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Developing a Test Protocol for Measuring Office Productivity in Different Indoor Environments

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1 Introduction

People spend up to 90% of their times indoors, of which 33% is in their place of work, typically office buildings. Therefore, the potential impact of the indoor environment on occupants' health, wellbeing and productivity could therefore be significant. Buildings are typically designed based on thermal comfort criteria; however, maximising productivity could be a greater motivator for change.

Indoor Environment Quality (IEQ) parameters including temperature and Relative Humidity (RH) which are the focuses of this study, act as stressors that are known to impact the building occupants physiologically and psychologically, and indirectly affect productivity. The consideration of temperature on productivity is not consistent (Zhang et al., 2019), taking an energy based approach or a human-centred approach. Zhang et al. (2019) suggests that within the thermal comfort zone, productivity is not affected considerably while the more human-centred approach claims that even a tiny deviation from the optimum temperature can affect productivity (Wargocki and Wyon, 2017, Seppanen et al., 2006). In addition, the RH impact has been mainly studied in extreme conditions rather than what can be really experienced in real offices. The inconsistent results may have arisen due to the lack of a standard method for measuring productivity in IEQ studies. The aim of this paper is to develop a methodology to allow for physiological and psychological testing under varying environmental conditions.

2 Methods

The VSimulators facility, in University of Bath is a climate chamber with virtual reality that can be used to simulate an office environment. The Vsimulators is capable of simulating the air temperature and radiant temperature between 15 ˚C and 40 ˚C, relative humidity between 20% and 80%, airflow between 0.05 m/s and 1.5 m/s, and fresh air between 1 l/s/p and 10 l/s/p. To investigate the impact of temperature and RH on occupants, steady state conditions are preliminary considered. Three temperatures of 17.5 ˚C, 21 ˚C and 24.5 ˚C and three levels of relative humidity, 30%, 50% and 70%, have been considered.

Direct measurement of productivity is through measuring the outcome of the work, which can reveal the expected changes in workplace performance but cannot explain how or why any effects arise. To address these points, our direct measures of workplace performance are supplemented with more fine-grained measures of cognitive performance to identify which specific mental mechanisms are affected by changes in IEQ. A battery of cognitive tests has been designed within PsychoPy 2020.3.1 platform to cover the main aspects of cognitive functions involved in office work. These tests and the categories of cognitive performance that they measure are shown in Table 1.

Table 1. Battery of productivity tests

Test	Cognitive function(s) involved
Stroop	Executive function, Processing speed, Selective attention
Go/No go	Executive function
RVIP	Sustained attention
Visual search	Attention, Processing speed
Corsi	Short term visual working memory, Processing speed
Proof reading	Attention, Reasoning, Memory
Addition	Problem solving, Processing speed
Typing	Working memory, Processing speed

As a pilot study, four students participated in the study. They were exposed to the neutral condition (21 ˚C, 50% RH) and the extreme conditions (17.5 ˚C, 30% RH and 24.5 ˚C, 70% RH) in the chamber. Each exposure session lasts 30 minutes. Participants were asked to complete a questionnaire about their perceived IEQ, perceived productivity, two times during each exposure, one in the middle and one at the end so that the battery included subjective and objective measurements of productivity. Accuracy and reaction time were measured in all tests.

3 Results and Discussion

The primary results suggest that IEQ can affect cognitive functions in different ways. For most of the tests, as it can be seen in Figure 1, the accuracy is not changed significantly under different conditions, apart from *corsi* and *proof reading* in which the accuracy has decreased in high temperature and RH. However, the reaction time is more affected (Figure 2). In *Stroop* and *Visual search*, the reaction time increased in extreme conditions. However, inversely in *Addition* and *RVIP*, the reaction time were lower in extreme conditions. *Go/No go* test has not shown any considerable change.

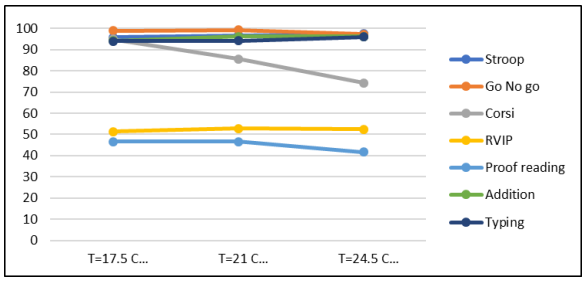

Figure 1: Average accuracy (%) of participants in different cognitive tests in the 3 conditions.

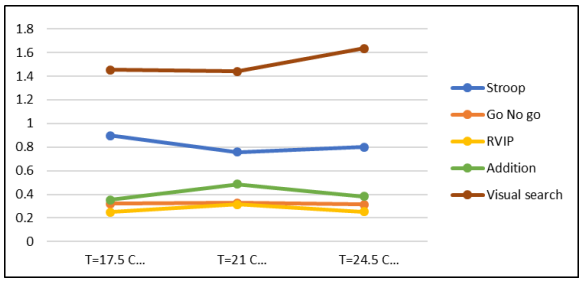

Figure 2: Average reaction time (seconds) of participants in different cognitive tests in 3 conditions

4 Conclusions

This paper has shown that cognitive performance can be used as a measuring method for the impact of IEQ on productivity. The results suggest that some cognitive functions are more affected in different IEQ conditions. So further experiments are needed to find a weighting factor for each cognitive function involve in productivity. In the pilots, the extreme conditions and the neutral one have been considered but other combinations of T and RH can help to develop a more robust method.

5 Acknowledgement

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