Generating Hypotheses to Explain Accidents and Other Rare Events

Prolog

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NOTE: Subsequent research revealed MES to be a "research defining" methodology with implicastions beyone accident investigations. See 2010 HPRCT paper, p 7-8 for hypothesis development example.

GUEST EDITORIAL

Generating Hypotheses to Explain Accidents and Other Rare Events

Ludwig Benner, Jr.

This paper focuses on hypothesis gene-ration. How does one generate propositions that can be tested by scientific methods? Popper (1959) says there is no logical path leading to new ideas-they can only be reached by "emfuhlung" or creative intuition. Polya (1957) offers a "rule of discovery" that approximates the fol-lowing: The first rule of discovery is to have brains and good luck; the second is to sit tight and wait until you get a bright idea. Their views are widely held.

As a safety researcher, I am experiencing growing concern about how hypotheses are developed for safety research. *What* is being researched is readily understood, but *why* it is being researched is often obscure. For example, when I ask why some factor was selected for investigation in a specific project, common answers are: "it's an obvious factor. ." or "my experience indicates. .. or common sense tells you. ." or I think what happened is. . ." Similar replies are given by investigators selecting conditions for hazard analyses, analyzing data for statistical significance, developing tests for safety performance standards, or selecting data to record from an accident. Significantly, no orderly method for generating the hypothesis being investigated is readily identified.

Surry's (1969) discussion of accident research methodology is useful to the reader seeking further understanding of some of the difficulties of existing accident research, but does not discuss the hypothesis discovery problem.

The problem of structuring the process of discovery, especially the development of hypotheses, has been with us for a long time. There may be a new way to do it and I would like to share with you some principles for generating hypotheses derived from my work as an accident investigator.

After an accident, every investigator is confronted with the need to answer the question "What happened?" regardless of the ultimate purpose of his investigation. The usual approach is to try to reconstruct" the accident. The method is used to try to isolate events suggested or indicated by evidence acquired after the accident. As the investigator becomes aware of events that occurred during the accident, outlines of what happened begin to emerge. As additional evidence of events comes to light, the investigator begins to speculate about possible hypotheses-that is, ways the accident might have happened. Each hypothesis is tested against the evidence subsequently developed to arrive at the most likely explanation of what happened.

As I have observed this process, elements common to the search for understanding of *any phenomenon* have been noted. These observations suggest, contrary to Popper's opinion, that there may be a logical path leading to new ideas, and that a general method for generating hypotheses during the study of phenomena, including rare event phenomena, like accidents, may be possible. The essential assumptions and principles follow.

My hypothesis generation method is based on the premise that the functioning of our universe and its constituent parts reflects a continuum of interacting event sets. Events, in this context, are used in the sense that someone or something does something (an actor + an action = an event). Each event influences one or more events that follow that event in time. It is the precede/follow logic of the related event sets and the simultaneous visual display thereof that provides the key to my hypothesis generation method.

The accident investigation process is based on an analytic or "events break down" principle. Take "an accident" and break it down into increasingly finite events in the following manner. "An accident occurred" describes a phenomenon as a gross event. 'A car slid and struck a tree" breaks down the gross event into two subevents. The car rolled onto an icy patch, began to slide, and struck a tree" further breaks down the phenomenon into even more discrete events. This "break down" process, one that involves more and more detailed specification of series of related events, can be continued for as long as necessary to gain the under-standing of the phenomenon required by the purpose of the study. Each time an event is subdivided, the need for more precise understanding of the actor-action relationships arises. And each time the need arises, the last known action by an actor provides a starting point to hypothesize the next action or actions that must have been taken by that actor in order for it to arrive at the next known action supported by the evidence. Thus, the bridging of the events gaps is circumscribed by logical, spatial, and temporal relationships among the events as they progress through their precede/follow sequence. This method of "breaking down" the events sequence structureS the discovery of unknown events required for the sequence to proceed from the beginning point to the end point of the phenomenon being studied. Thus, hypotheses regarding the explanation or mechanism of the total process are generated.

Usually for someone or something to (10 something (an event to occur) certain enabling conditions must exist. The creation of these conditions also flows from an event sequence. That is to say, events produce changes of state or outcomes. For any phenomenon under study, a description of the chronological flow of events can provide an explanation of what happened. This is similar to the way we naturally try to create mental movies when we attempt to describe events, or listen to such descriptions. The existence of the enabling conditions, which must have been present for each event to occur, can be traced backward in time to explain "why" the events sequences occurred, if that is your purpose.

Principles for displaying the event sequences, which further facilitate discussion and discovery, have been proposed where the event sequences involve two or more actors (Benner, 1975). The method is much like the development of a musical score, the actions (musical notes) for each actor (instrument) are set forth in the sequence needed to produce the intended outcome (music). Referred to as a "multi-linear events sequencing method," it provides opportunity for a precede/follow logic check along both the horizontal time coordinate for a single actor, and along vertical coordinates for the sequencing of related events by two or more actors. In other words, the timing of any event by an actor can be compared with any other event by other actors. This chronological and visual validation provides a method for "proving" a hypothesis that differs from the traditional statistical or experimental approaches of the scientific method. The display has the further advantage of highlighting unknown "linking" events in the sequence. It can also structure speculations about their occurrence or guide the search for evidence to confirm these speculations.

The multilinear events sequencing methodology can be useful for *predictive* study of rare events or accident phenomena. If one can accept that accidents are multievent phenomena. involving more than ,one actor, whose actions must occur in specified chronological sequence to achieve a harmful or other outcome of interest, it can readily be seen that if any of the events occur out of sequence, or not at all, the outcome being studied will not occur. Thus the *pattern* of events describing the "rare event phenomenon" can be studied. It is the occurrence of the event sets in the necessary relationship that is rare, rather than the occurrence of individual events within the set.

If this concept is valid, it suggests new approaches for the accumulation of data about rare events in the form of *event sets,* rather than in the form of individual conditions or isolated events constituting the phenomenon. The manipulation of chronologically sequenced *event sets* in process flow chart form appears to hold more promise for understanding rare events phenomena than the present approaches. In the accident field, the need for a unifying theoretical framework to organize the event sets for research purposes can be shown to be increasingly urgent.

Three general concepts of "accident" seem prevalent. They include: (1) The accident as a single event; (2) the accident as a single chain of events; and (3) the accident as a branched chain of events. None of these is as acceptable as the proposed method that involves the simultaneous and sequential ordering of event sets. The application of probabilistic estimates of the frequency of occurrence of these event sets provides an approach for predicting rare phenomena. Time or spatial logic tests, as well as traditional mathematical or other experimental methods, can then be used to validate hypotheses, without recourse to statistical inference.

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The views expressed are those of the author and not necessarily those of the National Transportation Safety Board.