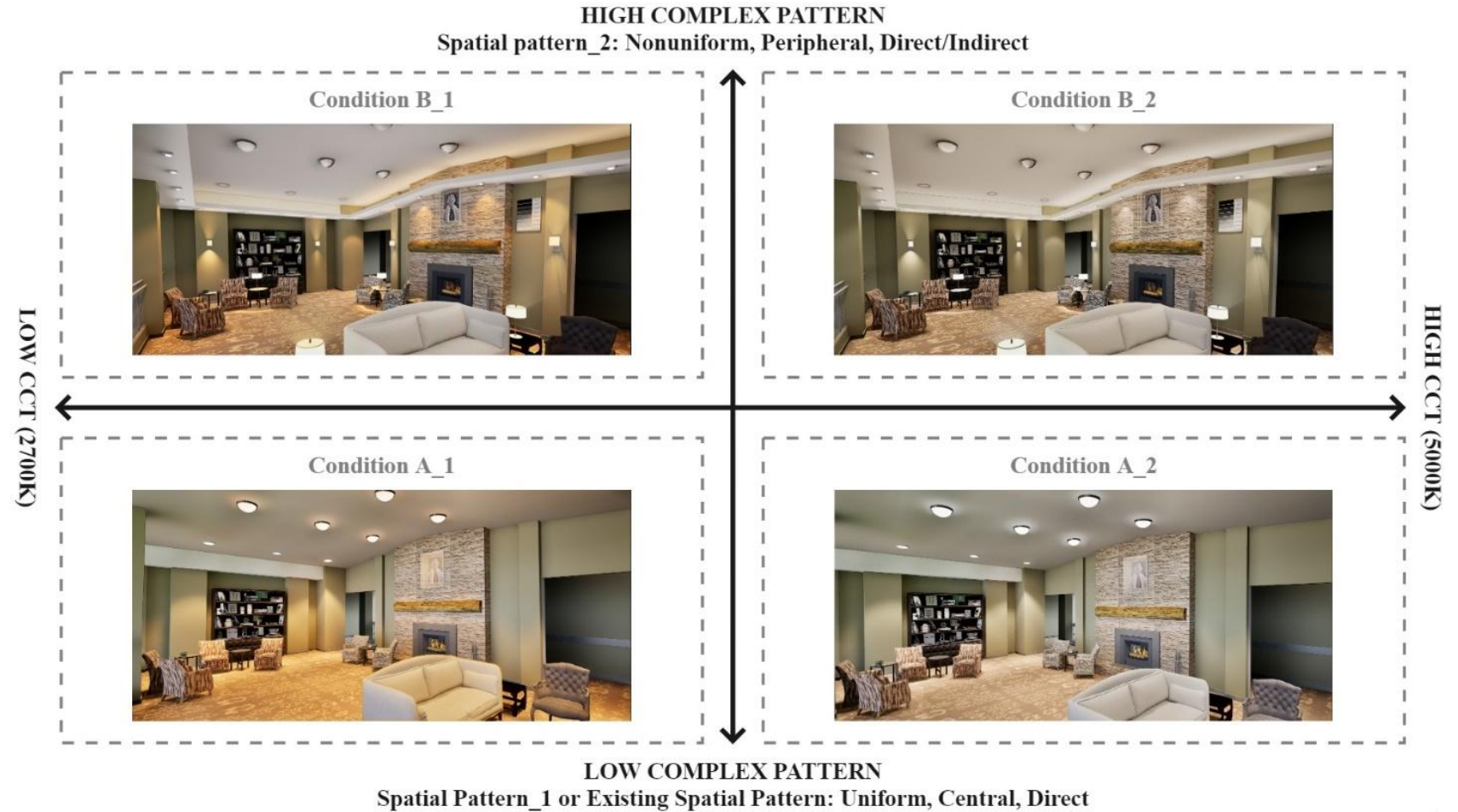
## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2x2 factorial design

