THE APPLICATION OF AN EXPANDED ACCIDENT SEQUENCE MODEL TO FORENSIC HUMAN FACTORS

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There are several models that assist the human factors specialist in identifying those behaviors that most likely contributed to an accident's occurrence. Of particular importance to forensic human factors specialists are models that can also serve as demonstrative aids in communicating the bases of their opinions to jurors. One such aid is a version of Ramsey's (1978) accident sequence model. The model, which has been expanded by the author, traces sequentially the activities that likely take place within the individual before an accident occurs. The expanded model prompts the investigator to ask the following questions: (1) Was the hazard detected? (2) If so, was it identified? (3) If correctly identified, were its characteristics perceived accurately? (4) If perception was veridical, was the individual alert to the danger? (5) If alert to the danger, did they appreciate the degree of risk involved? (6) If their assessment of risk was realistic, did the individual want to avoid the hazard? 7) And if they sought to avoid the hazard, could they to do so under the existing conditions? The author draws from cases in which he served as an expert witness to illustrate the model's application.

INTRODUCTION

Human factors specialists are increasingly being called upon to serve as expert witnesses. Typically, testimony is given in suits that claim an injury or death resulted from a failure to consider human characteristics in the design or operation of various products and settings. The challenge facing the expert witness is to formulate sound opinions. and to effectively convey those opinions to jurors.

It is the attorney's task to elicit information from the expert witness; it is the expert witness's task to educate jurors so they can make informed decisions. In doing so, the expert witness is operating under several constraints. Contact with jurors is limited to the time the expert is on the stand. Jurors may be bored and inattentive as there is usually little courtroom drama in civil cases and many interruptions to testimony. Questions posed during direct and cross examination largely dictate the direction and scope of testimony. Perhaps most significantly, there is no mechanism for obtaining timely feedback from jurors as to whether they understand the expert's testimony.

While expert witnesses have little control over many of the variables that affect their ability to educate jurors, they can increase the likelihood that their opinions will be registered and actively processed. One way to accomplish this is through the use of demonstrative aids. The court will usually permit reference to diagrams, charts, and other displays if their use will help the jury understand the expert's testimony.

Since few jurors are familiar with our discipline, models of accident-related behavior that can be outlined on a chart are of particular value to the expert witness in human factors. Ideally, the model should require little explanation and appeal to common experience. One model that appears to meet these requirements is Ramsey's (1978) accident sequence model.

Accident Sequence Model

The accident sequence model traces successive activities that likely take place within the individual when exposed to a hazardous situation. The model advances four stages: perception of hazard; cognition of hazard; decision to avoid; and ability to avoid. The probability of an accident should increase if the individual fails to perceive the hazard or appreciate the danger. Likewise, the probability should increase if the individual adopts risky behavior or does not have the ability to avoid the hazard under existing conditions. The model also includes "chance" as a factor, which includes unidentified variables that impact on the likelihood of an accident. The value of the accident sequence model is that it focuses attention on the adequacy of information available to the individual to avoid harm (McCormick and Sanders, 1982).

As with other models of accident-related behavior, the accident sequence model does not provide answers but only questions. In formulating the accident sequence model, Ramsey (1978) was concerned with exposure of consumers to poten tially hazardous products. While the questions presented in his model can be asked regarding exposure to other hazards, it can be advantageous to alter the questions to fit a particular application.

Expanded Accident Sequence Model

Figure 1 is a version of the accident sequence model that was developed by the author for use in forensic practice. The stages of the model will be illustrated through examples drawn from cases in which the author has testified.

