International Journal of Industrial Ergonomics 66 (2018) 221–229

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

The effects of a moving environment on postural control and task performance during manual materials handling, visual tracking and arithmetic tasks

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ARTICLE INFO

Keywords:
Manual materials handling
Cognitive tasks
Maritime environments

ABSTRACT

The purpose of this study was to evaluate the performance of cognitive tasks and manual materials handling in a moving environment. Specifically, we were interested in how task performance, postural control and lower limb muscle activation changed when tasks were performed in motion compared to no motion conditions. The motion trials were performed on a MOOG 2000E that created a 5-degree of freedom simulated environment. The tasks examined were a lifting task, a mental arithmetic task and a visual tracking task. Results of this experiment indicated that two outcome measures of a visual tracking task (time to task completion and performance errors) were negatively affected by motion, while arithmetic task performance was unaffected. Additionally, postural control was not affected by the presence of motion in the two cognitive tasks. Lifting was the only task where postural control appeared to be negatively affected as participants exhibited significant increases in lower limb muscle activation and non-significant increases in number of steps taken. The significant increase in time to completion and errors suggest that workers performing visual tracking type tasks in an offshore environment may be more prone to committing human factors errors. Furthermore, the results suggest that the risk of falls and injury due to loss of balance may be highest in workers regularly performing lifting tasks as this was the only instance where task performance in a moving environment negatively impacted postural control. These findings were attributed to greater demands placed on the postural control system when lifting during the motion condition. This study provides ergonomists with a resource they can use to better appreciate the risks associated with performance of job related tasks in a moving environment.

Relevance to industry

The results of this research confirm that postural control in moving occupational environments is influenced by the type of task being performed. These differences directly impact reactive stepping, muscle activation, and resultant risk of falls and human factors errors. These factors must be considered when evaluating offshore occupations.

1. Introduction

Maritime industries including container transportation, crude oil transportation, oil platform resupply and ferry services are an essential part of the work force for seafaring nations. The harsh maritime environment that these industries are conducted create unique challenges that can significantly impact human performance, particularly with respect to postural instability and physical and mental fatigue (Wertheim, 1998). In both simulated (Duncan et al., 2016; Matthews et al., 2007) and real world (Duncan et al., 2012; Duncan et al., 2010; Stoffregen and Smart, 1998; Crossland et al., 2007) conditions research has shown that in these environments individuals step more often to maintain balance and as such are more unstable. These increases in postural instability lead directly to higher proportions of fall-related injuries in maritime occupations (43% of injuries; Jensen et al., 2005) when compared to land-based occupations (17% of injuries; U.S. Bureau of Labor US Bureau of Labor Statistics, 2015). The postural challenges workers face in these environments is further complicated by the fact in most instances workers are rarely simply maintaining balance, but rather must perform a job related task at the same time. Both of these tasks must be done efficiently and safely to ensure work place injuries do not occur and task performance does not suffer (Duncan et al., 2010).

In order to reduce the risk of injury and/or human factors errors

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https://doi.org/10.1016/j.ergon.2018.03.007
Received 6 March 2017; Received in revised form 31 January 2018; Accepted 19 March 2018

ergonomists must understand the impact of these dual task situations on performance and injury risk. While research has provided ergonomists with considerable knowledge of the factors that impact performance of a variety of different cognitive tasks (e.g. memory tasks, arithmetic tasks, tracking tasks) while standing on solid ground, relatively little is known about how performing these work tasks in a moving environment impacts performance, injury risk or postural control. Insight into the possible effects of these competing demands of balance and task completion can be gained from examining literature related to dual tasks.

In non-moving environments postural sway has been shown to increase with a concurrent cognitive task (Pellecchia, 2003), and prolonged lifting tasks have been shown to increase postural sway and horizontal ground reaction forces (Kollmitzer et al., 2002; Shu et al., 2005). Furthermore, the type of cognitive task (e.g. visual or auditory) has been shown to have differing affects on postural sway (Riley et al., 2005). Relatively less is known about how individuals maintain balance in 6 degrees of freedom moving environments when performing cognitive-based tasks. Many studies (Duncan et al., 2007, 2010, 2012; Holmes et al., 2008; Matthews et al., 2007) have explored how performing manual materials handling tasks affects postural control in such environments. A few studies (Bles and Wientjes, 1988; McLeod et al., 1980; Wertheim and Kistemaker, 1997) have examined the effects of motion on task performance in a 3-degree of freedom motion platform. However, to the authors' knowledge, a direct comparison of the effects of ship motion on cognitive and manual materials handling does not exist. From an ergonomics standpoint, information, and particularly direct comparisons, of how different types of tasks influence the dual task paradigm are necessary to understand their associated influence on fall risk and performance errors. This research looks to fill in the gaps by using a 6-degree of freedom motion platform to determine the effects that ship motion has on postural control and the performance of two types of tasks. Specifically the following research questions this research aimed to determine how type of task (ie. Cognitive vs. manual material handling) affects postural control and lower limb muscle activation when performed in a moving environment.

