

# Effects of Correlated Colour Temperature (CCT) on Performance

Dr. Nilgün OLGUNTÜRK

Assoc. Prof.  
Bilkent University, Ankara



# Performance

<http://www.merriam-webster.com/dictionary/performance>

## Full Definition of *performance*

1 *a* : the execution of an action *b* : something accomplished

2 : the fulfillment of a claim, promise, or request

3 *a* : the action of representing a character in a play  
*b* : a public presentation or exhibition <*a benefit performance*>

4 *a* : the ability to perform: efficiency  
*b* : the manner in which a mechanism performs <*engine performance*>

5 : the manner of reacting to stimuli : behavior

6 : the linguistic behavior of an individual : parole;  
*also* : the ability to speak a certain language — compare competence

# Wayfinding is

the ability to situate oneself in a location and reach at intended destinations or

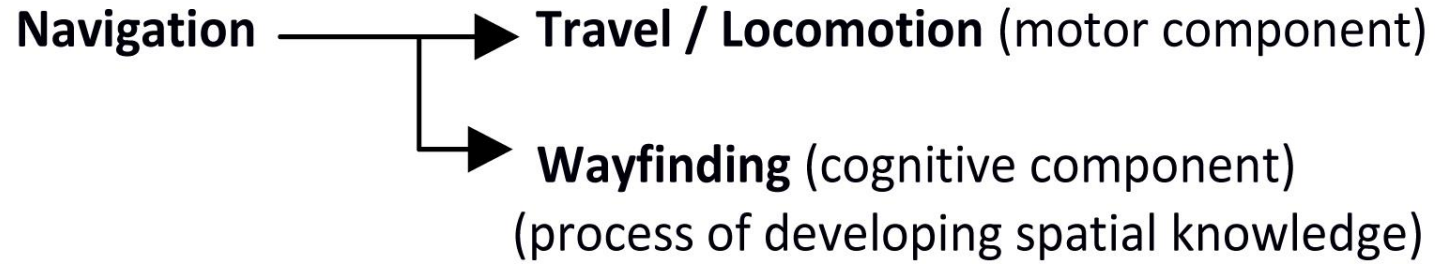
to navigate in spatial environments, both cognitively and behaviorally.

Passini, R. (1984). *Wayfinding in Architecture*. New York: Van Nostrand Reinhold.

Rovine, M. J., & Weisman, G. D. (1989). Sketch-map variables as predictors of way-finding performance. *Journal of Environmental Psychology*, 9(3), 217-232.

## CCT on wayfinding





Locomotion is body movement coordinated to the local surrounds; wayfinding is planning and decision making coordinated to the distal as well as local surrounds.

Montello, D. R. (2005). *Navigation*. In Shah, P., & Miyake, A. *The Cambridge Handbook of Visuospatial Thinking*. Cambridge University Press.

## CCT on wayfinding

# Wayfinding is

a spatial problem solving activity that comprises of three specific but interrelated processes:

- Decision making (the development of a plan of action)
- Decision execution (transforms the plan into appropriate behavior at the right space)
- Information processing (environmental perception and cognition)

Arthur, P., & Passini, R. (1992). *Wayfinding*. New York: McGraw-Hill Book Co.

## CCT on wayfinding

CCT on Wayfinding  
in Airports  
with Özge Kumoğlu



H1. There is a significant effect of CCT on wayfinding in airports.

H2. There is a gender difference due to CCT and wayfinding in airports.

Hypotheses

CCT on wayfinding

- Comparison of 3000 K, 6500 K and 12000 K
- Under approx. 200 lux
- 90 University graduate and undergraduate students across central Anatolia (age between 19 to 45)
- 3DS Max for modeling, Mental Ray renderer for simulation, a generic airport.
- 35 cameras total, every six meters.
- Tested individually.
- Background noise of a generic airport.

