THE INFLUENCE OF EDUCATION AND EXPERIENCE UPON CONTEXTUAL AND TASK PERFORMANCE IN WAREHOUSE OPERATIONS

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ABSTRACT

We believe worker-performance may be affected by the individual's knowledge of why and where they fit into a larger system, defined as mission clarity. We conduct a controlled experiment to discern how education, experiences and subject characteristics impact mission clarity and subsequently contextual and task performance in a pick-and-pack operation.

INTRODUCTION

In 2010, about 750,000 warehouses worldwide distributed approximately $1 US trillion in goods. Warehouses represent approximately 20% of the logistics costs for many businesses, and order picking accounts for 55% to 65% of the total operational costs of a warehouse [4]. The large costs associated with warehouse operations generate the need for efficient and effective operations. The operations within a warehouse can be parceled down into individual tasks. Each task is affected by a number of known and unknown influences. Managers seek out practical methods to improve task performance, thereby increasing warehouse, firm and supply chain performance.

The many processes in a warehouse can be crudely categorized into four basic areas: 1) to receive the goods from a source, 2) to store the goods until they are required, 3) to pick the goods when they are required, and 4) to ship the goods to the appropriate user. Of these four areas, order picking is the most fertile process for productivity improvements since it is the most labor-intensive operation in warehouses with manual systems, and a very capital-intensive operation in warehouses with automated systems [10]. Being labor-intensive and the most expensive warehouse activity, errors in order picking can lead to increased inventory inaccuracies [26] and higher costs for the entire supply chain [4].

Order picking is the term for all the sub-tasks required to gather items from an assorted inventory in preparation for shipment or internal movement [2]. Often, the items are located in bins placed on shelves or large racking. Accompanying the task of order picking is the process of packing the picked items in preparation for shipment to the customer. Individuals are now capable of attaining 1000 picks per hour [4]. Such a vast number of actions creates significant potential for errors. Errors in the shipping process come from a variety of sources such as picking the wrong item, wrong amount, breakage, and confusion [4]. Another common source of errors arises from the necessity to for workers to enter data into an information system. These errors can frequently result in increased order-return costs, create negative publicity, and can even pose safety hazards, such as critical items not arriving when needed [3].

In supply chain management (SCM), human errors have been addressed peripherally. The Toyota Production System (TPS) and Lean initiatives have emphasized the impact of individual performance on overall production systems [24]. TPS implements kanban structures, which are visual motivational elements to enhance performance. The kanban process makes a previously arbitrary action visible and is a constant reminder of the task at hand [25]. Beyond TPS and Lean process movements, other aspects of the supply chain can be affected by human errors [6]. SCM literature has called for more studies assessing how individuals affect supply chain performance [1] [5].

Literature Review

A recurrent model in human-error literature is the generic error-modelling system (GEMS). Its ubiquitous nature in human factors, psychology and management fields means that many of articles have been influenced by its structures, even if not explicitly stated. The GEMS has its foundations in the work of Rasmussen [14] and Rouses [19], but was synthesized and popularized by James Reason and Donald Norman through the 1980s and 1990s [15]. The GEMS proposes three types of errors based on three types of performance. The *execution* stage of cognitive processing is where most actions occur and functions at the skill-based level. The errors at this stage are manifested as slips and lapses. Slips and lapses are errors due to failures in execution and/or storage of an action sequence [15]. The next type of error occurs at the rule-based level of performance. Errors at this level are classified as rule-based mistakes. They are based on faulty rules for execution and associated with *storage* cognitive processes. A faulty rule will lead to a "strong-but-wrong" response. These types of error are often harder to detect as rapidly as skill-based errors. In fact, if there are not subsequent checks, the mistake may never be found [22]. Finally, the third level of performance is the knowledge-based level and invokes *planning* cognitive processes. Here, mistakes require feedback because the individual is consciously aware of the problem and recognizes the need for problem solving [15].

