Effects of Simulated Masonry Work on Physical and Cognitive Performance: A Pilot Study

Qian Zhang[1], Vivekanandhan Thangavelu[2], Rocco Corbisiero[1], Ignacio Galiana Ruiz de Adana[3], Nils Napp[2], Lora Cavuoto[1]
[1]Department of Industrial and System Engineering, University at Buffalo
[2]Department of Computer Science and Engineering, University at Buffalo
[3]Universitat Politècnica de València

INTRODUCTION

Working in the construction industry is one of the most dangerous occupations. From workforce statistics of the U.S. Department of Labor, there are ~7 million employees in the construction industry, in which 1.5 million in construction of buildings and 1 million engaged in heavy construction (https://www.bls.gov/iag/tgs/iag237.htm). According to the 2016 statistics by the U.S. Bureau of Labor Statistics (BLS) there were 197,700 reported non-fatal injuries and 5,700 reported illnesses in the construction industry, resulting in 24,650 days away from work. Within the construction sector, masonry and concrete jobs lead to the highest rates of overexertion at 66.5 and 49.2 per 10,000 workers (BLS, 2016). Handling heavy loads, sometimes upwards of 80 pounds, remains a common characteristic of many construction jobs. A recent survey of construction workers showed that 49% reported being "tired some days" and 10% reported being "tired most days or every day" (Zhang et al., 2015). These workers reported high difficulty with physical and cognitive function as a result.

Previous studies have considered how physical exercise affects cognitive performance (Brisswalter, Collardeau, & René, 2002) and how physical workload and difficulty of tasks influence on human cognitive processing (Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007). It has demonstrated that both the intensity and duration of the physical exercise are related with cognitive performance (Abd-Elfattah, Abdelazeim, & Elshennawy, 2015). However, few studies have focused on how heavy physical demands will affect cognitive performance, particularly with construction work. This is of particular concern as unsafe worker behavior plays an important role in safety accidents and this unsafe behavior has been linked to cognitive failures (Fang et al., 2016).

Therefore, this study aimed to answer the following research questions:

RQ1: How does concrete block masonry work affect physical strength and performance?

RQ2: How does this masonry work affect construction workers' cognitive performance?

It was hypothesized that with time, physical workload would lead to muscle fatigue. As an effect of the physical workload and fatigue, cognitive performance was expected to degrade.

METHOD

Ten healthy student subjects (8 male, 2 female), aged 19-31 years old, were recruited to this study. The study was approved by the university's Institutional Review Board, and all participants provided written informed consent prior to participation. For the study, participants first completed a pulling/low back strength test where they pulled upward on a load cell. Then they completed a two minute cognitive performance test where they counted by either 13 or 17 until they made a mistake, at which time they started again with the other number. Once these baseline tests were complete, they built four adjacent walls made from concrete blocks that were 40 cm long x 15 cm tall x 15 cm wide and weighed ~13 kg. The walls were 5 blocks long by 5 blocks tall for a total of 100 blocks placed across the four walls. Participants laid the blocks at a self-paced rate. After each row was placed, a simulated mortar mixture was laid down prior to the next row of blocks. The wall building task took approximately 40 minutes. These tasks were designed based on observational and simulation data from a recent study of concrete block masons (Seo et al., 2016). Afterwards, they completed a post-task strength test and cognitive performance test, using the same procedures as the baseline tests.

Measurements of physical performance included back posture extracted from the Vicon motion capture system, change in pulling/low back strength from the start to the end of the session, and subjective ratings of perceived exertion (RPE). RPE ratings were collected every 5 minutes for the whole body, arm and back using the Borg CR-10 scale. Cognitive performance was assessed based on the number of errors in responses and number of correct responses to the arithmetic task. In addition, participants completed the Situation Awareness

 DOI 10.1177/1541931218621395

Rating Technique (SART) questionnaire to assess situation awareness and the NASA Task Load Index (NASA-TLX) to assess perceived workload.

