Human Factors Questionnaire measurement of engineer decision frequency

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Abstract

The University of Virginia Center for Rail Safety-Critical Excellence (CRSCE) has developed a questionnaire for measuring railroad engineers’ beliefs regarding the frequency of unusual action decisions based upon scenarios encountered during a daily work schedule. The questionnaire is designed to collect responses via a secure web-based interface. Scenarios describe railroad conditions such as work zones, temporary speed restricted zones, control point signal aspects, and emergency braking. Engineers are given the correct response according to rulebook regulations. Given these conditions, engineers are asked to rate the frequency of unusual action decisions of a hypothetical crew, based upon performance-shaping factors of fatigue, broad and specific experience, training, and attention. Engineers respond to categories of Never, Once in 50 years, Once in 20 years, Once in 5 years, Once in a year, Once in a month, or Regularly.

Psychometric analyses include the estimation of probabilities of an action, given the scenario conditions and behavioural shaping factors. Item characteristics relating scenario-action rarity, and engineer response characteristics related to background experience, training, and work satisfaction are specified in the study design. Results will indicate the relative importance of work conditions and performance conditions towards predicting unusual action frequency so that railroad transportation safety and human decision-making is better understood.

Keywords: human factors, railroad safety, decision-making processes.
1 Introduction

Measuring the decision-making frequency of railroad engineers for actions experienced during routine train operation is an important process that has received scarce attention in the field of railroad human factors research. While much of the human factors work has been conducted under experimental conditions [1], work in the area of observational survey work has been neglected. Despite the fact that train accidents continue to occur as a result of human errors [2], little is known regarding the relative frequency of particular human actions and decisions under particular mechanical, experiential, and environmental conditions, as studied in an observational survey framework. Evaluating the safety of such defined conditions allows the quantification of risk assessment, and determination of the probability of an action, given engineer attributes and environmental-scenario conditions. This information will help the railroad industry to actively manage employee fatigue, alertness, and training [3] issues to maintain an optimal level of operational safety and productivity.

2 Probabilistic risk assessment and the Human Choice Model

The CRSCE has designed a Human Choice Model [4] in which decision-making processes are mathematically modelled using stimuli, actions, and agents. The Human Choice Model predicts the decisions in the following way: A railroad stimulus, e.g., a signal, is presented to an agent, presently defined as an engineer. The engineer-agent selects from a set of possible actions given stimulus conditions (e.g., signal aspect is red), outcome state conditions (e.g., outcome speed), and human behavioural shaping factors, and makes a decision. Four critical behavioural shaping factors of the engineer-agent are considered. These behavioural shaping factors are defined by experience, formal training, fatigue, and attention. The Human Choice Model predicts the probability of selection of each potential action through a functional mapping of the conditions to outcome probabilities. There are several fixed parameters associated with this mapping which should be estimated externally, preferably through empirical analysis of data provision.

3 The Human Factors Questionnaire

In coordination with the CRSCE’s Human Choice Model, the design goals of the Human Factors Questionnaire [5] include the prediction of the probability or frequency of decisions, given stimulus conditions and behavioural shaping factors. The decision-responses to conditions are estimated by the human engineers, who engage in railroad decision-making processes daily. In order to protect objectivity and to encourage free responses, engineers are asked to assess the frequency of frequency of unusual action decisions of a hypothetical standard operating crew. The frequency of the decision types within stimulus conditions varies from very rare to unusual.
3.1 Questionnaire sections

The questionnaire is divided into four main sections: Background, Experience, Work and Safety, and Scenarios. The Background section assesses the engineer’s general, visual, and auditory health, and educational level. The Experience section addresses detailed train-related formal training, professional background, work shift information, current work assignment, and attentional/fatigue self-assessment. The Work and Safety section requests the engineer’s beliefs about work satisfaction and safety concerns.