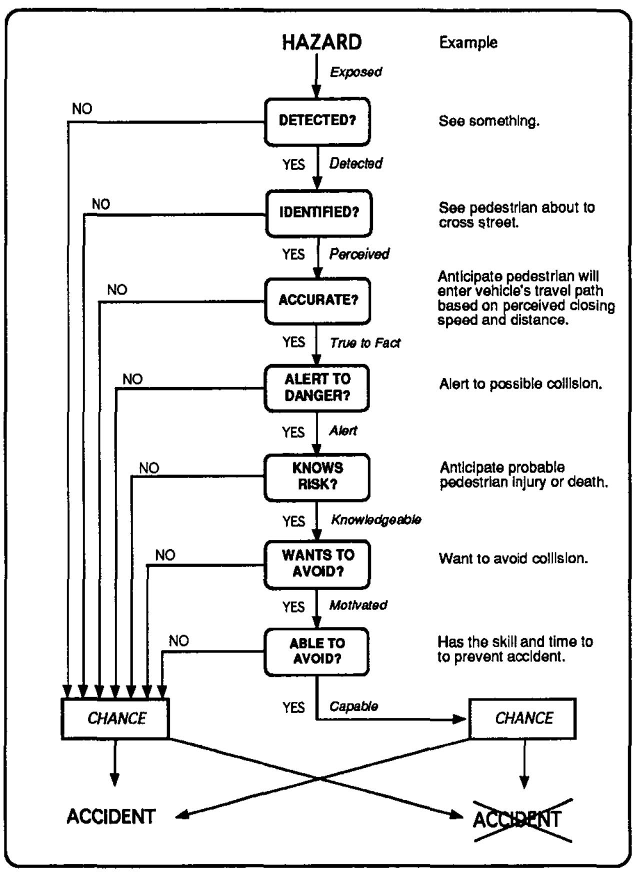

Figure 1. Expanded accident sequence model.

"Detected?" and "Identified?" The detection of a state is not synonymous with its identification. Identification requires more information than detection; for a state to be identified, it must be attended. The difference between detection and identification can be blurred. For example, the basis for negligence may be the plaintiff's failure "to see what was there to be seen." "See" and "seen" are ambiguous in this context. An examination of the evidence may reveal that the plaintiff failed "to identify what was there to be visually detected." By analogy, since the sound could be heard, the plaintiff would be negligent for not comprehending its meaning. The accident sequence model can aid the expert to center attention on the adequacy of information available for detecting and then identify a hazard. Two examples will be given to illustrate this use.

Example 1. Hole in the floor. Figure 2 depicts a man entering a room in which there is a hole in the middle of the floor. The man was a drywaller whose task was to mask a window and tape outlets and light boxes. After masking the window, he stepped back to inspect his work and fell into the hole. The worker claimed he did not see the hole until he fell into it. The plaintiff's attorney argued that the hole should have been covered or guarded in accordance with state and federal regulations. Defense countered that the worker should have seen the hole and have taken reasonable precautions to avoid harm.

Analysis indicated that there was adequate illumination and luminance contrast for the hole to be detected. However, unless its physical features make it conspicuous, an object that falls outside the effective visual field may not be attended even if it is detected (Zohar, 1978). Did the hole fall outside the worker's effective visual field?

After entering the room, the drywaller turned right to tape a light box. He then moved along the wall to the window, taping outlets as he went. His best opportunity for identifying the hole probably occurred when he entered the room. If, at this time, he either looked toward the window (which was the brightest surface in the room) or straight ahead, it is unlikely that the hole would have entered his effective visual field. Was the hole sufficiently conspicuous to draw foveal attention when viewed peripherally?

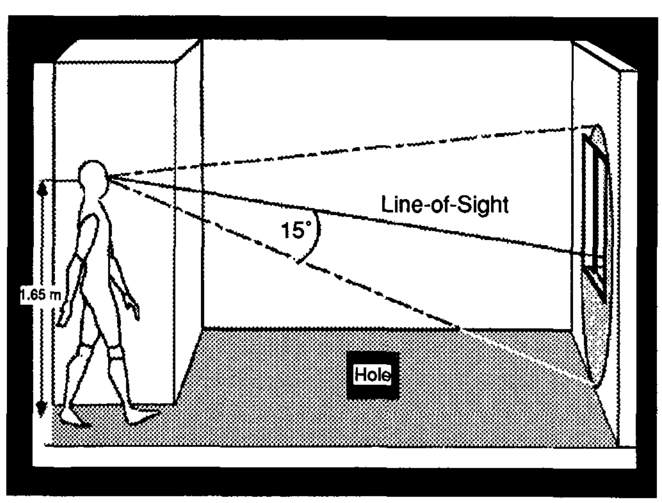

Figure 2. Probable effective visual field of worker upon entering room.