## 2X2 factorial design



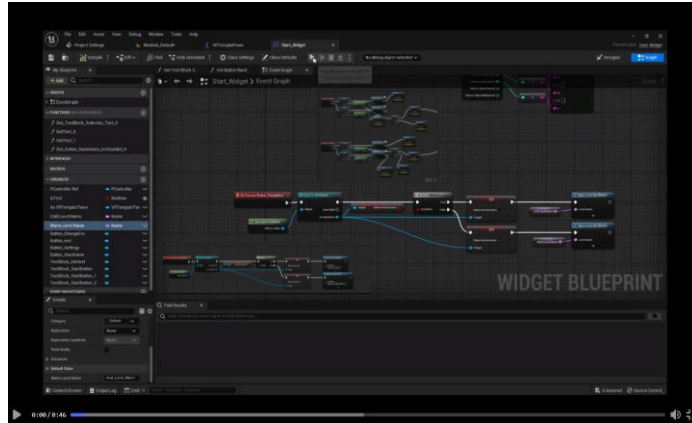
## Background

# Virtual Reality Development

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2x2 factorial design
- **VR development**



Oculus rift s

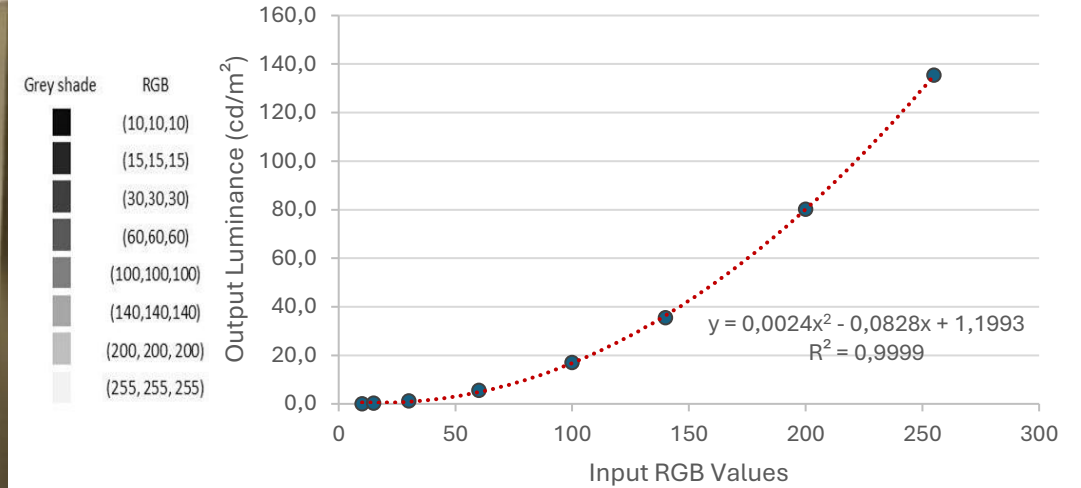
## Background

# Virtual Reality Development

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- **VR development**




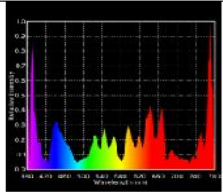

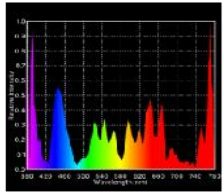

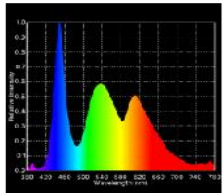

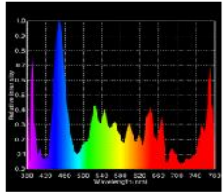
## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- VR development

# Light intensity, spectral power distribution, and CCT

	Light intensity, Wavelength, CCT	Gray scale card appearance	Spectral Power Distribution
Condition A_1	Illuminance= 100 lux $\lambda_p$ = 770 nm CCT= 4369 K		
Condition A_2	Illuminance= 100 lux $\lambda_p$ = 770 nm CCT= 5976 K		
Condition B_1	Illuminance= 200 lux $\lambda_p$ = 448 nm CCT= 6187 K		
Condition B_2	Illuminance= 100 lux $\lambda_p$ = 447 nm CCT= 12084 K		

## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- VR development
- **Experiment design**

## Design and delivery of the experiment

- 32 participants (17 female, 15 male)
- MMSE, 12-item Short Form Survey (SF-12), visual condition



## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- VR development
- **Experiment design**

