Topic A7: Thermal comfort

THE EFFECT OF HEAT STRESS ON WRITING PERFORMANCE IN A CLASSROOM

Alan KABANSHI[1], Marijke KEUS[1], Hans WIGÖ[1], Robert LJUNG [1], Patrick SÖRQVIST[1,2]

[1] Department of Building, Energy and Environmental Engineering, University of Gävle, Sweden
[2] Linnaeus Centre HEAD, Swedish Institute for Disability Research, Linköping University, Sweden

**alan.kabanshi@hig.se*

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SUMMARY

Studies have shown that heat stress impairs performance. This depends on the mental loading capacity of the task performed and the exposure time. This is a study of a common task in schools: writing task. It also analyses the occupants' perceived thermal comfort. The experiment was done in two heat conditions: 20 and 25 º C centigrade. The between participant design was used. ScriptLog was used to perform the writing task, while questionnaires and a Sudoku task were paper based tasks. The results show that the predicted mean vote between conditions was significant ($p<0.02$) and participants perceived the 20 º C condition to be draughty. They however preferred a little more air movements in both conditions. Writing performance only showed a significant difference ($p = 0.03$) on deleted characters but the other variables considered did not show any significant differences but showed a strong tendency that with a long exposure time it would eventually be impaired. This shows that writing despite being a complex task is not a high mental loading and is not quickly impaired by heat stress.

INTRODUCTION

Heat in workplaces often is uncomfortable and results in performance impairment on cognitive and physical tasks. It also contributes to how the indoor environment is perceived. There is quiet extensive research on the effects of heat stress on humans (Hancock, 2003). The findings have been well documented and understood, but most of the research pertains to physiological rather than the psychological findings. Hence, research on cognitive performance under heat stress is still on-going and few findings have been presented in this regard (Hancock, 2003). Other studies show that the effects of heat stress on cognitive performance depends on the mental loading capacity of the task at hand, some tasks show little or no effect at all under heat stress while others show high decrements in mental abilities with a short period of exposure to heat stress (Hancock, 1982, 1986; Pepler & warner, 1968; Wyon et al., 1975, 1996). The variations in findings reported can be attributed to differences in the methodological approach and other variables involved like skill level, participant acclimatization level, exposure time and task complexity (Hancock, 2003). The understanding that task complexity has the ability to impair cognitive performance makes research of various everyday tasks under heat stress pertinent.

The objective of this study was to investigate the effect of temperature on writing tasks in a classroom. This knowledge contribute to research in thermal comfort and would help understand whether current thermal comfort conditions used in ventilating schools and offices optimize performance on writing.

METHOD

The experiment was conducted in a mock up classroom at the University of Gävle. The following is what was done in the design and execution of the experiment:

Participants: Students at the University of Gävle participated in the study. All participants used Swedish and reported to be fluent in it. As a token of appreciation they were all given a cinema ticket for participating.

Experiment Room Environment: The environmental conditions were determined by two temperature conditions, 20 ºC (cooler) and 25 ºC (warmer). In each condition the parameters like lighting, noise level and other external conditions were kept constant; a mixing ventilation system with airflow rate of about 260 l/s was the primary ventilation system. The room air temperature was maintained and controlled using the supply airflow temperature. The activity level of participants was about 1.2 met and the expected clothing insulation level was between 0.8 to 1 clo.

Design and procedure: A between participant design was used. A group of 12 participants took part per session and used a computer to do the writing task and 'pencil and paper' to do: Sudoku filler task and questionnaires.

The dependent variables of interest in the experiment were defined, extracted and analyzed by use of ScriptLog application software. The software was used to do all the writing tasks and the dependent variables were: characters (the total number of characters generated in the final edited text), deleted characters (the total number of deleted characters in the writing task), Frequency of deletion, pause frequency (the total number of pauses longer than 5 seconds) and writing fluency (the sum of the total number of characters and deleted characters).

The experimental session lasted about 45 minutes. The tasks performed per session were ordered and done respectively as shown below:
Questionnaire 1– Writing task 1– Questionnaire 2– Sudoku 1– Writing task 2– Questionnaire 3– Sudoku 2– Writing task 3– Questionnaire 4.

The participants began with a questionnaire which addressed participant's health status at start of the experiment (a cold, flu, fever, fatigued, tired or alert etc.). The remaining questionnaires in the session had self-rating questions about the participants' state of mind (alertness, concentration and performance). The participants gave their perception of the indoor thermal climate through answering the subjective questions on room thermal conditions. The final questionnaire in the session included also the preferred personal thermal conditions and air movements during the experiment if participants had power over ventilation controls. A total of four questionnaires were done per session and each lasted for about a minute.

A total of three writing tasks were performed using the ScriptLog application. The participants were asked to write three short stories associated with the presented words. They were instructed to be thorough, avoid typing errors, and generate as much text as possible. One word was presented in each task, the three words used throughout the experiment were: Bicycle, Ice Cream and Ball. These words were counterbalanced across participants. The participants began first with a writing task which also included a minute long practice phase where they were presented with a word and wrote a story about it. This was then followed by the writing task. In each writing task, after being presented with a word, the participants had a minute to formulate a story they will write about. During this period no typing was allowed until the minute elapsed. Two Sudoku filler tasks were included, this was only to keep the students active and motivated during the session.