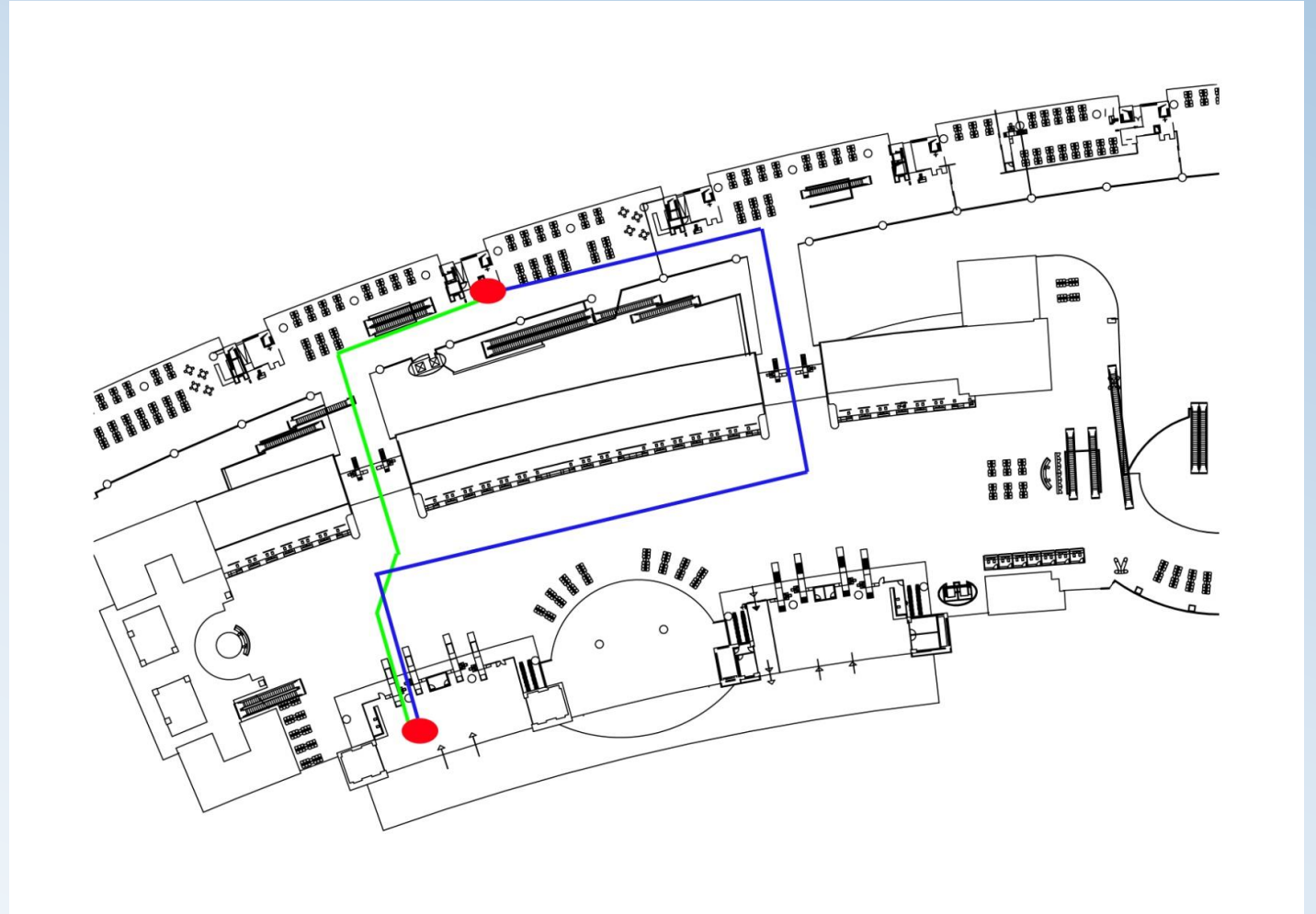
Method

CCT on wayfinding



Method

CCT on wayfinding



Airport building  
green line: short route, blue line: long route



3000K



6500 K



12000 K

CCT on wayfinding

## Wayfinding performance criteria

- Time spent
- Number of errors (commonly a miss)
- Route choice (preferably with less decision points, the short way)
- Hesitation (the number of full stops)

## Method

## CCT on wayfinding

- The effect of CCT on time spent is not significant ( $p=0.164$ ).
- The effect of CCT on total number of errors is not significant ( $p=0.954$ ).
- The effect of CCT on route choice is not significant ( $p=0.567$ ).