## Design and delivery of the experiment



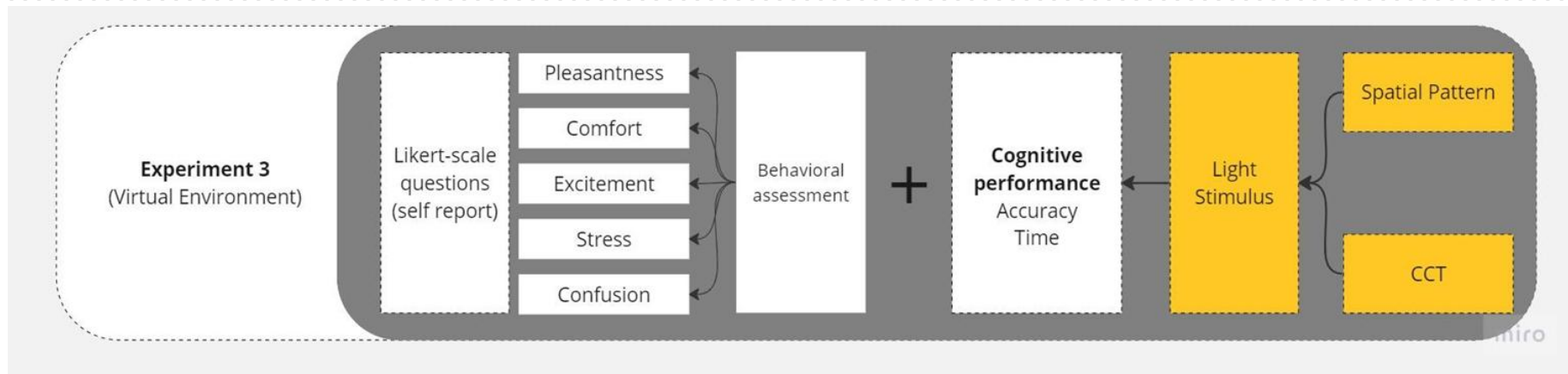
## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

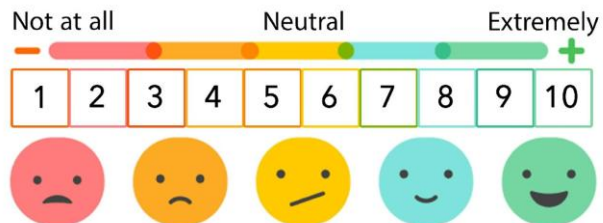
- 2×2 factorial design
- VR development
- Experiment design
- **Data Collection**

## Data Collection

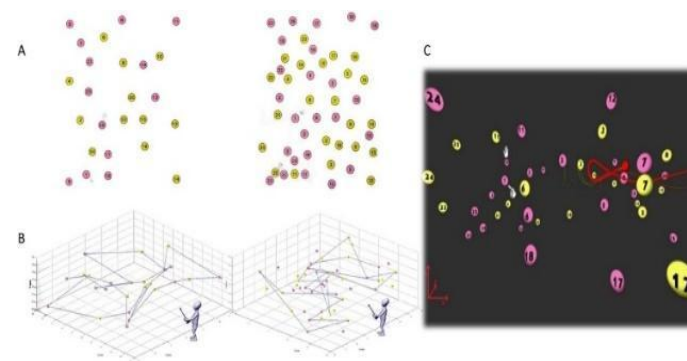


### Self-reported subjective perceptual data

Please rate your confusion level:



### Trail B\_ Trail Making Test (TMT)



(Plotnik et al., 2021)

## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

- Participants demographic

# Self-reported subjective perceptual data

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## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