A person can attend to only a small portion of their visual field at any moment. In effect, detected states compete with one another for attention. Conspicuity pertains to how well an object fares in this competition. It was the author's opinion that the hole would fare poorly in such a contest. When viewed peripherally, a dark area on a littered floor would carry little significance for the worker. The dark area was not in his intended path of travel. Further, the hole's location was inconsistent with expectancy according to the worker's deposition and those of other workers. More likely than not, the plaintiff detected but did not identify the hazard.

Example 2. Power line contact. According to the National Safety Council (1985), contact between cranes and uninsulated power lines is the largest single cause of fatalities associated with cranes. Figure 3 is a characterization of a crane operator's view in one such accident. The operator was attending the load when the crane's boom made contact with an overhead power line. As a result, one of the load handlers sustained severe burns.

The attorney for the injured load handler maintained that the crane manufacturer should have been well aware of the problem presented by overhead power lines. He further contended that

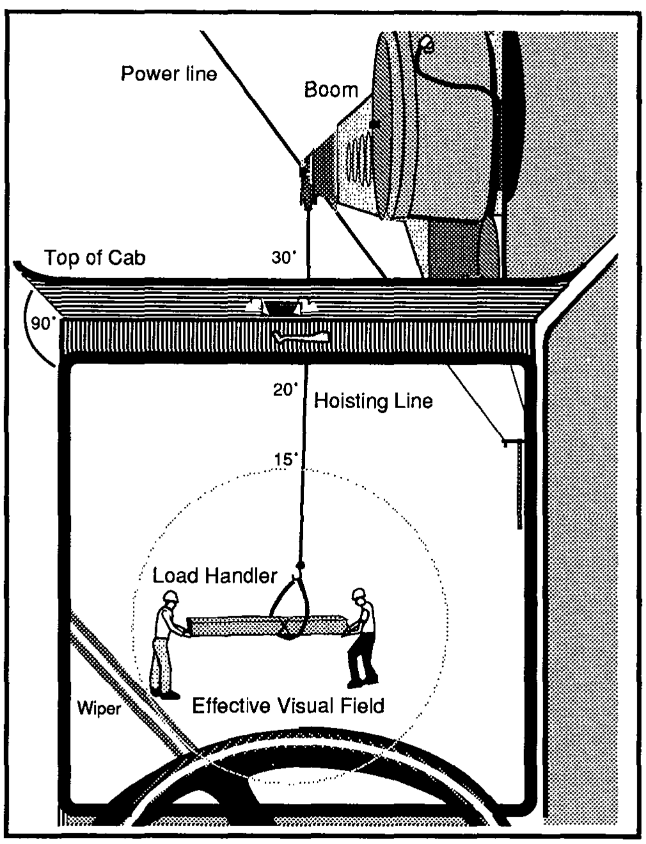

Figure 3. Characterization of crane operator's view.

the manufacturer should have equipped its cranes with available safety devices that either reduced the likelihood of contacts or their negative consequences. Defense countered that the safety devices were unreliable and that dependency on them could result in an increase in accidents. Moreover, the power lines were there to be seen and had established safety procedures been followed there would not have been an accident.

Unlike the worker in the previous example, the crane operator and load handler were aware of the hazard. They knew there were power lines overhead and were alert to the danger. Nonetheless, in the author's opinion, the conspicuity of the power lines was an issue. The point of contact between the boom and power line was about 35° above the operator's dominant line-of-sight. Relative visual acuity at this distance from the fovea is less than .1 (Woodson, Tillman, and Tillman, 1992). The power line's relatively small cross-sectional diameter did not promote its conspicuity. In addition, the power line and the crane's hoisting line were similar in form and color and could have been grouped together into a perceptual unit (see Gillam 1972). If the power line was perceptually grouped with the crane, it would have been rendered less conspicuous. In the author's opinion, the conspicuity of the power lines represented in Figure 3 was not sufficient to attract the crane operator's attention when viewed peripherally.

The crane operator was aware of the power lines, but at a critical moment his attention was diverted. Even very experienced crane operators are likely to have logged relatively few hours working under power lines. A lapse in attention may result in a return to well-established patterns of behavior that are ill-suited to working under power lines. In view of the power lines' low conspicuity, the crane operator needed to be reminded of their presence in time to avoid an accident.