Reason's model associates the types of errors with resulting accidents. The fundamental concept of his model is that accidents are rarely, if ever, the result of a single error. Normally, a single error is detected at a subsequent step and remedied before the initial error results in an accident. However, sometimes the subsequent fail-safes also fail. The series of errors was compared to slices of Swiss cheese that all happen to have holes lined up in such a fashion that an error flows through multiple checks. Reason further proposes that each slice of cheese represents specific aspects of the accident environment. Reason proposed organizational influences, unsafe supervision, and preconditions for unsafe acts all facilitate conditions for latent failures. These hazards lead to an environment where active failures flow through expected checks resulting in a mishap. The weaknesses of the latent layers are not necessarily active failures but may manifest when they should catch an unsafe act; for example, fatigue or complacency [8]. Shappell and Weigmann [20] modified Reason's model by including 19 specific causal categories and called it the human factors analysis and classification system (HFACS). The categories are subordinate definitions for four main domains that mirror Reason's model.

Swain [23] states that better implementation of human factor considerations will reduce the likelihood of an unnoticed error. The current method of reducing error is to rely on difficult-to-follow written procedures; an alternative would be to make relatively minor changes in processes or system structures to better mitigate the impact a single error will have on the system [23]. Another area for improvement is to implement a system of unannounced emergency exercises with "table-top" walkthroughs. It appears that his recommendation has been heeded more fully since the publishing of this article. Currently, the Department of Homeland Security exercises civilian organizations that have the potential for catastrophic emergencies…such as a nuclear power plant. Individual plants also have implemented measures akin to Swain's recommendations. The Diablo Canyon nuclear power plant has it workers conduct normal operations for three weeks, then has one week of training and exercises [18]. He also observed that checklists for normal operating procedures are commonly used during emergencies. A better practice would be to develop emergency operating procedures that can be accessed based on symptoms. This would be similar to pilots having normal procedural checklists in written format in addition to memorized "bold-face" checklists for specific emergencies. Finally, he recommends displays and controls be organized to aid the creation of accurate mental models when there is an error [23]. An example can be found in the C-17 aircraft. Its fuel system controls are laid out in the shape of the aircraft. To transfer fuel from one tank to another, the pilots activate a switch that is located graphically on the panel between the tanks. When there is a problem in a given location of the fuel system, the location blinks.

Additional initiatives to mitigate errors have been popularized by Lean initiatives and the TPS [25]. Poka-yoke is a Japanese term meaning "fool-proof" or "mistake-proof." The poka-yoke principle is to design a system so it cannot be accomplished incorrectly under normal circumstances [15]. An example is electrical plug-ins; if a device requires a specific polarity, one prong will be wider than the other preventing users from inserting the plug incorrectly. Nolan proposes that processes can be designed to reduce the error-rates [13]. The example he provides is receiving cash from an ATM. Since the objective is receiving cash, some customers will walk away before the transaction of finalized and the card returned. However, if the process is changed so that the cash is not dispensed until the very end (after the receipt and card are dispensed) then fewer people will forget their card in the ATM. A supply process change example would be to not stock easily confused items in the same areas [17].

The DOD has employed some of the above suggestions to reduce accidents and supply error-rates. The DOD changed how it stores nuclear weapon related material (NWRM) after two highly publicized events when NWRM was mistaken for other inventory [21]. The Air Force and Navy implemented the recommendation to store critical items that are easily confused in separate locations. Now, all NWRM is stored in a physically separate part of the warehouse. An ongoing area of improvement is new training methods. Roberts et al. [18] state that formal training can be effective for improving workers' ability to recognize when they commit an error. However, in the most reliable organizations, the formal training is accompanied by strong cultures that recognize that the system is not perfect and that improvements can be noticed at all levels [18]. The DOD is still formulating how it can foster a culture of safety when the profession inherently participates in high-risk activities. The military cannot eliminate all dangers or human errors. Reason suggests the goal is to understand that processes involving humans will have human error; however, creating a culture of safety will enable the mission to continue even in the presence of errors [16].

