On the Role of Ergonomics at the Interface Between Research and Practice

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Abstract. Ergonomics is comprised of a scientific discipline and professional practice. Broadly speaking, these two components are often referred to as research and practice, and the individual members sometimes identify as researchers or practitioners. Some subset of ergonomists conduct both research and practice. Since the early days of the field, there has been a certain amount of tension between research and practice. Although such tension is not specific to the ergonomics field, ergonomics is uniquely positioned to analyze the interface between researchers and practitioners to optimize the interaction between these two groups of stakeholders. Ergonomists have varied experience and education, and perhaps too little attention has been focused on understanding both the capabilities and limitations of ergonomists. More specific attention to understanding the needs of users of ergonomics research is proposed as another avenue to reduce the research-practice tension. Similarly, the organizational needs and expectations of consumers of ergonomics services will lead to research being better able to result in tools and assessments that will help ergonomists fulfill the needs of their customers. An example from the U.S. mining industry will be used in this paper to illustrate how understanding the eventual application context of ergonomics and its end users can create relevant and easy-to-use ergonomics tools.

Keywords: Ergonomics practice · Research · Practitioner

1 Introduction

Ergonomics has always been an applied discipline, especially when compared to sciences that are more basic. To some extent, ergonomics was formed in response to human performance problems and the need to design systems to better accommodate the capabilities and limitations of users. In the earliest stages of the field, scientists of varying backgrounds but with similar interests in the study of work convened to discuss common interests (Waterson and Sell 2006). Psychology, anatomy and physiology, and engineering are among the disciplines that were brought together to study these human performance and behavior challenges.

More recently, ergonomics has made strides in becoming a unique scientific discipline. There are also professional practitioners, with an increasing number of countries and regions having some form of professional certification, such as the Board of

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Certification in Professional Ergonomics in the United States. Like other disciplines with scientific foundations in universities, as well as professional practitioners, there is tension between researchers and practitioners. In fact, the journal *Applied Ergonomics* was formed 50 years ago out of the desire to better address the needs of practitioners within The Ergonomics Society (UK) at the time (Waterson and Sell 2006).

The purpose of this manuscript is to explore some of the characteristics of the tension between researchers and practitioners of ergonomics with the goal of suggesting solutions or at least approaches to resolving these differences. Due to the lack of empirical research in this area, some of the points raised are speculative and will require structured investigations to confirm or refute. The ultimate goal is to have a more effective interface between these stakeholders to increase the performance of researchers and practitioners with respect to advancing ergonomics.

1.1 Definitions

For the sake of consistency, the following definitions for both ergonomics and practitioners as per the International Ergonomics Association (IEA) in 2018 will be used in this manuscript:

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance."

> "Practitioners of ergonomics and ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people."

Like many disciplines, ergonomics is comprised of people who characterize themselves as researchers, those who characterize themselves as practitioners, and a smaller subset that identify as both. When research and practice are compared, the differences are often implied. For the sake of simplicity, research will be characterized as systematic investigations to discover new generalizable findings, whereas practice will be characterized by the IEA definition of practitioners and ergonomists above.

2 Users and Customers

When thinking about and discussing issues facing ergonomics practice and practitioners, it is natural to start using the same terminology that practitioners use when describing their practice. It is at least somewhat ironic that the field of ergonomics, in general, has done relatively little inward analysis by using ergonomics to increase the performance of ergonomists! Clearly, much research is intended to be used by practitioners, who are the *users*. Not all ergonomics research is intended to be used immediately, and some proprietary or especially complex research may be intended for a narrow population. The remaining discussion in this section will consider research intended to appeal to a broad range of practitioners.

The term *customers* will be used to denote the stakeholders that pay for the services of ergonomists. Customers can be in the same organization as the ergonomist—such as in the case of corporate and plant ergonomists—or in an external organization that uses a consultancy. Ultimately, the strength and success of ergonomics overall requires that customers see value in having staff, consultants, or contracted expertise apply ergonomics in their organizations. Ergonomics customers are diverse and come from the public and private sectors. Customers can include organizations engaged in military, commerce, energy, manufacturing, and service sectors, among others.

