

## REVIEW ARTICLE

# THE EFFECTS OF TEMPERATURE LEVELS ON TASK PERFORMANCE: A REVIEW

Ezrin Hani SUKADARIN<sup>1</sup>, Tan Zhen SHENG<sup>1</sup>, Junaidah ZAKARIA<sup>1</sup>, Fazrina SALLEH<sup>1</sup> and Khairul Amri Abdul AZIZ<sup>2</sup>

<sup>1</sup>Occupational Safety and Health Program, Faculty of Engineering Technology

<sup>2</sup>Centre for Modern Language and Human Sciences, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia.

### ABSTRACT

Temperature may negatively affects human performance rate and human physical response if it is not properly controlled. Effects of temperature on task performance and its contribution to the occurrence of thermal comfort had been a major focus in hundreds of studies. However, until now inconsistent results were yielded from those studies. This paper presents the literature review of the researches on the effects of temperature on task performance. To gain better understanding, thermal comfort issue and task performance also have been reviewed. Conclusively, there are some researches which have proved that the variations in temperature levels can affect task performance and thermal comfort, while some researchers disagreed with the finding.

**Keywords:** *Temperature, Task Performance, Thermal Comfort*

### INTRODUCTION

Temperature plays an important role as one of major fundamental characteristics for indoor environment (Parsons, 2014). Imbalance temperature level with human task can gives impact, in terms of thermal comfort, performance at work, perceived air quality and the occurrence of sick building syndrome symptoms (Seppänen, Fisk, & Lei, 2006). The incremental of carbon dioxide (CO<sub>2</sub>) composition in the air for example may increase levels of temperature (Masiren et al. 2016). It is important to understand the sources of temperature as it may affect workers' psychological state. Human being has their own thermal sensation which reflects on varied comfort level among individuals.

Heat balance measurement is used to determine human thermal comfort. These experimental approaches measures four physical variables namely air temperature, air velocity, mean radiant temperature, and relative humidity, and the two personal variables including clothing insulation and activity level, Fanger (1970). Temperature may affect human performance rate and physical response respectively. The Study of temperature and human task performance and its contribution to the occurrence of

thermal comfort had become a focus subject in many researches nowadays. This paper presented a review on the published papers focusing on the impact of temperature to human task performance and thermal comfort issues.

### METHODOLOGY

Literature search had been conducted to search for relevant materials. Science Direct journals database had been used as a major source of reference; this search was limited to the following keywords: temperature, thermal comfort and task performance. Other than that, 'Human Thermal Environments' textbook was referred in this review paper. The effect of temperature were highlighted and associated with the task performance. There were all 11 different journals that have been reviewed.

### RESULT AND DISCUSSION

#### Effect of Temperature and Task Performance

The relationship between air temperature and human task performance had been focus in many studies; yet, inconsistent results were yielded from those studies. In the study

by Fang et al. (2004), 30 female respondents were exposed to 3 different environment conditions which consists of temperature and relative humidity respectively (20°C /40%; 23°C /50%; 26°C /60% ) for 280 minutes. They showed that the performance of office work was not significantly affected by indoor air temperature and humidity.

Besides that, a study of Kahl & Voorhis (2005) showed that room temperature do affected the physical comfort, but there is no impact on human task performance in solving mathematics problems, reading comprehension or word recall. However, in a study of Lan et al. (2010), they showed an opposite result from the Kahl and Voorhis' (2005). In contrast, study of Lan et al. (2010), showed an opposite result from the Kahl and Voorhis' (2005).

Lan et al. (2010) conducted an experiment on 21 volunteered participants with 3 different air temperature levels (17 °C, 21 °C, and 28 °C). They used computerized neurobehavioral tests during exposure in the lab to measure the participants' performance. The results indicated that thermal discomfort caused by air temperature had negative influence on office workers' productivity. The rating scales supplements in the neurobehavioral performance were useful when evaluating the effects of indoor environmental quality on productivity.