RESULTS

The average completion time for the walls was 42 minutes, 20 seconds (standard deviation = 10 minutes, 53 seconds). Pulling strength decreased after wall building from 98.6 (32.8) kg to 90.9 (28.0) kg. However, the paired t-test results of strength showed that the task did not significantly affect strength (t=1.84, P=0.099). Similarly, cognitive performance was equivalent between baseline and after wall building (mean errors = 3.0 (1.9) vs. 2.7 (1.6), t=0.76, p=0.468, mean counting number = 24.8 (8.7) vs. 26.1 (11.3), t=-0.51, p=0.622). Average RPE scores of Whole Body, Arm and Back RPE increased generally while finishing the wall building tasks. Participants reached an average 6.3 (2.2) for their whole body rating, with a range from 3-9. Final RPE arm and back scores were significantly related with that of whole body (arm r=0.884 and back r=0.724, both $p<0.05$). Pearson correlation was used to investigate the relationship between RPE and subjective mental workload questionnaires (SART and NASA-TLX). The NASA-TLX scale revealed significant correlation of condition for physical demand (r=0.828, $p<0.05$) and effort (r=0.724, $p<0.05$) with whole body final RPE. There was a positive relationship between time ratio of bending angle 30-60^{o} and the situation awareness response on information quantity (r=0.628, *p*=0.052). There was also a significant relationship with between the time at 30-60° and the NASA-TLX performance subscale (r=0.716, $p<0.05$).

DISCUSSION AND CONCLUSIONS

The aim of this pilot study was to investigate how heavy physical workload from a masonry task affects physical and cognitive performance. It was hypothesized that heavy physical workload would lead to a decrease in both physical strength and mental performance. The results indicated that the masonry task did not significantly affect pulling strength. However, the observed decrease of ~10% is reasonable as the task did not push participants to exhaustion. In addition, participants may have adjusted their posture during the lifting task to recruit additional muscles for the pulling task. Future work should consider a different strength task that better recruits the specific muscles involved in masonry work to determine the effect of the workload on muscle strength.

When comparing the mental performance before and after the wall building, there was no significant difference for the errors and largest counting numbers. The original hypothesis was based on an expectation that the participants would reach a fatigued state following the task and would thus exhibit impaired cognitive function. However, it was instead likely that the participants experienced an exercise-induced improvement in cognitive performance. The current study was limited to a sample of students and to a relatively short task duration. These participants may have performed the task with different postures and perceived workload levels than experienced masons. Further work is needed, with a larger sample of masons, to evaluate the postures adopted and the effects on physical and cognitive performance. In addition, the task demands should be increased to induce both physical and mental fatigue in the participants in order to evaluate the how the fatigued state can affect task performance.

ACKNOWLEDGEMENTS

Research reported in this publication was supported by a pilot grant from the University at Buffalo Sustainable Manufacturing and Advanced Robotic Technologies Community of Excellence.

REFERENCES

Abd-Elfattah, H. M., Abdelazeim, F. H., & Elshennawy, S. (2015). Physical and cognitive consequences of fatigue: A review. *Journal of advanced research, 6*(3), 351-358.

Brisswalter, J., Collardeau, M., & René, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports medicine, 32*(9), 555-566.

Bureau of Labor Statistics (2016), *Nonfatal occupational injuries and illnesses requiring days away from work, 2015.*

Fang, D., Zhao, C., & Zhang, M. (2016) A cognitive model of construction workers' unsafe behaviors. *Journal of Construction Engineering Management,* 142(9), 12 pp.

Kamijo, K., Nishihira, Y., Higashiura, T., & Kuroiwa, K. (2007). The interactive effect of exercise intensity and task difficulty on human cognitive processing. *International Journal of Psychophysiology, 65*(2), 114-121.

Seo, J.O., Lee, S.H., & Seo, J. (2016) Simulation-based assessment of workers' muscle fatigue and its impact on construction operations, *Journal of Construction Engineering Management, 142(11),* 12 pp.

Zhang, M., Murphy, L.A., Fang, D., & Caban-Martinez, A.J. (2015) Influence of fatigue on construction workers' physical and cognitive function. *Occupational Medicine, 65(3),* 245-250.