Problem Statement, Research and Investigative Questions

This research will integrate the current needs of SCM, regarding human errors in the order picking and packing process, with principles from human factors engineering, inventory management, and psychology. Considering the above research and observed opportunities, *it is proposed that supply chain workers make observable, preventable errors while completing their assigned tasks in the shipping process.* A quote by Baron von Steuben succinctly captures the essence of our research. Baron von Steuben was a Prussian officer in George Washington's Continental Army. He was responsible for training and discipline of recruits. In his memoirs he records "You can tell Prussian, German, French soldiers to do this and he does

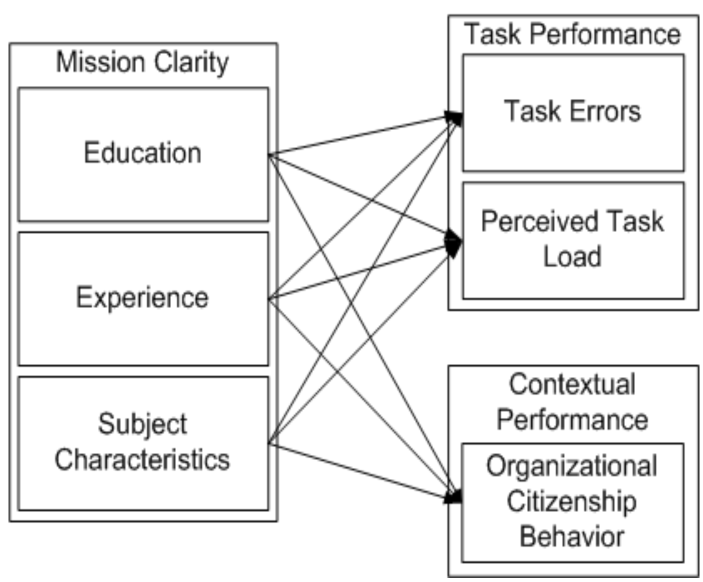

Figure 1. Proposed Research Model

it; with the Americans I am obliged to say 'this is why you do it, then he will do it" [11]. The concept is, at least in American-culture, performance may be affected by an individual's knowledge of why and where they fit into a larger system. The individual's grasp of how he/she fits into the larger mission is proposed as *mission clarity*. Thus, the overall research question is: What is the relationship of mission clarity to job performance? The first investigative question is: *How does education affect job performance?* The second investigative question is: *How do novel experiences affect the job performance?* Finally, individuals who have a greater grasp of their work and know how their effort impacts the larger system are less likely to commit errors [18]. The third investigative question would be: *What is the relationship of mission related subject characteristics and job performance?* Job performance includes both task performance and contextual performance elements (Conway, 1999). Furthermore, task performance will be measured by error counts and the NASA-TLX to assess perceived task load. This will expand the three investigative questions into nine specific questions. The formal hypotheses stem from the investigative questions and are presented below. The subject characteristics of interest relate to mission clarity such as experiences, previous careers, years of experience, depot tours, deployments, and specialty courses. It is important to consider subject characteristics because previous research suggests that a decision maker's experience with solving a particular type of problem, can impact their future performance [12]. Moreover, the items that comprise subject characteristics are likely to vary across a wide spectrum for workers.

Hypotheses

H1: There is a negative relationship between mission-related <u>education</u> and *performance*.
H2: There is a negative relationship between mission-related <u>education</u> and *perceived task-load*.
H3: There is a positive relationship between mission-related <u>education</u> and *OCB*.
H4: There is a negative relationship between mission-related <u>experience</u> and *performance*.
H5: There is a negative relationship between mission-related <u>experience</u> and *perceived task-load*.
H6: There is a positive relationship between mission-related <u>experience</u> and *OCB*.
H7: There is a significant relationship between mission-related <u>subject characteristics</u> and *performance*.
H8: There is a significant relationship between mission-related <u>subject characteristics</u> and *perceived task-load*.
H9: There is a significant relationship between mission-related <u>subject characteristics</u> and *OCB*.