"<u>Accurate?</u>" There can be a lack of correspondence between the actual characteristics of an object and those properties attributed to it. Inaccuracy can be the consequence of a lack of information, misleading information, or the erroneous evaluation of information.

Example 4. Headlights. While approaching an intersection with the intent of making a left turn, a driver sees the distant headlights of an oncoming vehicle. It is late and there is no other traffic. The driver is familiar with the road and discerns by the headlights' lateral location that the vehicle has just entered "the 'S' curve." The posted speed limit is 30 mph (48 km/h), he knows from experience that drivers occasionally exceed the speed limit by as much as 10 mph (16 km/h). He infers from the vehicle's location and expected maximum speed that he has sufficient time to make a left turn. He tentatively decides not to stop at the intersection before turning. After checking traffic conditions to his left, he glances again at the approaching headlights. Their lateral location indicate that the vehicle is coming out of the "S" curve. He executes the left turn confident it is safe to do so. His car is struck by another car traveling 60 mph (97 km/h).

Suit was brought against the driver making the left turn for failing to yield the right of way. It was argued he should have appreciated that the approaching car was speeding and have stopped at the intersection. Part of the author's testimony concerned the ability of people to estimate the speed of oncoming vehicles. If Figure 4 is held at arm's length, the depicted headlights correspond in visual size to what the defendant could have experienced when he initially saw the approaching headlights. It was the author's opinion that, at this time, it was unlikely that the defendant could have appreciated the speed of the oncoming vehicle on the basis of changes in the appearance of its headlights alone.

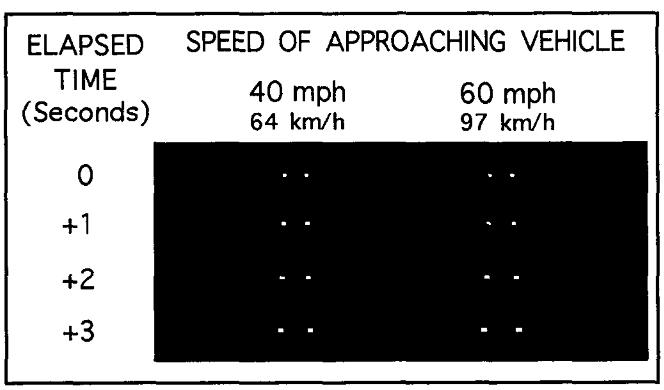

Figure 4. Changes in the visual size of approaching headlights at two speeds. If held at arm's length (2 feet or 61 cm), the headlights at Time 0 are the size they would appear at a viewing distance of 710 feet (216 m).

<u>"Alert to Danger?"; "Appreciates Risk?"</u> The *Final Report* of the National Commission on Product Safety (1970) concludes: "Risks of bodily harm to users are not unreasonable when consumers understand that risks exist, can appraise their probability and severity, know how to cope with them, and voluntarily accept them to get benefits that could not be obtained in less risky ways" (in Lowrance, 1976). This implies that a preventable risk is unreasonable when people are not given the opportunity to reduce their exposure to danger.

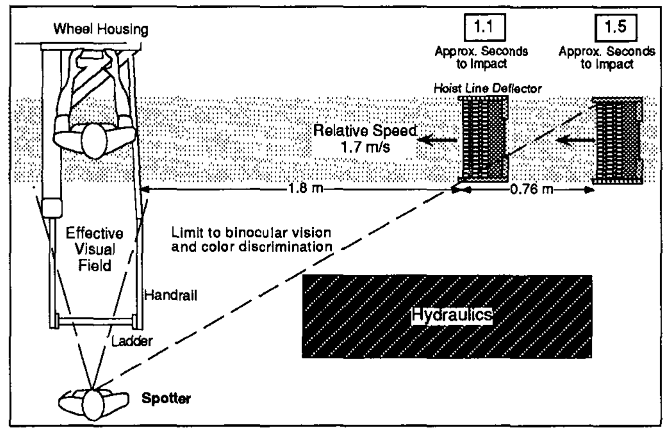

Figure 5. Relative speed and location of deflector in relation to the accident victim and spotter.

