COGNITIVE RESPONSES TO MELANOPIC EQUIVALENT DAYLIGHT ILLUMINANCE

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Joint CNC/CIE, CIE-USNC & CORM Lighting Research Conference 2025
11.19.2025

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BACKGROUND

- Intrinsically photosensitive retinal ganglion cells (ipRGCs) use melanopsin to sense light and regulate non-image-forming functions (e.g., circadian photoentrainment and pupil reflex) as well as image-forming aspects (i.e., brightness).
- IpRGCs are primarily sensitive to short wavelength energy (peaking around 480 nm and 490 nm), which appear blue.[1]

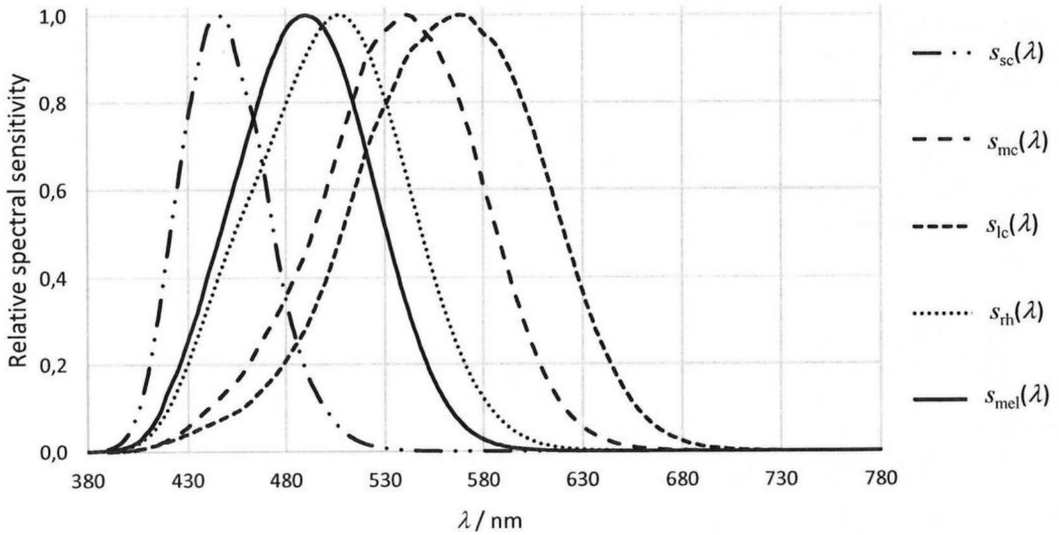


Fig. 1: The 5 action spectra plotted against wavelength (CIE 2018)

BACKGROUND

- The CIE introduced melanopic equivalent daylight illuminance (mel-EDI) as a standardized metric.[1]
  - Mel-EDI quantifies how electric lighting compares to daylight in stimulating non-visual responses.
- This helps bridge the gap between what we see and how light makes us feel and function.

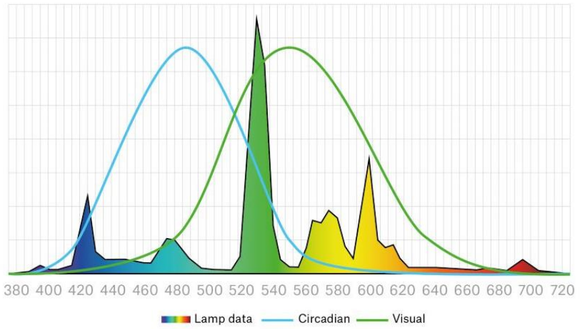
3.9
α-opic equivalent daylight (D65) illuminance, <at a point on a surface>
$E_{v,\alpha}^{D65}$
illuminance produced by radiation conforming to standard daylight (D65) that provides an equal α-opic irradiance, E_α, as the test source, expressed by