## Findings

### CCT on wayfinding

Turning right at the entrance, ignoring the signage would lead to long route. Signage of domestic flights would lead to short route.

- The effect of CCT on total number of hesitation points is significant ( $p= 0.001$ ).

3000 K significantly increased hesitations.

6500 K and 12000 K did not significantly differ in number of hesitation points.

Recorded reaction times for direction responses to be max three seconds (Beusmans et al, 1995). Experienced hesitation accepted to be more than 3 seconds.

## Findings

### CCT on wayfinding

Beusmans, J.M., Aginsky, V., Harris, C.L and Rensink, R.A. (1995). Analyzing situation awareness during wayfinding in a driving simulator. *Proceedings of the International Conference on Experimental Analysis and Measurement of Situation Awareness*. Daytona Beach, Florida: Embry-Riddle Aeronautical University Press. Pp 245-251.



- The effect of CCT on total number of hesitation points is significant for males ( $p= 0.007$ ).

3000 K significantly increased hesitations.

6500 K and 12000 K did not significantly differ in number of hesitation points.

## Findings

### CCT on wayfinding

- The effect of CCT on total number of hesitation points is not significant for females ( $p= 0.087$ ).

## Wayfinding studies

- Colour
- Landmarks
- Familiarity
- Signage systems
- Spatial differences
- Plan layout
- Behavior of users

but **not on** the effects of **Lighting**

wayfinding

## CCT studies

- Perception
- Individual liking-preference
- Working performance
- Psychological and physiological effects

but **not on wayfinding**

CCT on

This research tries to fill the gap in the literature about the effects of CCT on wayfinding.

6500 K and higher CCT significantly lowers hesitations during wayfinding.



CCT on wayfinding

with Özge Kumoğlu

Attention is a set of processes that supports the preservation of goal-directed behaviour during several competing distractions.

Parasuraman, R. (Ed.). (2000). *The Attentive Brain*. USA: Mit Press.

CCT on sustained attention

The ability to **sustain attention** is also known as vigilance:

The ability to notice and react to the stimulus changes which happen rarely or at unequal recesses, so they are hardly noticeable.

Warm, J. S. (Ed.). (1984). *Sustained Attention in Human Performance*. New York: Wiley.

## CCT on sustained attention



Publication	Participants	Method	CCT	Illuminance	Task	Findings
Boray et al (1989)	Undergraduate students	Tests about cognitive performance	3000 K 4150 K 5000 K	500 lux	Visual tasks	No sig. Diff. in quantitative tasks
Vrabel et al (1998)	Undergraduate students	Visual clarity and brightness response scale	2700 K 4100 K 4200 K 5000 K	538 lux	Visual performance and clarity	No sig. Diff. on visual performance and clarity
Slegers et al (2012)	Students	d2 Test of Attention	2900 K 6500 K 12000 K	300 lux 1000 lux 650 lux	Concentration	6500 K increases concentration
Rautkyla et al (2010)	Undergraduate students	Karolinska Sleepiness Scale	4000 K 17000 K	1000 lux	Daytime alertness	17000 K assists to have higher levels of alertness
Huang et al (2014)	Undergraduate students	Chu Attention Test	2700 K 4300 K 6500 K	500 lux	Focused and sustained attention	4300 K increases attention

## CCT on attention

# CCT on Sustained Attention

with Rengin Kocaođlu



The d2 test of attention is

- a cancellation test
- involves simultaneous presentation of visually similar stimuli
- measures sustained attention and concentration processes

It was created by Brickenkamp in 1981 in Germany.

Brickenkamp, R., & Zillmer, E. (1998). *The d2 Test of Attention*. USA: Hogrefe & Huber Pub.

## CCT on sustained attention

	TN	E1	E2	CP
1				
2				
3				
4				
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6				
7				
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9				
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11				
12				
13				
14				

d2 Test of Attention

# CCT on sustained attention

Measures of d2 test of attention are

- Total number of items processed
- The number of misses (errors of omission: unmarked items)
- The number of false alarms (errors of commission: incorrectly marked items)
- Concentration performance (total number of correctly marked items)

CCT on sustained attention



H1. Student's concentration performance will increase at 6500 K.

