BEYOND "HUMAN ERROR" IN INCIDENT INVESTIGATION: WHY PEOPLE MAKE MISTAKES

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Human Error is often found to be a contributing factor in the events leading up to a incident or in the severity of the final outcome. The "no blame" concept, industrial relations environment and common law implications of incident investigation has lead us to become very cautious about probing into the errors that were made prior and during a event. This caution may also be preventing us from understanding the event and therefor limit our ability to learn from the event and prevent similar incidents.
Oversimplification and a blinkered approach may result in all human error being treated the same and the approach to prevention being simplistic and often ineffective. Training tends to be the standard method to prevent errors and is not the most effective intervention for many types of errors.
This paper will discuss the types of errors people make, the factors that increase and decrease the likelihood of errors and suggest some methods for reducing the different types of error in the future. The types of questions that need to be asked when investigating human error will be discussed.
Through understanding human error and why is occurs the incident investigator can probe into the contributing factors of a incident and identify how to minimise the likelihood of similar occurrences.

BACKGROUND

The traditional antagonistic relationship between management and the workforce in the mining industry has lead to a climate where there is reluctance to look into what "human errors" occurred to contribute to (creation of risk) incident occurrence and/or the final outcome.
This reluctance is further enhanced by the mining industry interpretation of the "no blame" principle of accident investigation. This creates a reluctance to examine where a person contributed by purposeful behaviour or unintentionally by error to the incident. Therefore some root causes are ignored and no appropriate controls put in place.
The vast majority of models or accident causation models highlights that rarely is an accident/incident the result of a single cause. It is generally accepted that incidents are the result of multiple factors interacting and the purpose of incident investigation is to identify the contributing factors so that they can be controlled. Human error is one factor that needs to be considered as one of the contributing factors but not as the only factor.
A number of models of accident causation centre on the mental processes involved in the person exposed to the risk.

- The Task-Demand model of Walker & Klien (1973)
- Slurry J (1974)
- Corlett & Gilbank (1973)
- Wigglesworth Error Model (1979)

These models are psychological models and are described in Viner D (1994).
Viner 1994 p36 stated, "*Psychological Models are of particular interest where the person is undertaking a perceptual task such as vehicle driving*" Viner describes the psychological approach as applicable in the monitoring of processes in control rooms and other tasks. According to Viner theses models are important aids to getting the human factors design correct in the first place.
In mining operations the operation of machinery and or processes in control rooms are common tasks and are associated with many of incidents, injuries and fatalities. Vary rarely does an incident occur in the absence of human involvement in design, maintenance or operation. As an industry we need to examine in more detail the human errors and human behaviours that are contributing factors of an incident. The purpose of this is not to alot blame but to look for the reasons for the error or unsafe behaviour so that the likelihood of reassurance can be minimised or eliminated.

WHAT IS HUMAN ERROR

Wigglesworth (1974) (in Viner 1994 p 35);
"*Human error... This term is defined as a missing or inappropriate response, and requires the investigator to ask to what system cues or demands the response would have been made. This definition ensures that human error is looked at objectively in relation to the system design and ensures that it is regarded as a different concept from unsafe acts.*"
Reason (1980)
" *occasions in which a planned series of mental or physical activities fail to achieve the intended outcome,*

and when these failures cannot be attributed to the intervention of some chance agency."

Salminen & Tallberg (1996)

"*when a workers action creates errors and/or fails to correct his/her mistakes or those of others to maintain the normal action of the system* ".

"Human error" only refers to unintentional "failures", however, many human failures are performed with some degree of intention.

Reason 1988 defines these intentional acts as;

"*...deviations from those practices deemed necessary (by designers, managers and regulatory agencies) to maintain the safe operation of a potentially hazardous system*".

This second group is commonly called "unsafe acts" or " unsafe behaviour" and characterises situations where a person choices to adopt a undesired behaviour and no slip or mistake was made.

This group will not be discussed in any detail in this paper, however should be considered when investigating incidents to look at the reinforcers and extinguishers in the environment that shape the behaviour.

DOES HUMAN ERROR CONTRIBUTE TO INCIDENTS

Various researchers have stated different findings to how often human error contributes to incidents.

- 50-90% of accidents according to statistics are stated by industry as due to human failings - Kletz 1985 (in Viner 1994)
- 35-80% of flying accidents due to pilot error - Various authors (in Viner 1994)
- 2/3 fatal occupational accidents in Australia - Willimason & Feyer (in Salminen & Tallberg 1996)
- 80-90% of accidents due to human error - Heinrich 1980 (in Salminen & Tallberg 1996)
- 84-94% of fatalities and serious accidents due mainly to human error - Salminen & Tallberg 1996
- 80-90% of road accidents and 60-80% of aircraft accidents said to be the results of error - Carlton 1996
- 45% of critical incidents in nuclear power plants, 60% or aircraft accidents, 80% of marine accidents and more than 90% of road traffic accidents, human error is said to be a major causative factor - Pheasant 1991.

This is not surprising when you consider that a person may commit an error when they;

- "fail to identify a risk"
- "fail to assess the risk accurately"
- "fail to correct the risk appropriately"

and this may occur in design, maintenance operation and other processes.

The error may occur proceeding or during a incident eg misjudging the road condition before loss of control, failing to act appropriately to prevent or correct loss or control, failing to activate fire suppression and turn off engine when a fire has started on a machine. The error may be a incorrect action or a omitted action.

In mining many of our fatalities particularly those involving mobile machinery have a human error component.