$$E_{v,\alpha}^{D65} = \frac{E_\alpha}{K_{\alpha,v}^{D65}}$$

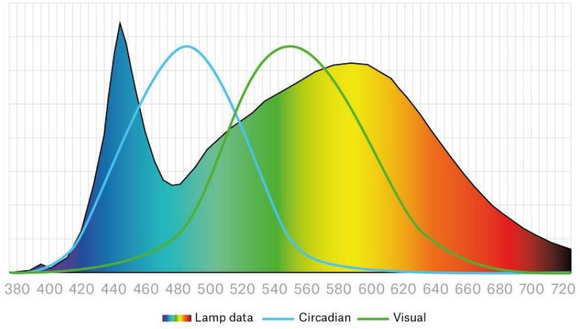
(CIE 2018)

BACKGROUND

- Current guidelines for integrated lighting (all in melanopic EDI):[2]
  - Minimum of 250 lx during the day
  - Maximum of 10 lx in the evening
  - Maximum of 1 lx at night



FL4000-R:0,580



LED 4000-R:0,760

https://www.lamp.es/images/579796/default.jpg

LITERATURE REVIEW

- One study explored the connection between psychophysical state and cognitive performance due to lighting conditions[3]
  - Located in military camp tent and performed tasks related to executive function and visual processing
- Results show quicker thinking and response under higher CCTs, combined with higher states of arousal

Fig. 1: Each session took place in this tent (Hawes et al., 2012)

LITERATURE REVIEW

- Another study investigated neural activation and performance due to blue and amber colored light[4]
  - Performance remained consistent across conditions
  - fMRI images demonstrated higher brain activation in participants exposed to blue light
- Limited due to computer screen testing

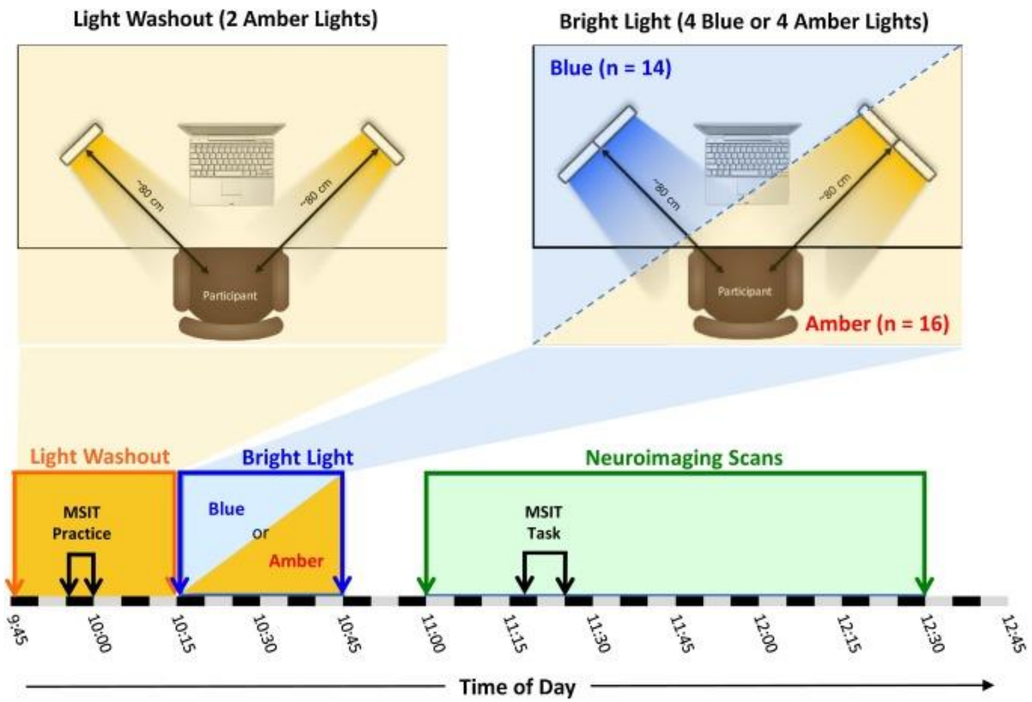


Fig. 2: Experimental set-up and timeline of procedure (Killgore et al., 2020)

RESEARCH GAP

- Blue light has gained attention for its effects on alertness, sleep, and overall well-being,[5] impacting cognition even in durations as short as 1 min.[6]
- Research focuses on how melanopsin-driven, non-image-forming receptors trigger brain activity that influences perception and physiology.
- However, the acute effects of lighting on cognitive performance has not been systematically tested (controlling mel-EDI, CCT and color at the same time).