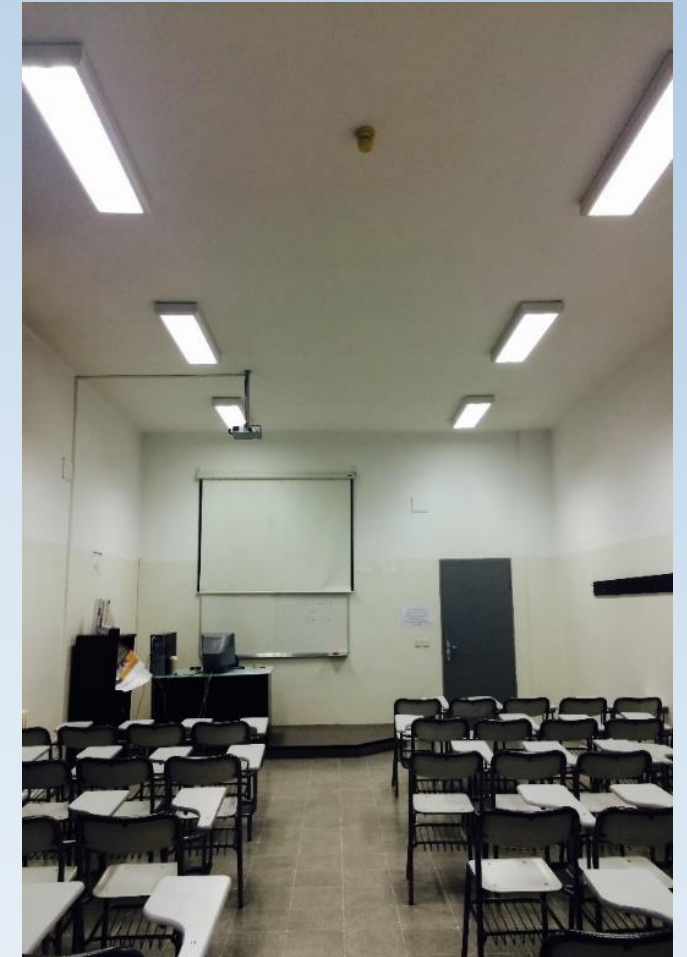
H2. Student's number of errors will decrease at 6500 K.