Example 5. Adequate warning. A large gantry crane used in loading and unloading container ships was undergoing final testing before it went into service. The crane was seemingly of the same design as several other cranes in operation at the port. During testing, the crane operator heard a strange noise coming from the moving trolley. He told one of the maintenance personnel, who happened to be an electrician, about the noise. The electrician asked a second crane operator "to trolley out and then in" as he and the first operator attempted to determine the noise's source. The electrician suspected that the noise was coming from the trolley wheel housing, which he reached by climbing a ladder and then negotiating a somewhat dangerous walkway. (See Figure 5.) A short time after the electrician reached the area of the wheel housing, he was struck by a projecting metal surface that pressed him against a rail. The electrician died. Unknown to the electrician and operator, the hoist line deflector, which is what struck the electrician, had been modified. The manufacturer's modification had increased its underside length by 33 cm.

Defense maintained that the electrician should have known better than to be in the area of the wheel housing when the trolley was moving. There was a warning sign posted nearby that read: "CAUTION: MOVING MACHINERY." The writer expressed the opinion that the warning was inadequate. The sign conveyed little information about the nature of hazard or what to do to avoid harm. It provided no information about the probable negative consequences of entering the area when the trolley was moving. The author developed the warning sign shown in Figure 6 to support his testimony.

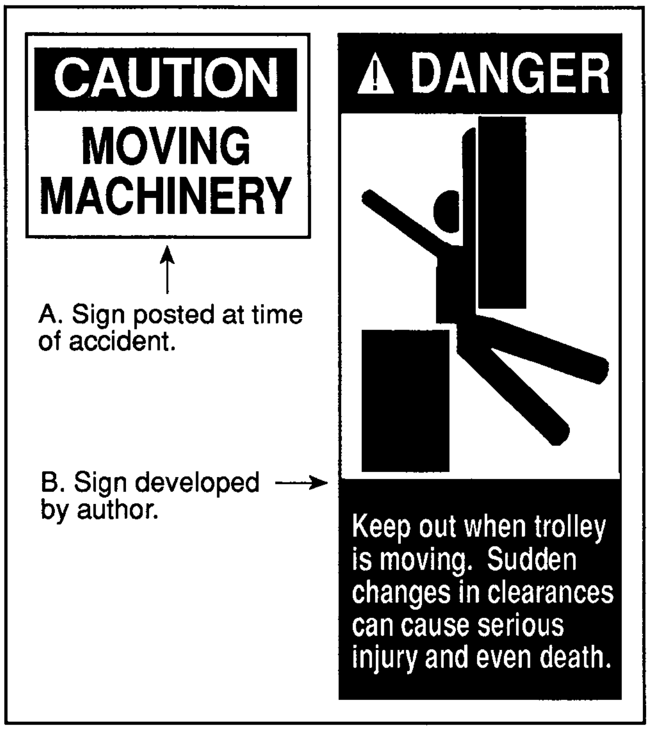

Figure 6. Two warnings intended to discourage people from entering the area near the wheel housing when the trolley is moving.

"<u>Wants to Avoid?</u>" People can elect to follow unsafe practices even if they appreciate the attendant risks. When they do so, they voluntarily assume the consequences of their behavior.

With regard to the previous example, the electrician had engaged in some unsafe work practices. He had stood on a narrow rail of a moving trolley and had not made use of a tie line even though he was many stories above the water. The defense attorney argued that, in view of such behavior, the electrician would not have heeded a sign alerting him to the danger posed by the deflector had one been provided. The warning sign would have made no difference. The author testified that the warning sign would have made a difference, it would have provided the electrician with the opportunity to comply. Ignorance blinds people to their options.

"<u>Able to Avoid?</u>" A person who wants to avoid an accident may be unable to do so under existing conditions. The limitations may be physical, physiological, perceptual, or cognitive. For example, the ability to grasp a critical control can depend on whether it falls within one's reach envelope. The ability to regain one's balance can be compromised by age-related changes to the vestibular system. The ability to avoid a collision may be limited by one's skill as a driver and the time available in which to respond.

CONCLUSION

If an accident can be predicted, then every reasonable precaution should be taken to reduce its likelihood and to minimize its negative consequences. It is ultimately the trier of fact who decides whether reasonable precautions were taken to reduce risk. The expert witness in human factors can help judges and jurors make informed decisions. The expanded accident sequence model can be a useful tool in this pursuit.

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