HYPOTHESIS

- Melanopic daylight equivalent (mel-EDI) can be used to predict cognitive performance.
  - The chromaticity of the lighting is not the critical factor, while the melanopsin content is more decisive.
  - The increasing cognitive effects of mel-EDI enhancing lighting will be accompanied by lower ratings of sleepiness.

METHODS

- Three lighting conditions were developed
  - 15 channel color-tuneable LED cubes programmed in three scenes
  - Illuminance taken in vertical plane
- Participants experience all 3 conditions in a randomized order

Table 1. Summary of lighting conditions

	Condition 1	Condition 2	Condition 3
Nominal Color	White	White	Blue
Illuminance (lux)	250	248	240
CCT (K)	4198	3879	N/A
mel-EDI (lux)	138	189	196

METHODS

- Participants arrive in the minimum mel-EDI condition
- Each scene follows same procedure with slightly modified paper tests
- Entire experiment takes ~40 minutes to complete

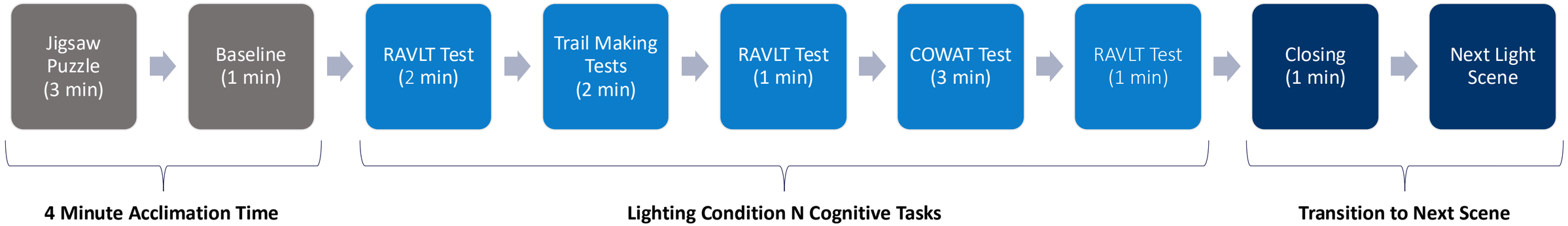


Fig 3: Flow chart of experimental procedure

METHODS

The Rey auditory verbal test (RAVLT)

- Given 15 unrelated words and repeat back as many as they can remember
- Repeated 2 times between other cognitive tasks, participant asked to rename 15 original words
- Tests memory over short and long term

List 1	List 2	List 3
Drum	Desk	Doll
Curtain	Ranger	Mirror
Bell	Bird	Nail
Coffee	Shoe	Sailor
School	Stove	Heart
Parent	Mountain	Desert
Moon	Glasses	Face
Garden	Towel	Letter
Hat	Cloud	Bed
Farmer	Boat	Machine
Nose	Lamb	Milk
Turkey	Gun	Helmet
Color	Pencil	Music
House	Church	Horse
River	Fish	Road

Fig. 4: Example word lists
https://www.researchgate.net/figure/Word-Lists-Used-in-Modified-Auditory-Verbal-Learning-Test_tbl1_283821213

METHODS

Trail making tests (TMT-A and TMT-B)

- Sequencing, cognitive flexibility, and visual scanning are examined
  - Version A: Connect numbers in order 1-15
  - Version B: Connect numbers and associated numbers (1-A-2-B-3-...)

