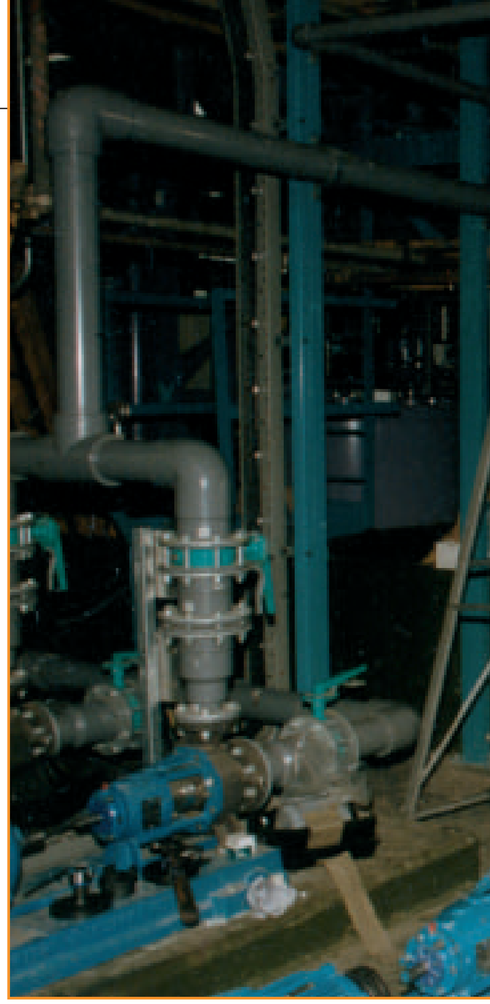
The ERROR of our ways



Human error is thought of as an intrinsic part of the human condition but diagnosing it as the cause of an incident may mask serious deficiencies in the design of the working system. This was the subject of a well-received presentation at the recent Ergonomics Society Annual Conference, as **Duncan Abbott** reports.

Stories about human error in hospitals, on the railways, and in chemical and nuclear power plants make the headlines on a regular basis. It is said to be a major causative factor in up to 45 per cent of critical incidents in nuclear power station accidents, 60 per cent of aircraft accidents, and more than 90 per cent of road traffic accidents.[1]

To investigate errors, however, we must know what errors are. It would be impossible to look at all errors on an individual basis, so it makes sense to investigate whether mistakes fall into categories and, for each category, to determine what its distinctive characteristics are, thus providing a classification, or taxonomy of errors. A widely accepted taxonomy was put forward by Reason,[2] which divides unsafe acts into two broad categories: activities that are unintentional, and those that are intended. Unintended actions are further broken down into slips and lapses, and intended actions into mistakes and violations. Much of Reason's analysis is based on diary studies of everyday errors and case studies of large-scale technological disasters, such as the Chernobyl nuclear power plant explosion.

In terms of violations the HSE defines these as 'any deliberate deviation from rules, procedures, instructions and regulations'.[3] Violations that occur in the workplace have serious implications for safety. The HSE divide violations into three categories: routine, situational and exceptional. Routine violations occur when workers break the rule to an extent that it becomes the normal way of working. Their motivation is to save time and energy, or purely because they see the rules as too restrictive. Situational violations occur when resources needed are not available and this forces the worker to improvise. Exceptional violations are rare, but occur when the worker has good intentions but acts on a risky decision.

"A commonly held view is that errors arise as a result of a mismatch between the characteristics of the human and the design of the task"

Ergonomic perspective

The ergonomic perspective on human error as a field of enquiry is concerned with why people make mistakes, or forget to do critical parts of their job. Often, 'human error' is identified as the cause of a serious accident but the real cause frequently is in the design of the system, in the operating procedures, in the expectations placed on the employees, or in the lack of appropriate training.