Methodology

The above hypotheses are operationalized to conduct a controlled experiment; we setup a mock warehouse where participants collected needed items and place them in tubs for processing. The dependent variables that represent task performance are error-rates and perceived task-load during a simulated warehouse order-picking task. An error is defined as not performing a task according to provided instructions. In the operational environment, it would be a failure to follow applicable technical orders. In the experiment, an error is recorded when the participant selects a wrong item, selects too many or too few of the correct items, or mislabels the order. Contextual performance is represented and measured via a 20-item organizational citizenship behavior (OCB). Education is operationalized with traditional education methods; specifically, the subjects will receive a verbal explanation via a computer based presentation. A novel experience will be operationalized by having them meet an end user of the supplies. In this experiment they will meet a confederate who has flown medical evacuation missions. The confederate will relay personal experiences of medical evacuation missions. He will explain the importance of having exactly what is needed in order to complete life-saving flights. The target population is Air Force Airmen, Grade E-1 to E-6, in the supply specialty-core. Our desired number of participants is at least 100.

The participants are given disclosure information and instructions before beginning the tasks. Following the instructions, the participants complete a baseline-order shipping label without a time limit. Next, they have 5 minutes to pick as many lines from the order pick-list as they can. After the baseline assessment, the treatments are administered. Participants are randomly assigned to one of four groups receiving no treatment (control), traditional educational, experience meeting confederate, or both education and experience. Then, participants will complete three shipping labels for three corresponding pick-lists, with no time limit. Next, they are allowed 15 minutes to fill the three orders. After they complete the picking tasks, they are moved to a workstation with a laptop to complete the web-based post survey measures.

After the experiment, the NASA-TLX [7] is administered to assess the perceived task load and effectiveness. The end goal is to determine if a relationship exists between any combinations of task-education, experiences, subject characteristics and task-errors or perceived task-load. The next measure is a survey that obtains participant demographics. The third measure is a locally-developed questionnaire to assess the participants' mission clarity. It included questions from the instructions and the task context. Next, they complete the 20-item OCB measure. Finally, they complete the 44-item version of the Big-Five inventory [9]. The total time for the measures took 10-20 minutes for most individuals.

Conclusion

We propose that supply chain workers make observable, preventable errors while completing their assigned tasks in the shipping process. We believe worker-performance may be affected by an individual's knowledge of how, why, and where they fit into a larger system—defined as mission clarity. We conduct a controlled experiment to discern how education, experiences and subject characteristics impact mission clarity and subsequently contextual and task performance in a pick-and-pack operation. Some of the results of the analysis (which is currently occurring) of the data obtained during the experiment will be briefly discussed in the final version of the paper should the paper be accepted for publication in the proceedings and in the associated presentation at the conference.

REFERENCES

[1] Ballard, R. (1996). Methods of inventory monitoring and measurement. *Logistics Information Management, 9*(3), 11-18.

[2] Baumann, H., Starner, T., & Zschaler, P. (2012). Studying order picking in an operating automobile manufacturing plant. Paper presented at the*, 16th International Symposium on Wearable Computers (ISWC),* 112-113.

[3] d'Hont, S. (2004). The cutting edge of RFID technology and applications for manufacturing and distribution. *Texas Instrument TIRIS, 16*

[4] De Koster, R., Le-Duc, T., & Roodbergen, K. J. (2007). Design and control of warehouse order picking: A literature review. *European Journal of Operational Research, 182*(2), 481-501.

[5] Fawcett, S. E., Waller, M. A., & Fawcett, A. M. (2010). Elaborating a dynamic systems theory to understand collaborative inventory successes and failures. *International Journal of Logistics Management, 21*(3), 510-537.