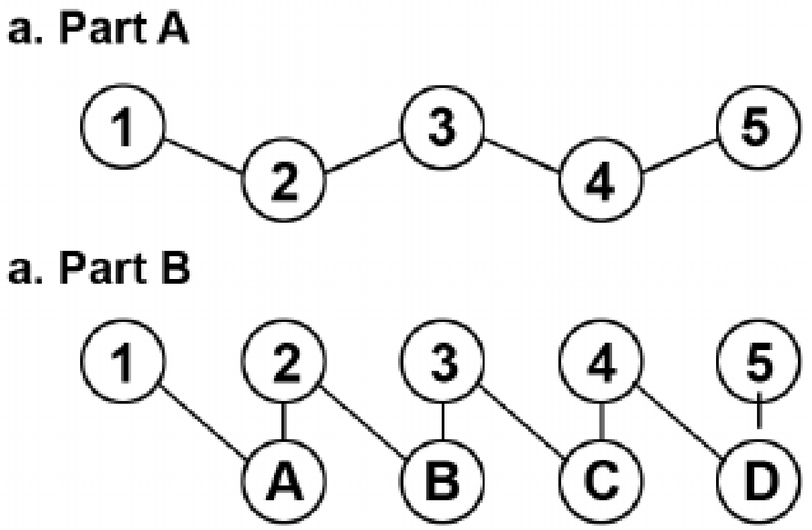


Fig. 5: Sequence of connections https://www.researchgate.net/figure/Sample-of-TMT-A-and-B-test-sheet_fig11_228080507

METHODS

Controlled word order association test (COWAT)

- Name as many words as possible beginning with a specific letter
  - One consonant, one vowel, one consonant (e.g., the letters F, A, and S)
- Tests verbally fluency, semantic memory, and processing speed

Fig. 6: COWAT Example Video
https://i.ytimg.com/vi/8r7t8Qplje8/mqdefault.jpg

METHODS

- 5 participants were recruited for the pilot study
  - Mean age of 21 years old
  - 4 females and 1 male
  - 1 participant excluded from data
- Vision clarity and color vision were tested for each participant