A study on the effects of work on hot environment had been conducted by O'Neal & Bishop (2010) with 10 respondents. The respondents were tested with three different simple mental task tests in 30°C and 38°C hot environments. The tasks were short-term memory test (MEM), simple arithmetic test (MATH) and computerized reaction time/tracking test (RTT). The study suggesting that the heat and physical activity did alter cognitive performance. In a study by Melikov et al. (2013), they required the participants to be exposed to 3 different temperatures of 23°C, 26°C and 28°C in climate chamber. The experiment was held for 4 hours. Sudoku test was used as a parameter for task performance. At the end of the experiment, subjective responses were collected through questionnaires. Physiological test results were also taken. The results showed that the increase of the influence the productivity and thermal comfort. From all the data, they summarized that performance increases with temperature up to 21-22 °C, and decreases with

temperature and relative humidity significantly decreased tear film quality and the concentration of salivary alpha-amylase. All of these indicating lower mental arousal and alertness.

According to Cui et al. (2013), 36 subjects were recruited and exposed to 5 different temperatures which were 22 °C, 24 °C, 26 °C, 29 °C, 32 °C for 150 minutes. The parameters used to measure the performance rate were the memory typing and the number of correct letters. It has been proven that performance rate was greatly affected by the temperature. In this study, they found that the highest task performance was at 26°C.

Kahl (2005) found that temperature had affected individual on thermal comfort and sensation, but they are no significant decrement or increment on the task performance. Similarity, Zhang et al. (2010) showed that the typing rate as task performance assessment among all the temperatures setting is insignificant.

Lan et al (2011) has conducted their study on 12 respondents regarding the effects of discomfort and task performance. Respondents were exposed to 2 different conditions which were 20°C and 30°C of temperature in office setting conditions. Physiological measurements such as body temperature and heart rate were taken. Office tasks were performed as parameters of performance. The results showed that the performance is decreased when the workers felt warm. Besides that, their heart rate and body temperature increased significantly.

The thermal sensation scale and thermal comfort scale were used to predict thermal comfort among the respondents, Cui et al. (2013) found that 26°C was the most comfortable temperature and believed that it is the neutral temperature or environment. They have also concluded that 26°C is the most comfortable temperature for learning and task performance.

Seppänen, Fisk, & Lei (2006) collected and analyzed the literatures relating to the performance in work and temperature. Findings revealed that, room temperature could affect productivity at

temperature above 23-24 °C. The highest productivity was recorded at temperature of around 22 °C. According to Tham & Willem (2010), prolonged exposure to moderate high

or low temperature will result in thermal discomfort. It is also believed that temperature may also lead to activating the brain amygdala, which is induced by thermal responses and indicating low task performance.

To conduct an experiment approach on the effects of temperature on service employees' customer orientation had conducted by Kolb, et al. (2012) with 69 volunteers. Participants were randomly assigned to one of two temperature conditions which was a room with a relatively low or high operative temperature. Several customer behaviours might be affected by temperature. This study found that service personnel show more customer-oriented behaviour in lower temperatures than in higher temperatures. Thus, ambient temperature can impact customer orientation as a kind of social performance in service settings.

According to Varjo et al. (2015), sixty-five participants were tested in "Condition A", neutral temperature (23.5 °C) and high fresh air supply rate (30 l/s per person) were applied, while in "Condition B", with high room temperature (29.5 °C) and a negligible

fresh air supply rate (2 l/s per person). This study provides strong evidence that the combination of high intelligibility of irrelevant speech, high room temperature and low ventilation rate impairs the perceived working conditions and cognitive performance.

## **CONCLUSION**

This paper presents a review of published research related to the effect of temperature on task performance and thermal comfort from the year 2004 to 2015. Findings affirmed that, varying temperature levels can affect task performance and thermal comfort of a person while some disagreed with the findings. Moreover, findings from this study can be used as a baseline data for future research. However, numbers of scientific research to investigate on this issue is still inadequate. Perhaps, many future researches can be conducted to study specific on the cause effect relationship between temperature, thermal comfort and task performance.

## **Acknowledgment**

The authors wish to thank the Faculty of Engineering Technology, Universiti Malaysia Pahang (UMP), for the continuous support in terms of facilities provided.