## Hypotheses

CCT on sustained attention

Method

CCT on sustained  
attention



## Method

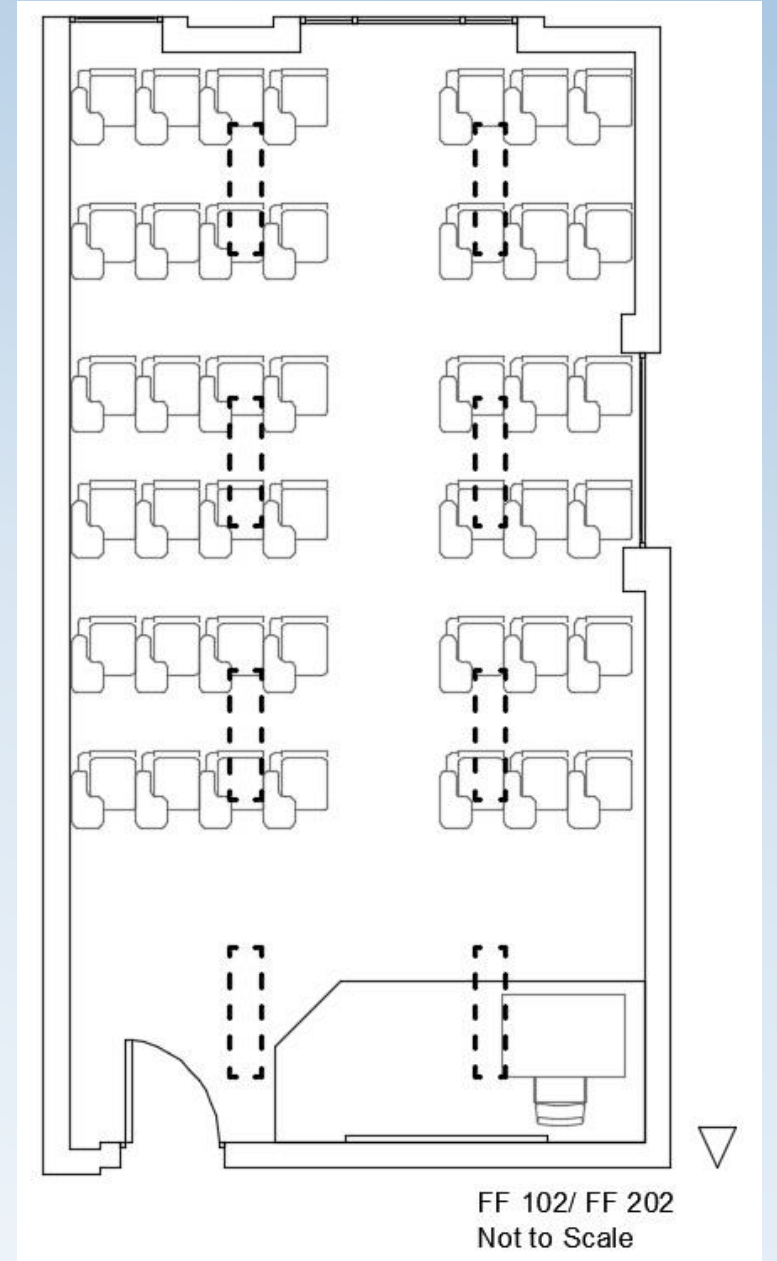
### CCT on sustained attention

- Comparison of 4000 K and 6500 K
- Under approx. 400 lux
- 97 University undergraduate students (age between 18 to 25)
- Two actual lecture rooms, two actual lecture course hours with two different CCTs.
- Same week, between 10.40-12.30, daylight totally blocked.
- Tested in group format after the lecture class.



## Method

## CCT on sustained attention



## Findings

### CCT on sustained attention

- The effect of CCT on the total number of items processed is not significant ( $p= 0.402$ ).
- The effect of CCT on the errors of omission (missed items) is not significant ( $p= 0.075$ ).
- The effect of CCT on concentration performance is not significant ( $p=0.296$ ).



- The effect of CCT on the errors of commission (incorrectly marked items) **is significant** ( $p = 0.001$ ).

6500 K significantly decreases incorrectly marked items.

## Findings

### CCT on sustained attention

- The effect of CCT on the error percentage is significant ( $p=0.0001$ ).

6500 K decreases the error percentage.

## Findings

### CCT on sustained attention

$$\text{Error \%} = \frac{\text{errors of omission} + \text{commission}}{\text{total items processed}}$$

- Findings promote 6500 K over 4000 K.
- Complies with Slegers et al (2012) work also promoting 6500 K in primary schools with Dutch students (note that sample group and environment is changing).
- Contradicts with Huang et al (2013) promoting 4300 K with undergraduate students. Might be due to lighting technique of LED desk lighting (not general lighting).