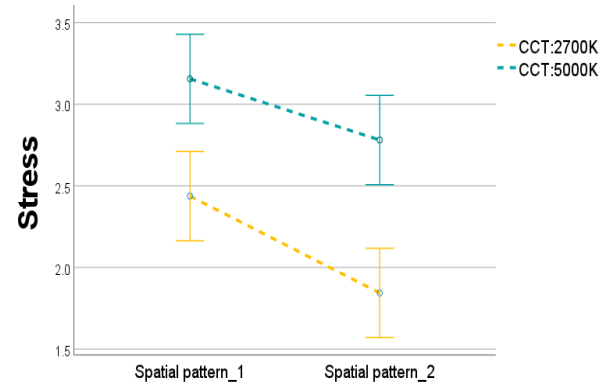
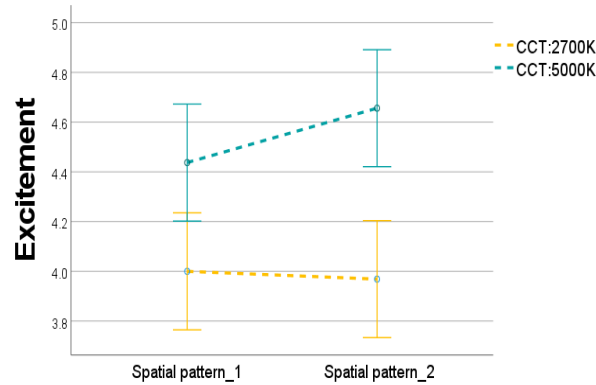
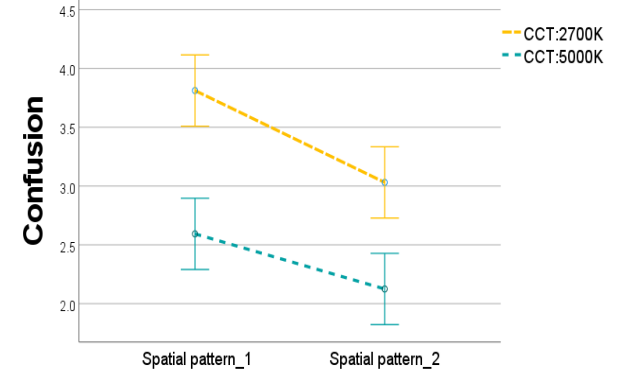
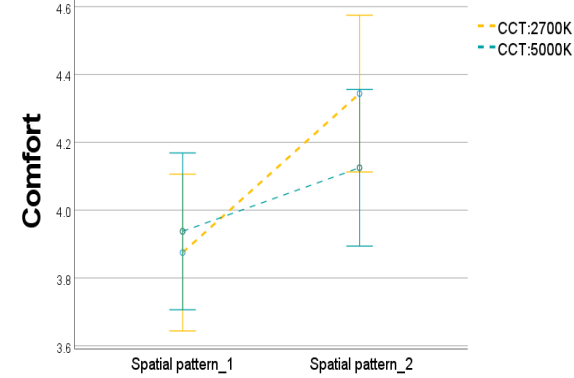
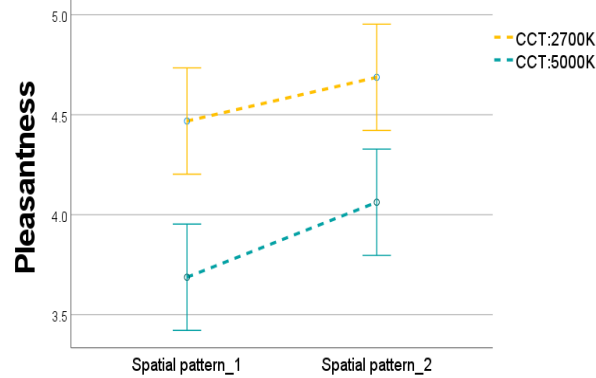
## Method

- 2x2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

- Participants demographic
- Self-reported data

## Self-reported subjective perceptual data



		Pleasantness			Comfort			Excitement			Stress			Confusion		
		p-value	Eta-square ( $\eta^2$ )	Observed Power	p-value	Eta-square ( $\eta^2$ )	Observed Power	p-value	Eta-square ( $\eta^2$ )	Observed Power	p-value	Eta-square ( $\eta^2$ )	Observed Power	p-value	Eta-square ( $\eta^2$ )	Observed Power
Main effect	Spatial pattern	<b>.029*</b>	.038	.592	<b>.006*</b>	.060	.796	.432	.005	.123	<b>.001**</b>	.090	.935	<b>.000**</b>	.118	.982
	CCT	<b>.000**</b>	.181	.999	.505	.004	.102	<b>.000**</b>	.153	.997	<b>.000**</b>	.225	1.000	<b>.000**</b>	.280	1.000
2-Way interaction	CCT × Spatial pattern	.562	.003	.089	.231	.012	.223	.295	.009	.181	.430	.005	.123	.310	.008	.173

## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

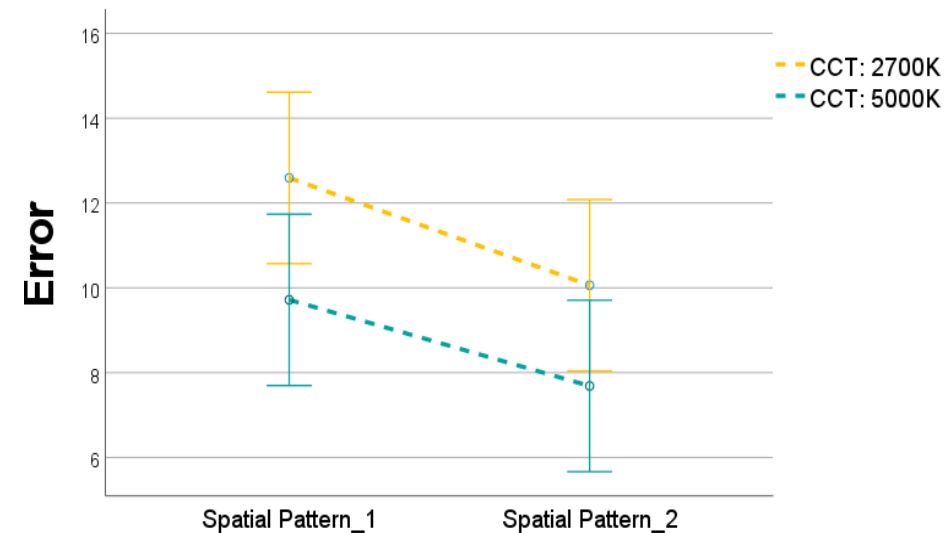
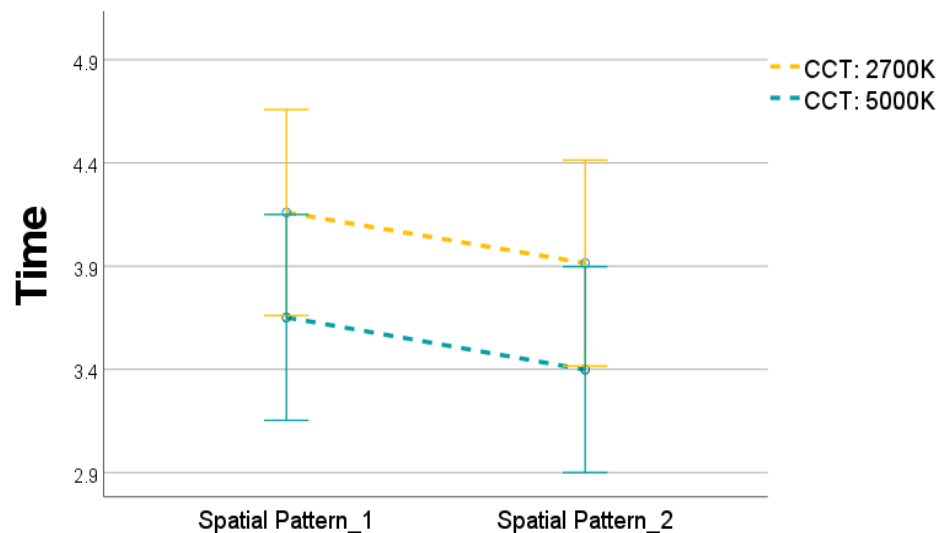
## Method

- 2×2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

- Participants demographic
- Self-reported data
- **Cognitive performance**

## Performance on the Cognitive task



		Time			Error		
		p-value	Eta-squared ( $\eta^2$ )	Observed Power	p-value	Eta-squared ( $\eta^2$ )	Observed Power
Main effect	Spatial pattern	0.325	0.008	0.165	<b>0.027*</b>	0.039	0.602
	CCT	<b>0.044*</b>	0.032	0.523	<b>0.011*</b>	0.051	0.723
2-Way interaction	CCT × Spatial pattern	0.987	0.000	0.050	0.807	0.000	0.057

## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2x2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

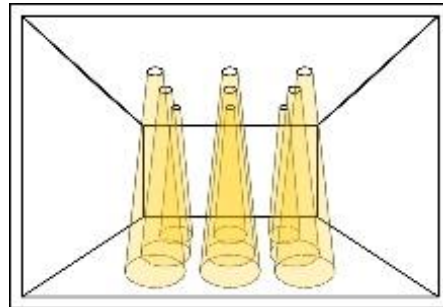
- Participants demographic
- Self-reported data
- Cognitive performance
- **Summary**