The main reason for bringing up the distinction between the user and the customer is that for researchers to increase the relevance of research to practitioners, and subsequently uptake and use, researchers need to understand the needs of users with respect to their need for tools and techniques that satisfy customer requirements. A considerable body of research and practice related to users and usability exists, but more formal analyses of uptake have focused on the *post hoc* extent to which practitioners access journal articles (e.g. Chung and Shorrock 2011) or use available tools and techniques (e.g. Dempsey et al. 2005; Dempsey et al. 2018). While these are valuable and provide insight, they focus on what was used and postulations of why or why not with respect to uptake. Moving beyond this will require *a priori* needs assessments of practitioners so that we can better understand the types of research information that users desire or the types of tools they need to better meet the demands of customers. Like product design, this will require researchers to understand the desires and requirements of users early on.

A subtle point that illustrates a researcher-centric view and how researchers infer the relevance of research to practice is the nature of the statements of relevance that some journals require. For example, *Applied Ergonomics* does not require a statement of relevance, but it is somewhat implicit that articles are relevant to the practice of ergonomics. *Ergonomics* has a "Practitioner Summary" section, while *Human Factors* has an "Application" section that describes the "practical impact of work to a broad audience" for non-theoretical manuscripts. In essence, researchers are required to state the relevance of the research, whereas a more accurate view (at least from a practitioner's view) would have practitioners write these relevance statements. Furthermore, the customer view may likewise be quite different. The point is not to criticize this approach, rather to suggest the "eyes of the beholder" may be those of the users and customers rather than the researchers.

3 Industry-Specific Needs and Training

Unlike other professions such as medicine and accounting, there has not been significant effort to consider developing or cultivating different types of practice specialties for industries, except perhaps for the military. Much of the early research and practice in ergonomics addressed manufacturing applications. As economies mature and change, the mix of employment in different industries changes. Within countries and regions, ergonomics also needs to adapt and change.

There can also be changes related to technology and economic development. For example, internet shopping has resulted in products being shipped to residences rather

than consumers going to retail brick-and-mortar locations, purchasing items, and transporting them. The increase in hydraulic fracturing as a means of extracting fossil fuels has increased demand for sand and other products and associated delivery methods. These changes may in turn create new opportunities for ergonomists. The author has researched wholesale and retail trade, meat processing, and mining, for example, each requiring industry-specific knowledge, particularly at the stage of implementation or intervention. Health care ergonomics is an area that is experiencing rapid growth, with the existence of conferences specific to the industry. The autonomy of vehicles and equipment is an example of complex applications that are going to require research that is more specific. Demands on practitioners will increase as well, particularly with respect to the engineering and design of systems.

Many practitioners tend to learn industry- and organization-specific requirements on the job. While it has been quite common for researchers to specialize in a given area, students are often required to take a broad range of courses, with some specialization in specific areas through electives. More significant training in systems engineering and related technical topics needed to support advanced ergonomics implementation will likely be needed in the future. Specialization will be a possible means of addressing these demands. To some extent this is already occurring, exemplified by the Board of Certification in Professional Ergonomics in the U.S. now offering different designations (ergonomics, human factor, and user experience) to certificants.

Ergonomics programs, in the United States at least, are housed in different university departments such as industrial engineering or psychology. Broadly speaking, this has led to more training in physiologic and biomechanics aspects of ergonomics in engineering schools, as well as more training in the perceptual and cognitive aspects of ergonomics in psychology programs. While students often take courses in both engineering and psychology departments at universities where both programs offer ergonomics coursework, the overall coursework, knowledge, and expertise of graduates will differ. In other countries, ergonomics is housed in medicine or kinesiology departments. The point is not to debate these, rather to point out that graduates of different programs can have considerable variability in training.

Industry-specific and education differences were mentioned here because they relate to the fundamental ergonomics concepts of designing work to accommodate the capabilities and limitations of workers. Different industries present very different job demands, which are not often explicitly recognized or addressed. Industrial production and nuclear control room ergonomics certainly have overlap in topics such as controls and displays, information transmission, etc. However, the role of, and demands on, the ergonomist will be very different. The notion of differences in capabilities due to differences in education also need to be considered when evaluating the appropriateness of a given ergonomist for a particular job. For some reason, there has been an uneasiness to discuss these issues, but they are very practical matters that ergonomists are well suited to address. There are no simple solutions to these differences, particularly given how hard it is to change university structures to accommodate ergonomics. Universities where ergonomics is established as its own department may be models for other universities. Although certification seeks to require a certain core knowledge, the key is that differences in capabilities and limitations will exist.

