The Measure of Human Error: Direct and Indirect Performance Shaping Factors

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Performance Shaping Factors (PSFs)

Definition

- Those influences that enhance or degrade human performance
- Provide basis for considering potential influences on human performance and systematically considering them in quantification of human error probabilities (HEPs)

Often characterized as internal and external

- *Internal PSFs*—influences that the individual brings to the situation such as mood, fitness, stress level, etc.
- *External PSFs*—influences in the situation or environment that affect the individual such as temperature, noise, work practices, etc.

internal ——→ ←—— external

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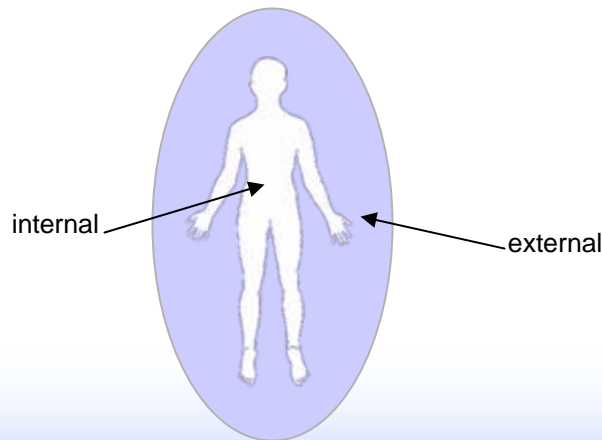
Performance Shaping Factors (PSFs)

To date, Human Reliability Analysis (HRA) has not considered direct and indirect PSFs

- *Direct PSFs*—measurable aspects of performance such as time to complete a task
- *Indirect PSFs*—aspects of performance such as fitness for duty that can primarily be measured through other measures such as fatigue or blood alcohol content

Purpose of this presentation is to explore direct and indirect PSFs

- Review direct and indirect measures found in natural sciences
- Discuss specific direct and indirect PSFs
    - Review Fitness for Duty as a case study for indirect PSFs
- Discuss implications of direct and indirect PSFs for HRA
- Provide some good practices for working with direct and indirect PSFs

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Direct and Indirect Measures Found in the Natural Sciences

The Galilean Prerogative

The goal of science
- Measure what is measurable
- Render measurable what is not yet so

Historical Phase 1: Conservative Conception of Measurement
- Measurement = <u>direct</u> one-to-one correspondence of a physical property to a number
- e.g., a metal rod of a given length equals one unit of measure; a second rod of equal length adjoining the first rod equals two units of measure
- Encompasses physical magnitudes such as length, weight, and angles

Historical Phase 2: Liberal Conception of Measurement
- Measurement = functional relationship between physical property and a number, often determined by the <u>indirect</u> effects on another physical property
- e.g., temperature is elusive to measure directly and must instead be measured by its effects on another object such as expansion or contraction of fluid

Indirect Measurement

Any given object has a multitude of dimensions in which in may be measured

- e.g., we may assign numbers to a steel rod to indicated its length, mass, etc.
- These measures may be orthogonal, but they may also overlap in some cases

Use of multiple indirect measures to account for a phenomenon under investigation can increase measurement fidelity

- e.g., evolving definition of length of a meter
  - 1889: a graduated platinum-iridium rod cross section at 0° C
  - 1983: the length traveled by light in a vacuum during a time interval of 1/299,799,458 of a second, where the speed of light is 299,792,458 m/s and light is a helium-neon laser with a wavelength equal to 632.99139822 nm
- Adding multidimensional indirect measures minimizes the variability in measurement
  - Precision of empiricism is limited by the noisiness of measurement
  - Goal of science is to achieve highest measurement constancy and fidelity (reliability and validity)

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Direct and Indirect Performance Shaping Factors (PSFs)

Direct and Indirect PSFs in HRA

Definitions revisited

- *Direct PSFs*—those PSFs that can be measured in a one-to-one relationship between the magnitude of the PSF and the property being measured
- *Indirect PSFs*—those PSFs whereby the magnitude of the PSF can only be determined by properties other than the property being sought

Reasons for distinguishing direct and indirect PSFs

- Treating all PSFs the same (by default, as direct measures) introduces potential sources of measurement errors
  - Properly characterizing PSFs as direct or indirect minimizes our epistemic uncertainty, potentially increasing reliability and validity of our measurement
- While measurement for direct PSFs is clearly defined, measurement of indirect PSFs may not be formalized
  - It is important to develop a standardized set of characteristics for indirect PSFs that link them to human performance

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Important Caveat

This is not a criticism of PSFs or HRA in current practice!

- Without specifically considering the difference between direct and indirect PSFs, HRA does an excellent job
  - Highly effective tool for identifying contributors to human performance
  - Individual methods offer reliable, validated approaches to quantifying human error probabilities
- However, failure to consider direct vs. indirect PSFs may introduce opportunities for measurement uncertainty
  - Controlling for direct vs. indirect PSFs potentially reduces that uncertainty and fortifies already strong HRA methods

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Classifying Common PSFs

An expert review of the PSFs found in *HRA Good Practices* (NUREG-1792)

- Are commonly used PSFs direct or indirect?