CCT on sustained attention

with Rengin Kocaoğlu

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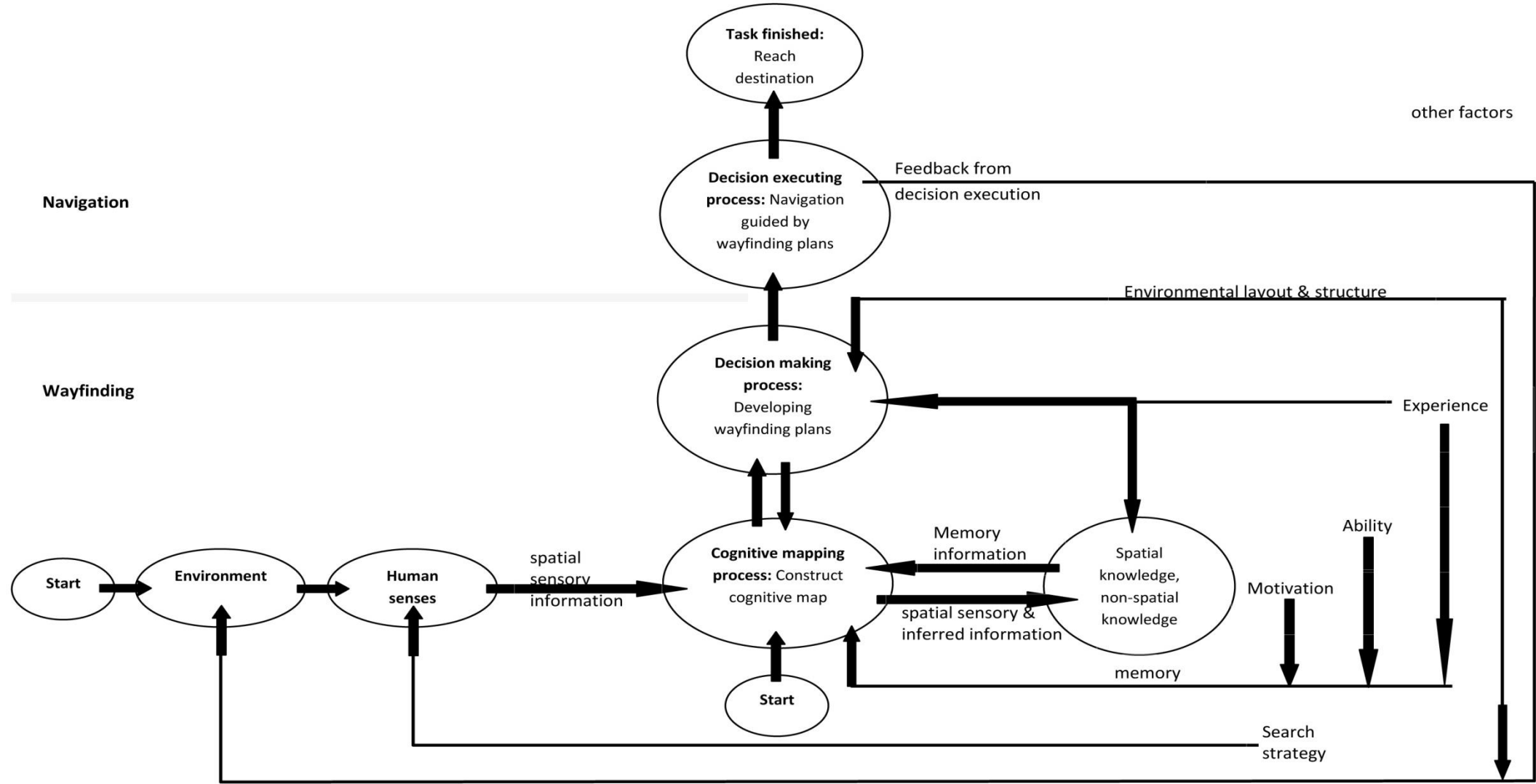
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Warm, J. S. (Ed.). (1984). *Sustained Attention in Human Performance*. New York: Wiley.



Theoretical model of wayfinding (adapted from Chen & Stanney; 1999:681)

CCT on wayfinding

Publication	Participants	Method	CCT	Illuminance	Task	Findings
Hidayetoğlu et al (2012)	102 university students	University Building Virtual environment via desktop	3000 K 4000 K 5300 K	10 lux 250 lux 500 lux	Remembering and perceptual judgements	4000 K the most positive perceptual evaluations. Lowest recall at neutral color, 250 lx and 4000 K.
Knez (1995)	96 participants	Laboratory	3000 K 4000 K	300 lux 1500 lux	2D cognitive tasks; memory, problem solving, long term recall etc.	Females' problem- solving and long- term memory performances enhanced in 3000K compared to 4000K conversely males.
Manav & Küçükdoğu (2006)	56 office workers	Real environment	4000K 2700K mixed CCT	500 lux 750 lux 1000 lux 2000 lux	the speed of answering questions and making errors	Under mixed CCT at 500 lux, the mean average of making errors was maximum
Manav 2007)	56 participants	Laboratory (cell office)	2700 K 4000 K	2000 lux 500 lux	Subjective impressions	4000 K was preferred to 2700 K for impressions of 'comfort and spaciousness', while 2700 K was suggested for 'relaxation' and 'saturation evaluation'

## CCT on different performances

Publication	Participants	Method	CCT	Illuminance	Task	Findings
Chellappa et al (2011)	Young people	GO/NOGO Task	2700 K 6500 K	40 lux	Capacity for sustained attention and response control	6500 K supports faster reaction times

CCT on sustained attention