4 Ergonomics Tools

One of the most compelling areas of ergonomics practice that has not been studied sufficiently is the usability and suitability of assessment tools. Broadly speaking, assessment tools should be reliable and valid. Previous research has shown a preference for simpler tools (Dempsey et al. 2005; Dempsey et al. 2018). While simplicity likely increases usability, it is possible some validity is sacrificed for simplicity.

There are several types of validity, one of which is content validity and will be discussed later. Criterion-related validity represents how well a method predicts future performance. In this context, an assessment method should be capable of identifying ergonomics deficiencies that will result in degraded system performance at the current time (sometimes referred to as concurrent validity) or in the future (predictive validity). Reliability can be divided into inter-rater reliability (different ergonomists applying the same method to the same context should arrive at the same conclusions) and intra-rater reliability (an ergonomist applying a method multiple times should arrive at the same conclusion each time). Stanton (2016) offers a much more detailed discussion and exploration of reliability and validity. The main point is that the performance of ergonomics practitioners, and hence the profession, can be affected by the reliability and validity of the tools used by individual ergonomists.

Three constraints of ergonomics methods with respect to uptake and use by practitioners are accessibility, usability, and contextual constraints (Shorrock and Williams 2016). Accessibility and usability are straightforward, whereas contextual constraints are more complex and include appropriateness for a given situation as well as concerns and requirements of the customer. Although studies of tool use by ergonomists shed some light on these in a *post hoc* fashion (e.g., Dempsey et al. 2005), they do not provide information about tools that would be more effective or more appropriate for different contexts. The needs of users and customers are rarely assessed before tool development begins. This is one area where more interaction between researchers and practitioners is needed.

Ergonomists have varying formal education and professional training ranging from bachelor's degrees to doctorates. In some cases, those without formal training (non-ergonomists) apply ergonomics. Although the author acknowledges that many may not agree with non-ergonomists applying ergonomics, this does happen and can happen with very good outcomes (an example will be discussed below). However, the results with some tools also result in rather poor outcomes (Stanton and Young 2003). Stanton and Young (2003) looked at specific tools used by a homogenous group of subjects, with varying results by tool. Very little is known about the broader range of ergonomics tools across the broad range of users. Given that ergonomists come from such broad educational and experience backgrounds, it is time to consider whether the user characteristics (i.e., capabilities) of tools should be specified or suggested. Just as movies and video games have age ranges as an easy-to-use guide for parents that agree with the rating scale, a more complex rating system could be used for ergonomics tools.

4.1 Mining Example

Dempsey et al. (2017) developed ergonomics and safety audits for small and bulk bag filling, haul truck, and maintenance and repair operations found at surface mining operations. The audits were developed for non-ergonomists, as ergonomists are not common in mining in the U.S. Significant effort was made to ensure the content validity of the audits, which was assured through the use of multiple and complementary methods to understand the ergonomics and safety deficiencies encountered at mine sites. Researchers developed audit items so that they could be easily understood and observable by mine personnel. Testing with eventual users was conducted by shadowing mine safety personnel as they completed the audits. They provided feedback on whether any questions were unclear or if they felt that the answer choices were inadequate. A formal inter-rater reliability study formed the basis of the effort to make sure the audits were reliably applied.

The Stanton and Young (2003) study mentioned earlier indicated that novice users did not reliably apply some ergonomics methods. By considering the users at the development stage, Dempsey et al. (2017) were able to develop audit items that did not require significant ergonomics expertise or vernacular to understand the audit items. Manual materials handling will be used to illustrate this point. There is very little