**Table 1**  
**Summary of effect of temperature on task performance**

Author (s)	Sample	Significantly-related	Not Significantly -related
Fang et al. 2004	30	-	Temperature does not affect the performance of office workers.
Kahl and Voorhis 2005	174	-	Only affected subjective physical comfort but have no impact on performance.
Seppänen et al. 2006	100	Performance and thermal comfort is affected by temperature.	-
Lan et al. 2010	12	Negative effects on health and performance occur when people feel thermally warm.	-
O'Neal and Bishop 2010	10	Heat and physical activity did alter cognitive performance.	-
Zhang et al. 2010	90	-	The differences in typing rate among all the conditions are insignificant and related to environmental conditions.
Lan et al. 2011	12	The negative effects on health and performance that occur when people feel thermally warm at raised temperatures.	-
Kolb et al. 2012	69	Ambient temperature can impact customer orientation as a kind of social performance in service settings.	-
Melikov et al. 2013	30	Increasing the temperature and relative humidity significantly lower mental arousal and alertness.	-
Cui et al. 2013	36	The learning effect and task performance is affected by the temperature.	-
Varjo et al. 2015	65	High room temperature and low ventilation rate impairs the perceived working conditions and cognitive performance.	-

## REFERENCES

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2009). *2009 ASHRAE handbook: Fundamentals*. Atlanta, GA: American Society of Heating, Refrigeration and Air-Conditioning Engineers.
2. Cui, W., Cao, G., Park, J. H., Ouyang, Q., & Zhu, Y. (2013). Influence of indoor air temperature on human thermal comfort, motivation and performance. *Building and Environment*, 68, 114-122.
3. Fang, L., Wyon, D. P., Clausen, G., & Fanger, P. O. (2004). Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance. *Indoor Air*, 14(s7), 74-81.
4. Kahl, J. K., & Voorhis, B. A. Van. (2005). Room Temperature and Task Effects on Arousal , Comfort and Performance. *Journal of Undergraduate Research*, 1-5.
5. Lan, L., Lian, Z., & Pan, L. (2010). The effects of air temperature on office workers' well-being, workload and productivity-evaluated with subjective ratings. *Applied Ergonomics*, 42(1), 29-36.
6. Lan, L., Wargocki, P., Wyon, D. P., & Lian, Z. (2011). Effects of thermal discomfort in an office on perceived air quality, SBS symptoms, physiological responses, and human performance. *Indoor Air*, 21(5), 376-390.
7. Masiren , E.E., Harun, N., Ibrahim, W.H.W., & Adam, F. (2016) Effect of Temperature on Diffusivity of Monoethanolamie (MEA) on Absorption Process for CO<sub>2</sub> Capture. *International Journal of Engineering Technology and Sciences (IJETS)* , 5 (1) , 43-51.
8. Melikov, A. K., Skwarczynski, M. A., Kaczmarczyk, J., & Zabecky, J. (2013). Use of personalized ventilation for improving health, comfort, and performance at high room temperature and humidity. *Indoor Air*, 23(3), 250-263.
9. O'Neal, E. K., & Bishop, P. (2010). Effects of work in a hot environment on repeated performances of multiple types of simple mental tasks. *International Journal of Industrial Ergonomics*, 40(1), 77-81.
10. Parsons.K. (2014). *Human Thermal Environments: The effects of hot, moderate, and cold environments on human health, comfort and performance*. Third Edition. CRC Press.
11. Seppänen, O., Fisk, W., & Lei, Q. (2006). Effect of Temperature on Task Performance in Office Environment. *Lawrence Berkeley National Laboratory*, 11.
12. Tham, K. W., & Willem, H. C. (2010). Room air temperature affects occupants' physiology, perceptions and mental alertness. *Building and Environment*, 45(1),40-44.  
<http://doi.org/10.1016/j.buildenv.2009.04.002>
13. Shaharon, M. N., & Jalaludin, J. (2012). Thermal Comfort Assessment-A Study Toward Workers ' Satisfaction in a Low Energy Office Building. *American Journal of Applied Science*. 9(7): 1037-1045.
14. Wafi, S. R., Ismail, M. R., & Ahmed, E. M. (2011). A Case Study of the Climate Factor on Thermal Comfort for Hostel Occupants in Universiti Sains Malaysia (USM), Penang, Malaysia. *Journal of Sustainable Development*, 4(5), 50-61.
15. Kolb, P., Gockel, C., & Werth, L. (2012). The effects of temperature on service employees' customer orientation: an experimental approach. *Ergonomics*, 55(November),621-635.  
doi:10.1080/00140139.2012.659763
16. Varjo, J., Hongisto, V., Haapakangas, A., Maula, H., Koskela, H., & Hyönä, J. (2015). Simultaneous effects of irrelevant speech, temperature and ventilation rate on performance and satisfaction in open-plan offices. *Journal of Environmental Psychology*,44,16-33.  
doi:10.1016/j.jenvp.2015.08.001