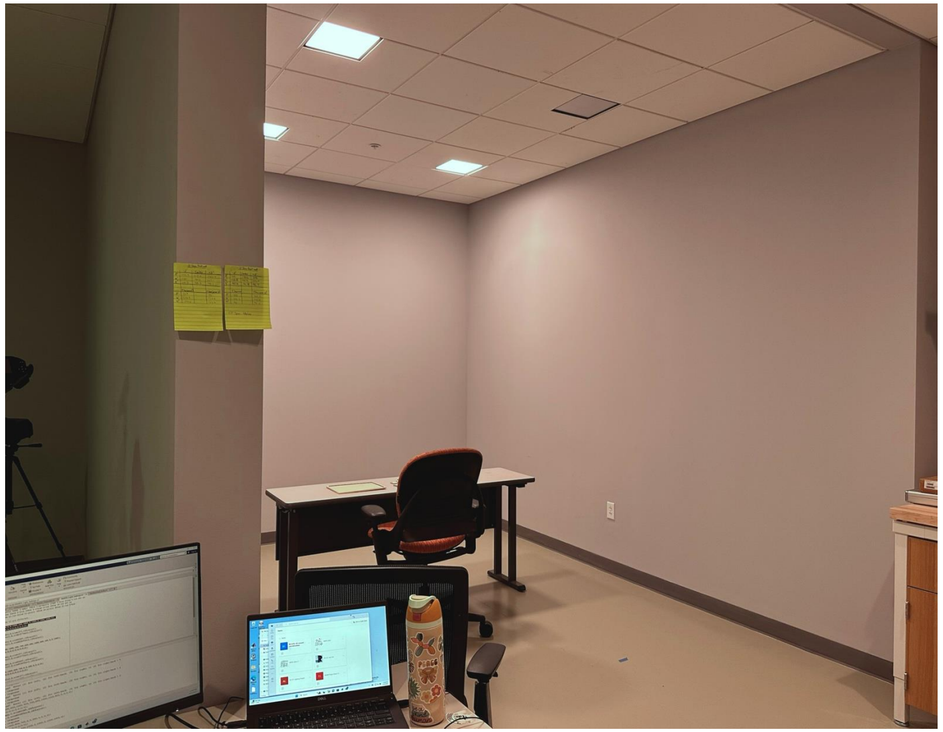


Fig. 7: Experimental Set-Up

RESULTS

- Results indicate minimal cognitive differences
- Slightly higher results in the minimum white condition for RAVLT and COWAT tests

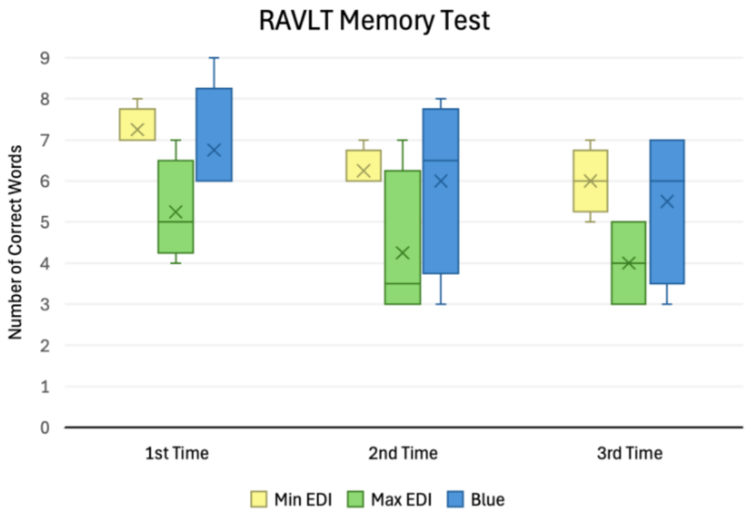


Fig. 8: Box and whisker plot displaying number of correct words for the memory test (repeated 3 times)

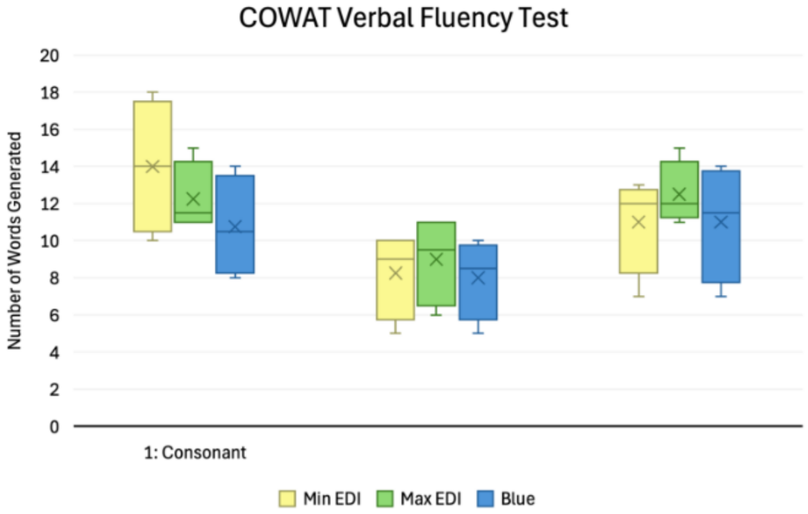


Fig. 9: Box and whisker plot displaying number of words recalled for each letter (3 letters per condition)

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RESULTS

- The blue light condition yielded slightly faster times in both trail making tests