RESULTS

48 students (26 male, 22 females, mean age = 25.42 years, SD= 6.92) participated in the experiment, 22 in the cooler condition (20 ºC) and 26 in the warmer condition (25 ºC). The filler task (Sudoku) was also analyzed to see the performance but did not show any significant difference between the conditions so it was not included in this paper.

Writing performance

The variables in the writing task were analyzed by use of ScriptLog. The descriptive statistics shown in table 1 below show the difference between the conditions across the variables considered. The performance in the 20 ºC condition was better than in the 25 ºC condition as participants generated more characters and deleted fewer characters (this was significant as shown). The 20 ºC had higher mean values of all the variables compared to the 25 ºC condition. This mean difference between the means suggest a strong tendency and with more participants or a longer exposure time the effect of heat stress would be significant.

Table 1. Means of the variables extracted from the writing tasks in group statistics

	20 °C Condition		25 °C Condition		
Variables	Mean	SD	Mean	SD	p
Characters	840.00	297.81	736.85	278.16	0.22
Deleted Characters	80.01	33.00	106.50	48.56	0.030
Frequency of Deletion	26.58	10.93	34.74	17.56	0.055
Pause Frequency	3.21	2.37	3.14	2.01	0.915
writing fluency	920.08	304.56	843.35	293.48	0.381

Note: SD- Standard Deviation

Thermal comfort

This was determined through mean thermal vote (MTV) scale. The MTV scale not only does it assess the thermal perception but also inquires on the participants comfort (Nilsson & Holmer, 2003). The comfort zone is clearly defined within +1, 0 and -1 and any score falling outside this is said to be uncomfortable (Wigö, 2008).

The MTV between the two conditions were significant with a multivariate analysis of $p \leq 0.01$. The total MTV score in the 20 ºC condition was -0.55, $SD = 0.74$ and in the 25 ºC condition was +2.12, $SD = 0.62$. If given control to change the temperature, the participants on average preferred to slightly increase the temperature signifying a MTV score +1, $SD = 0.86$ in the 20 ºC condition. In the 25 ºC condition, they preferred a lower temperature signifying an MTV score 0, $SD = 0.86$.

The participants also perceived the room to be draughty in the 20 ºC condition compared to the 25 ºC condition. A draught rating of range 1 to 5 was used with higher values meaning very draughty. 20 ºC condition had a draught rating of 2.78, SD = 0.93 and 25 ºC condition had 1.52, SD = 0.57. If given control to change the air movements in the occupied zone, the participants preferred more air movements in both conditions even in the condition that had a higher draught rating.

DISCUSSION

Writing performance did not yield much to our hypothesis (high temperature impairs performance on writing). The mean values where higher in the 20 ºC condition as compared to the 25 ºC condition, this shows that people performed better in a lower temperature. The results however may have been affected due to the short exposure time used. With these results shown here, we are confident that with long exposure time heat stress will gradually impair writing performance. This analysis shows a strong tendency that with the same exposure time but with more data collection (increasing participants) significant differences may also be noticed between conditions. The results obtained in this experiment can perhaps help understand that writing though being a complex task does not have a high mental loading capacity and thus there is a weak interaction with heat stress. However more elaborate studies are needed to well establish the relationship between the writing process and heat stress, as well as cancel out the large number of variables that may confound (exposure time, fatigue etc.) the effect of heat stress on writing performance.

The results on thermal comfort were expected as other studies indicated findings that increase in temperature resulted in bad thermal perception of indoor climate (Fang et al, 2004, Kostiainen et al, 2008, Melikov & Kaczmarczyk, 2012, Wigö, 2008). These were not far from the initial expected results. It was however interesting to note that the participants preferred more air movements in the condition that had a higher draught rating and a lower temperature. This perhaps could be due to some outliers as some participants had high values on draught rating.

6 participants reported to have colds and 4 said they were tired at the start of the session. However their performance did not show any differences in results from the rest of the group. Hence they were included in the analysis. The clothing insulation level of participants varied between 0.8 to 1 .2 clo. However no restrictions were placed on this so it was possible that some participants may have been outside the insulation range.

This study shows that further studies especially in environments were routine type of tasks are commonly done like classrooms and some offices needs investigation so as to identify performance limiting factors due to ventilation. Establishing relationships between type of task and ventilation factors like temperature, air quality and air movements may help optimize performance and wellbeing. This suggests that spaces in schools and some offices need to have task-specific ventilation standards. Optimal performance will only be derived when spaces are designed with ventilation boundaries that foster optimization, and this means task specific ventilation methods and controls.

CONCLUSION

We can conclude that writing though classified as a complex task has a low mental loading capacity and is not quickly impaired by heat stress. It is shown in the study that a rise in temperature may gradually impair performance on writing. Thus, for optimal performance of this task favorable temperatures need to be established and controlled.

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