[6] Galar, D., Stenstrom, C., Parida, A., Kumar, R., & Berges, L. (2011). Human factor in maintenance performance measurement. Paper presented at the *Industrial Engineering and Engineering Management (IEEM), 2011 IEEE International Conference on,* pp. 1569-1576.

[7] Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (task load index): Results of empirical and theoretical research. *Advances in Psychology, 52*, 139-183.

[8] Jennings, J. (2008). Human factors analysis & classification. *Professional Safety, 53*(6), 44-51.

[9] John, O. P., & Srivastava, S. (1999). The Big-Five trait taxonomy: History, measurement, and theoretical perspectives. In L. A. Pervin & O. P. John (Eds.), *Handbook of personality: Theory and research* (Vol. 2, pp. 102–138). New York: Guilford Press.

[10] Li, X., Chen, I. Y., Thomas, S., & MacDonald, B. A. (2012) *Using Kinect for monitoring warehouse order picking operations.*

[11] Lockhart, P. (2008). *The drillmaster of valley forge: The Baron de Steuben and the making of the American Army.* HarperCollins.

[12] Mennecke, Brian E., Martin D. Crossland, and Brenda L. Killingsworth. Is A Map More Than A Picture? The Role Of Sdss Technology, Subject Characteristics, And Problem Complexity On Map Reading And Problem Solving. *MIS Quarterly* 24.4 (2000): 601-629. Business Source Complete. Web. 18 May 2015.

[13] Nolan, T. W. (2000). System changes to improve patient safety. *BMJ (Clinical Research Ed.), 320*(7237), 771-773.

[14] Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering.* New York: North-Holland.

[15] Reason, J. (1990). *Human error* Cambridge university press.

[16] Reason, J. (1998). Achieving a safe culture: Theory and practice. *Work & Stress, 12*(3), 293-306.

[17] Reason, J. (2004). Beyond the organisational accident: The need for "error wisdom" on the frontline. *Quality & Safety in Health Care, 13 Suppl* 2, ii28-33.

[18] Roberts, K. H., Bea, R., & Bartles, D. L. (2001). Must accidents happen? Lessons from high-reliability organizations. *The Academy of Management Executive, 15*(3), 70-78.

[19] Rouse, W.B. (1981). Models of human problem solving: Detection, diagnosis and compensation for complex engineering systems. *Proceedings of IFAC Conference on Analysis, Design and Evaluation of Man-Machine Systems*, FRG.

[20] Shappell, S., & Wiegmann, D. (2004). HFACS analysis of military and civilian aviation accidents: A North American comparison. *Proceedings of the Annual Meeting of the International Society of Air Safety Investigators,*

[21] Snyder, D., Nowak, S. A., Amouzegar, M. A., Kim, J., & Mesic, R. (2013). *Sustaining the US air force nuclear missio*n RAND Corporation.

[22] Stewart, D. M., & Chase, R. B. (1999). The impact of human error on delivering service quality. *Production and Operations Management,* 8(3), 240-263.

[23] Swain, A. D. (1990). Human reliability analysis: Need, status, trends and limitations. *Reliability Engineering & System Safety, 29*(3), 301-313.

[24] Swamidass, P. M. (2007). The effect of TPS on US manufacturing during 1981–1998: Inventory increased or decreased as a function of plant performance. *International Journal of Production Research, 45*(16), 3763-3778.

[25] Takahashi, K., Morikawa, K., & Chen, Y. (2007). Comparing kanban control with the theory of constraints using markov chains. *International Journal of Production Research, 45*(16), 3599-3617.

[26] Thiel, D., Hovelaque, V., & Hoa, T. L. (2010). Impact of inventory inaccuracy on service-level quality in (Q,R) continuous-review lost-sales inventory models. *International Journal of Production Economics, 123(2),* 301-311.