Training & Experience	Procedures	Instrument Availability
Direct	Direct/Indirect	Direct
Available Time	**Complexity**	**Workload/Stress**
Direct	Indirect	Indirect
Team/Crew Dynamics	**Available Staffing**	**Ergonomics/HSI**
Indirect	Direct	Indirect
Environment	**Equipment Accessibility**	**Need for Special Tools**
Indirect	Direct	Direct
Communications	**Fitness for Duty**	**Realistic Accidents**
Indirect	Indirect	Indirect

- Please refer to paper for more detailed discussion of selection process
- Note the 9 of the 15 PSFs are indirectly measured

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Lessons Learned from Classification

Indirect PSFs

- Often, the assignment of a level or magnitude of an indirect PSF requires making a subjective judgment
  - e.g., the quality of procedures or the complexity of the scenario
- Subjective judgments are commonly multivariate, drawing on cognitive processes that may not be transparent to the person making the judgment
  - Without clear criteria to constrain the judgment process, the judgments may vary from one person to another or even within the same person
  - It may be possible to replace the subjective indirect measure with a more objective indirect measure
    - e.g., quality of procedures based on quality criteria scale

Direct PSFs

- Several of the direct PSFs are often measured in a Boolean manner
  - e.g., availability of instrumentation (yes/no)
- The absence of measurement grades does not allow for nuanced classification
- Indirect measures could increase the measurement resolution

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Fitness for Duty as an Example Indirect PSF

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Categorizing Fitness for Duty

Definition of Fitness for Duty

- Whether or not the individual performing the task is physically and mentally fit to perform the task at the time
- Affecting factors include fatigue, sickness, drug use, overconfidence, personal problems, and distractions
- Includes factors related to individual but not related to training, experience, or stress
- Further decomposed into psychological and physical factors

Is Fitness for Duty Direct or Indirect?

- As measured in some contexts, it is direct
  - e.g., blood alcohol content has a direct, known relationship to human performance
- Other measures are indirect
  - e.g., measuring fatigue through reaction time
  - e.g., measuring overconfidence through a subjective psychological assessment

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Lessons Learned from Fitness for Duty

Definition of Fitness for Duty

- Many possible definitions of this construct
- We know what it is, but we're not quite sure how best to measure it
- Different organizations performing HRAs may have different working definitions
    - Direct definitions seem to work for a subset of the overall concept
    - Multivariate definitions become necessary to encompass the full concept
    - The most comprehensive definitions encompass both direct and indirect measures
- The multifaceted definitions may not speak to a common process
    - Degraded performance due to psychological factors may manifest differently than degraded performance due to physiological factors
    - Quantification of such factors needs to consider possible different outcomes on performance

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Implications of Direct and Indirect PSFs

Consequences

Proxy Measures

- Measures that are developed as proxies (e.g., reaction time) for the theoretical construct of interest (e.g., fatigue) may exhibit poor validity and low reliability
    - *Validity*—degree to which inferences can legitimately be made from proxy measures to the theoretical constructs
        - e.g., does number of hours spent training in a simulator (proxy measure for Training PSF) correspond to human performance? If not, this is not a valid measure
    - *Reliability*—degree to which proxy measures are free from errors of measurement
        - E.g., does a subjective assessment of complexity encompass all aspects of complexity that come to play in the task?

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Overcoming Limitations

Ensuring Reliability and Validity

- Test and ensure that the proxy measure accurately predicts the construct it is describing
- Perform an *internal-structure analysis*
  - For a construct like Fitness for Duty, where there are multiple possible proxy measures, determine if those measures "hang together" or co-vary over time and acorss domains and individuals
- Perform a *cross-structural validation*
  - Determine whether a proxy measure is unrelated to constructs that are considered theoretically different
  - Are the constructs truly orthogonal?
    - e.g., blood alcohol content is a measure of intoxication, which is unrelated to fatigue
- To date, these analyses have not been systematically conducted on all PSFs

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Good Practices for Direct and Indirect PSFs

Some Guidance

Utilize PSFs that are compatible with good measurement practices

- Use PSFs that have clear definitions, offer a tractable corollary to human performance, and offer measures of continuous quantum

Pick the best available PSF, whether direct or indirect

- A direct PSF is not inherently preferable to an indirect PSF

Ensure the orthogonality of the definitional constructs

- To the extent practicable, utilize measures that do not overlap and could introduce the possibility of double-counting effects

Verify the validity of the PSF

- Ensure that the PSF as measured corroborates the performance effect that is predicted
- Especially a PSF that relies solely on subjective judgment needs careful validation

Verify the reliability of the PSF

- A PSF designed for a particular domain (e.g., nuclear power operations) may not automatically generalize to another domain (e.g., aircraft piloting)

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Questions?

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