A commonly held view is that errors arise as a result of a mismatch between the characteristics of the human and the design of the task.[4] In terms of managing human error in the workplace, there are basically two approaches: the personnel approach (PA) and the design approach (DA). The PA selects and trains only those workers suited to the operation of the machines and the equipment needed to perform the job. The DA involves designing equipment, procedures and environments that reduce the likelihood of errors, or the consequences of errors when they do occur. This is particularly true in safety-critical industries like avionics, where the outcome could be seriously disadvantaged by human error.[5]

Two studies presented at the 2003 Ergonomics Society's Annual Conference examined human error in the avionics industry.[6] Both are good examples of how human error is being actively investigated by ergonomists in one domain, with their conclusions and recommendations being easily transferable to other industries using similar types of working methods and tools.

Plane speaking

Accidents and incidents can result not only from improper operations but also from maintenance errors. Previous reseachers[7] revealed that aviation maintenance technicians who performed low-level inspections used spatial locations of tasks to sequence them. They found that aircraft mechanics rarely used checklists and viewed them as a guide for inexperienced mechanics. Experienced inspectors felt they had acquired sufficient skill to perform the inspection task using their memory and referred to the checklist occasionally. One study[8] found that a third of participants used their memory and not the task guidance system to perform the preflight inspection. In some sessions participants performed the task from memory and only consulted the checklist to see if anything was forgotten. This highlighted the importance of understanding the causes of maintenance errors – specifically deviations from normal maintenance procedures – and preventing them in the design of the system.

Repetitive inspection with checklists: design & performance

This paper[9] was based on the premise that many industries require long, complex procedural inspections. Inspectors are typically given checklists,

Above: Inspectors familiar with the lists often perform the tasks from memory, so is the design of the list to blame for their behaviour?

Left: Designing equipment, procedures and environments to reduce the likelihood of errors is particularly important in safety-critical industries like avionics

but after gaining familiarity with the checklist they will often perform the task from memory.[7] The research focused on whether such behaviour would occur under controlled conditions, and whether the design of the checklist contributed to behaviour.

Aircraft inspection tasks play a vital role in ensuring that aircraft systems are operational and are functioning properly. The use of a job-aid checklist during an inspection task is quite common in the aviation industry and is used as the primary tool to assist in the inspection process. The importance of the inspection checklist and its effect on the quality of the inspection has led to significant human factors research into the design and improvement of aircraft inspection documentation. Several studies have investigated the design and layout of the job-aid checklist to improve the efficiency of the inspection and to reduce the risk of human error.

This study used a 108-step procedure for an overnight check on a common airliner, taught to 24 (non-avionic) students and then repeated on eight different days. After training to perform the task in the order given on their checklist, with signoffs where specified, participants returned eight times to perform the task on simulated aircraft systems. Checklists were either arranged by function or by spatial location. There were either individual signoffs for each of the 108 items, or 37 signoffs for logical subsets of items. There was no difference in probability of defect detection between conditions, but the performance times and rates of both sequence and signoff errors changed significantly.

All participants tended to follow a spatial sequence, whatever their checklist. It was discovered that users of the functional checklist made more sequence errors (deviations from sequence of tasks exactly as arranged on the checklist) than those using a spatial checklist, and that they were also the slowest. Signoff errors (deviations in signoff inspection occurred after the subject has made a decision on the status of the aircraft system) did not differ between groups, although participants were quicker, with fewer signoffs, and preferred that condition in post-experimental ratings.

Errors were classed into outcome errors (OE), where a wrong outcome would be realised, and procedural errors (PE), where the correct procedure was not followed irrespective of whether the outcome was correct or not. OE rates were found to be low and participants moved toward the spatial layout irrespective of layout given. OE existed where the correct procedure was not followed, irrespective of whether the outcome was or was not correct. The overall difference in outcome error rates between the two layouts was: spatial – four errors; and functional – 12 errors.

Spatial layout had one third of sequencing errors (where participants were required to follow the sequence of tasks exactly as arranged on the checklist) compared to a functional layout. This would be expected when the layout of the job aid matched the way the participants performed the task in practice. The signoff error revealed that two thirds of these errors occurred in the spatial layout/108 signoff group.