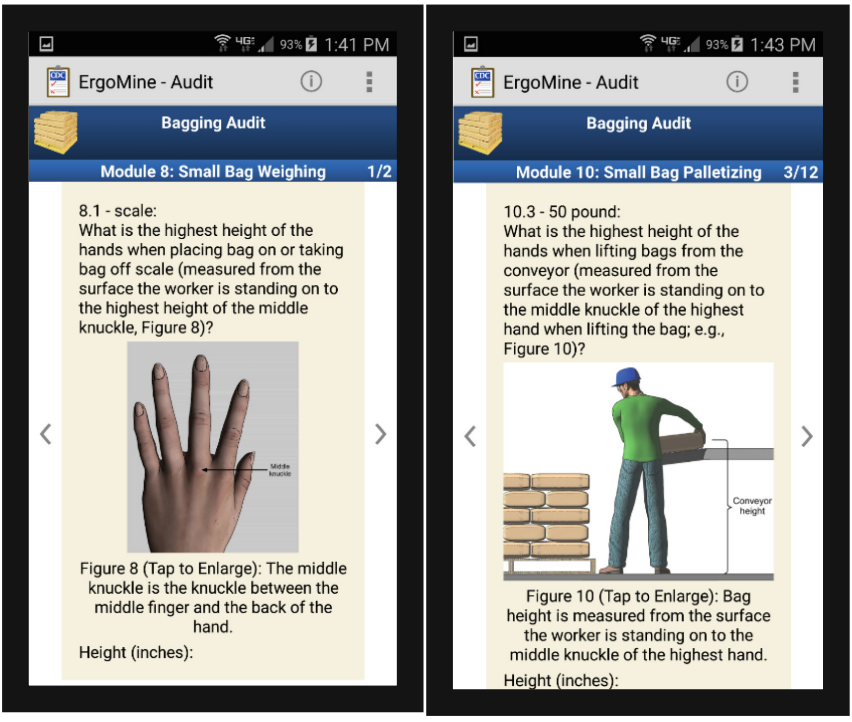

Fig. 1. Example of straightforward measurements used to assess materials handling tasks. The left figure shows the user the landmark on the hand used to measure hand height, while the right figure shows how to measure hand height for retrieving bags off conveyors.

information on the reliability of materials handling tools, but even tools that are perceived to be simple can have reliability issues. For example, Dempsey et al. (2001) found significant variability across parameters for an assessment of a laboratory simulation of materials handling tasks. To avoid potential problems, simpler measures were used. Figure 1 shows an example, with the left side of the figure showing the middle knuckle as the hand height landmark (rather than height of the third metacarpophalangeal joint). This landmark was used for numerous measurements (e.g. bag weighing, palletizing) since this parameter gives significant insight into whether the worker is bending down or reaching, etc. The right side of the figure shows an example for assessing conveyor height, as conveyors were common in small bagging operations.

Finally, Dempsey et al. (2017) chose to provide ergonomics recommendations for each ergonomics deficiency detected by the audit. The intended user group was not ergonomists, thus providing practical solutions to the identified problems was deemed critical. The goal was to provide a tool that was easy-to-use, reliable, and would solve problems common to these types of operations (content validity). This is one approach to avoiding the broader reliability and validity issues described earlier. The issue of contextual constraints discussed earlier is also largely eliminated, but the audits are not applicable to some other contexts, as would be the case for a more generic tool.

5 Conclusions

Several examples where ergonomics has not been fully utilized for the benefit of increasing the efficiency and effectiveness of ergonomics were discussed. These specific areas were identified:

(1) The views of ergonomics researchers and practitioners can be different, and there needs to be more communication as opposed to inference from the uptake of the scientific literature or available tools.
(2) Just as any population of users has a range of capabilities and limitations that need to be considered when designing work, ergonomics practitioners are the same in this regard.
(3) Ergonomics practice in several industries has become sufficiently complex as to warrant the consideration of professional specialization in ergonomics, similar to other professional disciplines such as medicine and accounting.
(4) Differences in education result in further differentiation of capabilities and limitations of ergonomist populations and should be considered more explicitly. Conversely, more universal curricula may be an approach to reducing these differences.
(5) Ergonomics tools need to consider user and customer needs and requirements before development begins, and the tool development cycle needs to include adequate attention to reliability and validity.

The challenges and solutions discussed in this paper will by no means be trivial to solve, but have the potential to lead to ergonomists that are more effective. This, in turn, will reduce some of the demands on ergonomists with respect to justifying methods to customers and convincing them of the overall value of ergonomics services. Just as we

often need to convince customers of the need to make ergonomics changes, the discipline itself may take some convincing of the need for this inward attention.

6 Disclaimer

The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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