First Principles Analogs for the Behavioral Sciences

Judi E. See, Ph.D., CPE
Sandia National Laboratories
P.O. Box 5800, MS0151
Albuquerque, NM 87185
jesee@sandia.gov

Problem Statement

The social and behavioral sciences (SBS) lack a concise and understandable approach to effectively communicate the critical tenets of human behavior to nonpractitioners such as engineering design and development teams. Other scientific fields such as physics, chemistry, and engineering rely on first principles or laws to convey fundamental information. SBS could benefit by adopting an analogous approach that converses in a language already familiar to fellow scientists and combats the perception that human behavior is arbitrary and unpredictable.

Background and Discussion

First Principles. First principles are basic, fundamental concepts about a scientific discipline. For example, electrical engineering has Ohm's law, which governs the relationship between voltage and current, and Kirchhoff's electrical circuit laws. Physics has Archimedes' principle, or the physical law of buoyancy, and Boyle's law—the inverse relationship between the pressure and volume of a gas. These principles or laws are immediately understood by scientists in their respective fields and are used to succinctly convey basic information.

SBS does not have principles or laws comparable to those used by other sciences. Instead, key information used to guide practitioner recommendations is scattered throughout detailed research articles reported in thousands of journals. Professional journal articles may or may not clearly specify how research findings should be applied, and the results are often written in a jargon that is difficult for professionals outside the SBS community to decipher. When there have been attempts to codify human dimension data into an accessible format (e.g., MIL-STD-1472G establishing human engineering criteria for design and development of military equipment), the end result is a dizzying array of very detailed requirements covering hundreds of pages. MIL-STD-1472G alone has 3958 requirements documented in 381 pages. This format may work well for human factors practitioners, but it does little to help nonpractitioners such as engineering design and development team members understand the critical elements of human behavior that must be considered. Implementing a set of SBS guidelines analogous to the first principles used in other scientific fields could help communicate the most critical tenets of human behavior to nonpractitioners.

Nonpractitioner Perceptions of SBS. An additional issue is the common perception among professionals outside the SBS community that human behavior is too variable and unpredictable to adequately portray within a system. The end result is that the technological component of a system becomes the focus of attention. The human component of the system may be poorly addressed, if it is considered at all (Schatz, 2016). As Cerri (2016) puts it:

> There are several generally accepted ideas held by many, if not most people, including engineers, scientists, technologists, and technical managers. The first idea is that people are mysterious and unpredictable creatures. For the typical engineer, scientist, or technologist, this idea often takes the form of a statement such as, "Science and the laws of physics are predictable and consistent. People, on the other hand, are just about as predictable as the weather."…it is much easier to deal with the laws of physics, or software, or circuitry, or biology, or dynamics, or geology, than it is to deal with the constant emotional unpredictability of people. (pp. 19-20)

Predictability of Human Behavior. On the contrary, however, SBS research repeatedly demonstrates that there are known bounds on human behavior that make it amenable to predictability. For example, the lower and upper bounds of human hearing effectively range from 20 Hz to 20,000 Hz (Rosen, 2011). While there can be considerable variability among individuals, humans simply are not capable of hearing the types of sounds in the 45,000 Hz range that dogs can detect. Within the known bounds of human hearing, some of the observed variability can be further explained by individual differences such as age. For instance, it is known that sensitivity to higher frequency sounds declines with age.

As another example, the capacity of human short-term memory is generally acknowledged to be limited to 7±2 chunks of information (Miller, 1956). Although other researchers have argued that the bounds may actually be closer to 4±1 (Cowan, 2001), the general range has not changed fundamentally over time. People may be taller and heavier than they were 100 years ago as a result of improved nutrition, food distribution, and health care; but they have not exhibited comparably larger short-term memory capacities. As with human hearing, observed variability in the capacity of short-term memory can also be explained by individual differences such as disease and task factors such as the nature of the material (e.g., the length, familiarity, and frequency of occurrence of words to be recalled). The "magical number 7±2" comes closest to a first principle for SBS—it is frequently even referred to as *Miller's Law*. As such, *Miller's Law* has demonstrated utility to convey critical human behavior data to nonpractitioners for practical use during task design. Bell Labs used *Miller's Law* when creating the standard seven-digit U.S. phone number. The length of the phone number was specifically designed to conform to the human short-term memory limitations identified by Miller in an effort to minimize errors during telephone calls—namely, the frequency of misdialing as a result of inability to remember all of the digits in the phone number in the correct sequence.

In fact, the majority of human characteristics and behavior—height, weight, intelligence, strength—can typically be modeled using the normal curve. The highest point on the curve represents the mean or average. About 68% of values are within one standard deviation above and below the mean, and about 95% are within two standard deviations. The fact that most human traits can be modeled with the normal curve means that a significant portion of human behavior will be predictable, falling within two standard deviations of the mean. More extreme values can occur, but they will be very rare. Anthropometry provides one of the best examples of use of the inherent normal distribution of human physical characteristics to optimize the design of products for which body dimensions are important (e.g., clothing design and architecture). Where possible, designs are optimized to accommodate the 5^{th} to the 95^{th} percentile for the affected body dimension. For example, if reach is critical, the system is designed to ensure that people at the 5^{th} percentile in arm length (i.e., those with the shortest arms) can reach the intended item.

Communicating Critical SBS Data. In essence, the underlying problem is not variability in human behavior *per se*, but rather the absence of a means to effectively convey the limits or bounds to nonpractitioners such as engineering design and development team members in a practical and usable format. In other words, SBS is not very effective at documenting and communicating simple rules that can explain available evidence regarding human behavior in a comprehensible manner. For successful communication with nonpractitioners who must effectively use the information, SBS professionals such as human factors practitioners need to speak the language of the engineers. Speaking in terms comparable to first principles or laws provides one such avenue for effective communication. Potential examples of such rules for the behavioral sciences include the following:

- *Miller's Law:* people can retain 7±2 pieces of information in working memory
- *Controls:* texture and shape are most critical to design knobs, buttons, and switches that minimize confusion and promote error-free use
- *Displays:* usable visual, auditory, and touch displays exhibit internal consistency, learnability, efficiency, memorability, minimal errors, and operator satisfaction
- *Work Physiology:* static work places a greater cardiovascular strain on the body than purely dynamic work

Recommended Research Strategies

The research upon which to base rules for the behavioral sciences already exists. At this point, it would be most beneficial to convene an organized forum of experts in SBS and other sciences to study the problem in depth and determine how best to proceed. Critical questions to address include the following:

- What is the appropriate terminology to use for this type of SBS guidance (rules, laws, first principles, or some other word)?
- Can a coherent set of rules be derived from existing SBS research?
- What additional research is needed to support development of SBS rules?
- Is there an overarching set of rules applicable to SBS in general?
- Should the various SBS disciplines each have their own set of rules?
- How should such rules be communicated and used?

Benefits

In terms of the possible contributions identified in the *Second Call for White Papers*, this effort would advance knowledge by improving our understanding of behaviors relevant to national security. The very act of attempting to reduce over 100 years of human behavior research into an elemental set of principles or laws might uncover avenues for additional exploration. The research would provide a clear and succinct method to convey the fundamental tenets of human behavior, thereby building coordination and improving communication among researchers, analysts, policy and decision makers and among teams.

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