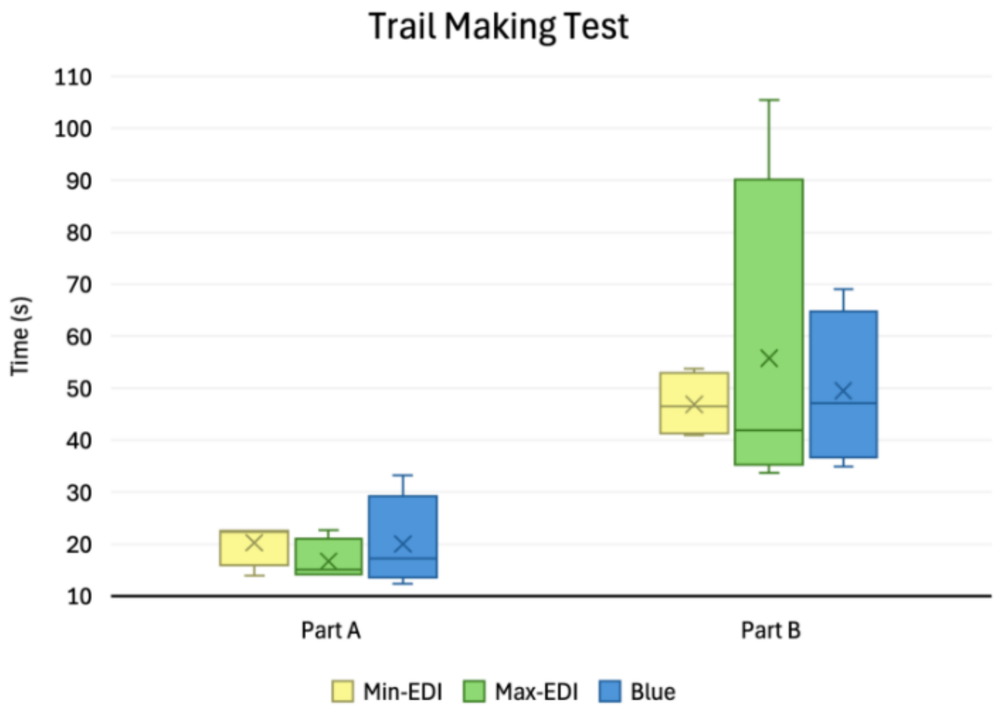

Fig. 10: Box and whisker plot displaying completion time for Parts A and B

LIMITATIONS

- Small sample size
- Lack of training
- Potential cognitive fatigue that varies with lighting condition

https://www.working2wellbeing.com/wp-content/uploads/2023/02/152028020_m-1100x733.jpg

NEXT STEPS

- Full study planned for early 2026
  - Increased participant gathering
  - Refined criteria
  - Practice period
- Will utilize two original tests and two new cognitive tests
- Time expanded to 1 hour with compensation

THANK YOU

QUESTIONS?

REFERENCES

[1] *CIE system for metrology of optical radiation for IPRGC-influenced responses to light*. CIE. (2018). https://cie.co.at/publications/cie-system-metrology-optical-radiation-iprgc-influenced-responses-light-0

[2] *CIE position statement on integrative lighting - recommending proper light at the proper time, 3rd edition*. CIE, International Commission on Illumination. (2024). https://cie.co.at/publications/cie-position-statement-integrative-lighting-recommending-proper-light-proper-time-3rd

[3] Hawes, B. K., Brunyé, T. T., Mahoney, C. R., Sullivan, J. M., & Aall, C. D. (2012). Effects of four workplace lighting technologies on perception, cognition and affective state. International Journal of Industrial Ergonomics, 42(1), 122–128.

[4] Killgore, W. D. S., Dailey, N. S., Raikes, A. C., Vanuk, J. R., Taylor, E., & Alkozei, A. (2020). Blue light exposure enhances neural efficiency of the task positive network during a cognitive interference task. Neuroscience Letters, 735, 135242.

[5] Silvani, M. I., Werder, R., & Perret, C. (2022). The influence of blue light on sleep, performance and wellbeing in young adults: A systematic review. Frontiers in physiology, 13, 943108

[6] Tonetti, L., & Natale, V. (2019). Effects of a single short exposure to blue light on cognitive performance. Chronobiology international, 36(5), 725-732.