The resultant proposed hypotheses were:

1) The cognitive task will have a greater impact on postural control than the lifting task.
2) The lifting task in motion will result in the greatest increase in lower limb muscle activation when compared to the control condition.

2. Methods

2.1. Participants

Nine male and seven female participants (males: height 183.5 ± 6.4 cm, mass 89.9 ± 14.3 kg and age 23.8 ± 1.7 years; females: height 164.7 ± 8.3 cm, mass 72.8 ± 24.2 kg and age 24.8 ± 3.6 years) were recruited. All participants were free from known musculoskeletal injuries, tendency to develop motion sickness or balance issues, had no previous exposure to marine moving environments, and no experience on a motion platform in the past six months. This study was approved by the Interdisciplinary Committee on Ethics in Human Research of Memorial University of Newfoundland.

2.2. Apparati and instrumentation

Surface electromyography was collected bilaterally from biceps femoris (BF), gastrocnemius (Gastroc), tibialis anterior (TA), peroneus longus (PL), and vastus lateralis (VL) and erector spinae (ES) using a Delsys Trigno wireless EMG system (Delsys Incorporated, Natick, Massachusetts; collection frequency 2000 Hz, CMR of 80 db; bandpass filter 20 Hz–450 Hz). Prior to placement of the electrodes the skin in the area was shaved, gently abraded and then cleaned with an alcohol swab. Participants then performed isometric maximum voluntary activations (MVAs) for each muscle of interest. Each MVA lasted for approximately 5 s and completed twice per muscle.

Fig. 1. Picture showing the motion simulator and setup used for the study. A table can be seen in front of the participant while he or she faced forward, unable to see outside of the simulator as a result of the cover.

The platform used was a Moog 6DOF2000E (Moog Inc., Elma, NY), a 6-degrees-of-freedom electric platform used to replicate underfoot platform motions caused by waves that occur in marine environments. For the current study the platform only moved in 5DoF, as rotations about the z axis (yaw) were not included due to the fact that they only contribute to ship motion during turning. The platform was equipped with a cover so that participants were unable to see outside of the simulator in the areas front of them and to their sides (Fig. 1). Participants were encouraged to face forward whenever possible. Each trial used the same motion profile, which was derived from deck motions collected on a research fishing vessel using linear theory (Crossland and Lloyd, 1993; see equations in Table 1). Participants were videotaped during all of the motion trials. One camera was located behind the participants so that movement of the feet could be observed, while another camera was located to the participants' left side to capture if any grasping of the table or platform railings occurred. For all trials participants wore their own running shoes/sneakers. All footwear worn by the participants was in good condition with a rubber sole.

2.3. Protocol

At the beginning of the session participants performed one, five-minute motion trial so they could become habituated to the simulated motions (Duncan et al., 2014). No data was collected during this trial. Once the practice trial was complete participants then completed the seven data collection trials: a control trial where participants were required to simply maintain balance while the motion bed moved (i.e. no additional task was performed), lifting (with and without motion),

Table 1
Equations used to create the motion profile used for the present study.

Direction	Equation
Roll	$0.8(6\sin(1.050t) + 1.25\sin(0.11t + 0.5))$
Pitch	$0.8(2.5\sin(1.76t + 0.5) + \sin(t - 1.5))$
Heave	$0.1(5\sin(1.595t + 2) + 15\sin(1.21t))$
Surge	$0.1(7.8\sin(0.649t + 4.8) + 7.8\sin(0.825t + 3.8) + 0.5)$
Sway	$0.1(18\sin(0.583t + 5) + 9\sin(1.122t + 5.4) - 0.25)$