The spatial layout appears to encourage signing off a block of task steps together. When spatial layout was combined with signing off by logical groups, the error rate was the lowest of all four groups, showing that all aspects of the job aid must be matched to the task itself if errors are to be avoided. The combination of spatial layout and 37 signoffs had the lowest error rate in all of the error measures, and the shortest task time.

The researchers concluded that in human-factor terms the design of the whole task should be integrated, with error-prone situations being avoided. A combination of logical groups of tasks was found to have the highest performance on all measures.

Do job aids help incident investigation?

This study[10] was designed to measure the effectiveness of job aids in improving the thoroughness of investigations of incidents in aviation maintenance. The methodology involved having participants investigate a known scenario by asking the experimenter for facts, as they would in their normal investigation routine. The two job aids used were the Maintenance Error Decision Aid (MEDA), developed by Boeing, and the Five Principles of Causation.[11] Both are used extensively in aviation maintenance. Fifteen experienced users of the two job aids were tested, where the testers were provided with the job aid they had been trained to use. Eleven of the 15 participants used their job aids during the investigation but four did not. The results showed a significant improvement in investigation performance when the job aids were actually used.

The researchers' assertion is that the accident investigation process itself is seen as an active rather than a passive task, and depends intimately on human cognition. An accident investigator must actively choose what lines of investigation to pursue, and when to stop following each causal chain. These decisions are likely to be influenced in a dynamic manner by the number and sequence of facts discovered, as well as biases or prejudices of the investigator.

The MEDA investigation consists of an interview with the mechanic(s) who made the error, to understand the contributing factors. A decision is then made by management as to which contributing factors will be improved in order to reduce future errors. Central to the MEDA process is the MEDA results form and MEDA users' guide (Boeing, 1997). The results form has six sections, moving the investigator from the background information on the incident in a logical manner towards error prevention strategies.

The MEDA is the most widely used aviation maintenance investigation tool; one airline that uses it has reported a reduction in flight departure delays due to mechanical problems of 16 per cent, while another reduced operationally significant events by 48 per cent over two years after implementing MEDA.

Conclusion

The first study shows that the tendency to work spatially is not just a function of expertise in maintenance or inspection, as the behaviour is characteristic of the task itself. The second study demonstrates that job aids are effective if they are actually used during the investigation. Although the studies were carried out in the avionics industry their findings and recommendations are equally applicable to many other industries with similar safety-critical procedures and systems.

References

1 Pheasant, S (1991): Ergonomics, Work and Health, Taylor & Francis ISBN 0-333-48998-5
2 Reason, J (1990): Human Error, Cambridge University Press
3 Health and Safety Executive (1999): Reducing error and influencing behaviour, HSE Books
4 Rasmussen, J, Duncan, K and Leplat, J (1987): New technology and human error, Wiley, Chichester, UK
5 Noyes, J (2001): Designing for humans, Psychology Press Ltd
6 Both papers were delivered at the conference by Colin Drury from the University of Buffalo, State University of New York, Department of Industrial Engineering
7 Pearl, A and Drury, CG (1995): Improving the reliability of maintenance checklists: human factors in aviation maintenance, Office of Aviation Medicine, Washington DC
8 Ockerman, JJ, and Pritchett, AR (1998): Preliminary investigation of wearable computers for task guidance in aviation inspection – paper presented at the Second International Symposium on Wearable Computers, Pittsburgh, PA
9 Larock, B and Drury, CG (2003): Repetitive inspection with checklists: design and performance,' in *Contemporary Ergonomics*, edited by Paul T. McCabe, Taylor and Francis ISBN 0-415-30994-8
10 Drury, CG, Jiao, Ma, Woodcock, K (2003): 'Do job aids help incident investigation?', in *Contemporary Ergonomics*, edited by Paul T. McCabe, Taylor and Francis ISBN 0-415-30994-8
11 Marx, D and Watson, J (2001): Maintenance Error Causation, FAA, Office of Aviation Medicine