The Scenario section provides defined sets of stimulus conditions for which the engineer selects the frequency of a specified action. These scenarios were carefully designed under the guidance of many railroad engineers, who advised the CRSCE researchers on selection of critical work stimulus conditions, and decisions. The scenarios include railroad conditions of permanent speed restrictions, control point signals, and dual track conditions. Each of these general scenarios varies with several stimulus conditions, for example, control point signal displaying “clear”, versus control point signal displaying “approach”. Each scenario specifies a set of railroad conditions, such as a fixed bridge, or designated speed, such as 30mph, and crew conditions, such as the crew’s failure to remember the signal aspect. Associated with each scenario set, the frequency assessment of the following behaviours is requested: for example, maintain speed, reduce speed, stop, and initiate heavy or full-service braking. These actions are defined under specified behavioural shaping factors, such as extensive, general experience and training, extensive general experience, but limited familiarity on the scenario track, limited training and limited track familiarity, and fatigue under varying conditions of experience. The engineer respondent assesses the frequency of these actions under the stimulus conditions according to categories of Never, Once in 50 years, Once in 20 years, Once in 5 years, Once in a year, Once in a month, or Regularly.

Hence, each scenario specifies a set of stimulus conditions for the railroad environment and the train crew, and the assessment of the hypothetical crew’s action is varied according to the behavioural shaping factors of training, experience, attention, and fatigue. Further, each action variation is presented under each scenario type, so that the relative weight of action frequency under engineer conditions and railroad conditions can be assessed, and the probabilities of safety risk associated with each stimulus condition and behavioural shaping factor can be estimated.

3.2 Questionnaire development and data collection

Questionnaire development occurred in three phases. In the first phase, we concentrated on identifying the relevant stimuli, action responses, and behavioural shaping factors. An initial list of stimuli was developed through examination of the GCORR rulebook. This extensive list was pared down by CRSCE staff by collapsing similar stimuli into a single stimulus whose results could be extrapolated to other stimuli. For example, the only stimulus addresses signals displaying green or “clear” involves a control point signal, and other
types of signals are considered similar and are not directly addressed in the questionnaire. CRSCE staff also identified a list of potential behavioural shaping factors. These two lists were presented to a focus group of labour union representatives, who pared down the lists, identified additional stimuli and behavioural shaping factors, ranked the importance of each item on the lists, and identified important rulebook non-compliant actions for each stimulus.

In the second phase of development, CRSCE staff created the questionnaire itself, addressing each of the stimuli, actions, and behavioural shaping factors identified in phase 1. We also created the Background, Experience, and Work and Safety sections. These sections have several purposes, including the assessment of distributions of values for the behavioural shaping factors (e.g., questions about fatigue are used to assess the general level of fatigue across all engineers). The entire questionnaire was given to the labour union representatives, who edited for content and clarity. After several rounds of editing, the questionnaire was administered to two focus groups of engineers, who provided feedback on content and clarity. The questionnaire was finalized based on these comments.

The third phase of development, which is still ongoing, is administration and data collection. CRSCE staff has created a web based questionnaire administrator built on an extensive database system. We are currently in the process of collecting the first wave of data. A group of approximately 100 representatives of engineer labour unions will be given individual access passwords to the web-based questionnaire, and will be asked to complete the questionnaire. As the questionnaire has the support of the leaders of the labour unions, we anticipate a high response rate. The second wave of data collection will involve administration the questionnaire to a large group of engineers.

3.3 Questionnaire response modeling and the choice model

In order to map the responses to the questionnaire to the parameters of the choice model, we will employ a data analysis technique known as item response theory (IRT). IRT is a collection of statistical models that are used to assess latent aspects of behaviour (in this case, probabilities of actions) based on observed characteristics (e.g., the behavioural shaping factors as defined in the questionnaire) and observed responses. We intend to employ several IRT models in order to assess a variety of important considerations. These include:

1. Does the effect of fatigue depend on the level of experience?
2. Do the responses depend on level of training of the respondent?
3. Do general experience effects override specific experience effects?

These considerations will be used to inform the choice model, both quantitatively and qualitatively.

4 Summary

The Human Factors Questionnaire promises to yield a large amount of data from a previously untapped source: the experiences of engineers in the field. This data
will be used to inform efforts aimed at understanding and predicting human behaviour in the railroad industry through a model of human choice. The validity of the data, however, is not entirely clear, because the relation between the questionnaire responses and actual behaviour is unknown. However, human in the loop data is not currently available, and experimental research (which also has questionnaire real world relevance) has addressed only a very small portion of the relevant conditions in the choice model. Therefore, the questionnaire will provide a much more complete understanding of railroad transportation safety and human decision-making.

References