## Summary of contributions

### The clearest pattern



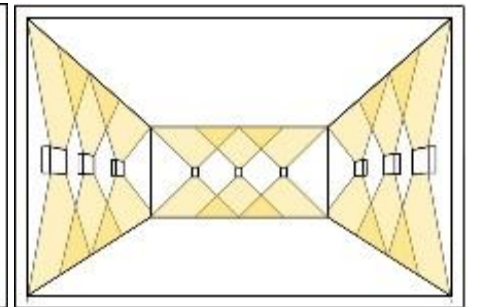
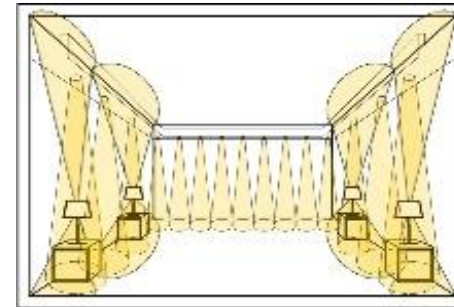
Uniform, Central, Direct



### Least stressful pattern



Nonuniform, peripheral, Direct/indirect



## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2x2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

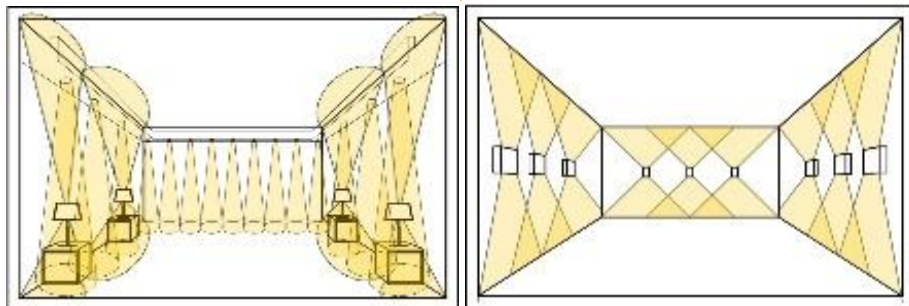
- Participants demographic
- Self-reported data
- Cognitive performance
- **Summary**

## Summary of contributions

### The most visually appealing pattern



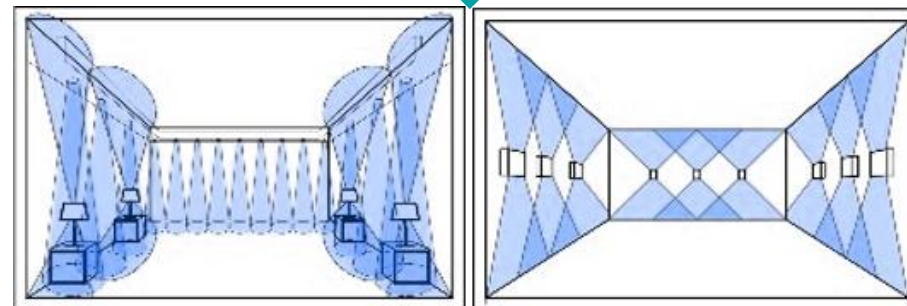
Nonuniform, peripheral,  
Direct/indirect  
+ CCT: 2700K



### The most non-visually efficient pattern



Nonuniform, peripheral, Direct/indirect  
+ CCT: 5000K



## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2×2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

- Participants demographic
- Self-reported data
- Cognitive performance
- Summary
- Application
- **Limitation**

## Limitation / Disclaimer

- This study has mainly focused on electric lighting, while questions regarding human-centric variables of daylight have not been addressed.
- There is also a need to assess other aspects of cognitive performance using different cognitive tasks and evaluate physiological measurements involved in the cognitive process.
- A significant limitation of this study was its reliance on a cross-sectional design rather than a longitudinal approach.

## Background

- Older adults' cognitive performance
- Light, perception, and cognitive performance
- Aims and questions

## Method

- 2x2 factorial design
- VR development
- Experiment design
- Data Collection

## Findings

- Participants demographic
- Self-reported data
- Cognitive performance
- Summary
- **Application**

Based on the findings of this study, identify lighting design strategies in this scene that are most impactful on older adults' cognitive performance



# Thank You!



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