Phillips 1996 made comments on the Alarm Warning Systems and the recommendations for gas monitoring protocols were provided by the Moura inquiry;

Phillips sums the recommendations as follows;

"It is recommended that mines be required to develop and implement protocols for the setting, resetting, the enoting and acceptance of alarm conditions raised by any gas monitoring system in use at the mine. In particular such protocols should define..."

Phillips concludes;

"*whilst these are reasonable recommendations to counter possible human deviation from informal procedure, the system is in fact sill inherently prone to human error because of its design. Formalising the response behaviours required may not consistently achieve the desired alarm initiated actions. These recommendations could in effect drive the latent "dominate" design faults further "underground" until local triggering agents again result in outcomes to that which seems apparent at Moura."*

Phillips goes on to;

"*strongly recommend that human factors experts/ergonomists are included in any further inquiries*".

At a mine level it may not be appropriate or practical to have ergonomists involved in every incident investigation but certainly is practical to include some ergonomic/human factor principles in accident investigation processes and training.

CRTIICISMS OF TRADITIONAL INCIDENT INVESTIGATION

Lacey 1994 in a discussion of accident investigation model comments:

"*The unsafe acts/unsafe conditions model was applied by Comalco from the early eighties. Supervisors conducted the investigations after being trained in the application of the model. In 1989 an audit of the resulting recommendations found that they were overwhelmingly "egocentric" in their focus. In the* *order of ninety percent were behavioural control oriented. Common recommendations included:*

- Told to take more care
- Re-read the standard operating procedure
- Told to slow down
- Use correct lifting technique

The following example is typical of situations in the old technology Plant which gave rise to injury and, all too often , to this sort of response. "

In the authors experience it is not uncommon to see similar recommendations on incident reports in the mining industry. This suggests that the basic causes for incidents are not being effectively identified and therefore the corrective actions being recommended will not be effective.

INVESTIGATIVE PROCESSES

As an industry we are currently in the opportune position to overcome reluctance to examine human error with the increasing involvement of employees and increased training of our Health and Safety Representatives and Supervisors etc in how to control risk and how to investigate incidents. It is time to openly investigate accidents/incidents with consideration to the multiple factors leading to the incident/outcome and this includes the 'human element' both human error and unsafe acts/behaviour.

The first step is to try and identify the various contributing factors and if one of the contributing factors was human error then look at the type of error.

CLASSIFICATION OF TYPES OF HUMAN ERRORS

There are various ways to classify errors. The first method is the one described by Rasmussen 1996 where error is be divided into 3 groups that relate to three cognitive levels of information processing (thinking);

- skill based
- rule based
- knowledge based

"*Skill-based behaviour represents our sensory-motor performance during acts or activities that, after a statement of an intention, take place without conscious control as smooth, automated and highly integrated patterns of behaviour*" (Reason 1988). Example: operating car or mobile machinery- a experienced person changes gears with little thought about when, the direction and amount of movement involved.

"*At the rule-based behaviour level, the composition of a sequence of subroutines in a familiar work situation is typically controlled by a stored rule or procedure with may or may not have been derived empirically during previous occasions, communicated from other persons' know how as an instruction or cookbook recipe, or it may be prepared on occasion by conscious problem solving and planning" (Reason 1988).* Example: overtaking procedures - a person applies a series of steps and rules to overtake.

"*During unfamiliar situations, faced with an environment for which no know-how rules are available from previous encounters, the control of performance must move to a higher conceptual level, in which performance is goal controlled, and knowledge-based. In this situation the goal is explicitly formulated, based on an analysis of the environment and the overall aims of the person*" (Reason 1988). This is basically problems solving. Example: travelling a unfamiliar route without prior experience or a map - a person consciously decides at each intersection where to turn using a compass to guide direction.

People move between the cognitive levels depending on task demands and skill/experience of the person. *"Humans generally can be thought of as working on a least effort principle, and thus usually avoid using knowledge-based behaviour where possible. This type of "new thinking" is not something humans do well and it us used for short periods in order to develop rules.... As we become more experienced with a task (eg. Driving a car), control moves from the knowledge-based level, through the rule-based level, to the skill-based level. However, some tasks are too complex to be performed at the skill-based level and this may even be undesirable for some critical tasks."* (Murphy S 1994)

When a person first performs a task, for example driving he/she consciously thinks and decides to change gears when and how. In contrast a experienced driver automatically changes gears without consciously thinking about it. The reason for using the lowest level possible for the task is to allow most conscious attention to focus on what is important in the situation eg when driving it is more effective to focus on the road pattern and cars moving around us than the gears.

Based on above, error can occur at any of the above cognitive levels. At knowledge based level a person may make the wrong conscious decision. At the rule based level, errors include applying the incorrect rule to the situation, missing or adding a step to the process etc. At the skill based level a error occurs in the automatic behaviour. This indicates the need to look at what level the person was working at when a error occurred.

Another way to group errors is into primary types:

- Mistakes
- Slips

A mistake is when conscious deliberation results in a incorrect decision. Reason (1988) defines as;
"deficiencies or failures in the judgement and/or inferential processes in the selection of an objective or in the specification of an objective or in the specification of the means to achieve it, regardless of whether or not the actions directed by this decision-making scheme run according to plan".
A slip is an error in automatic behaviour. Reason (1988) defines slips as errors that
"result from some failure in the execution and/or storage of a planned sequence, regardless of whether or not the plan that guided them was adequate to achieve its objective".
Typically mistakes are the more common error for learners and slips for experienced persons (Salimen et al 1996).
"If sufficient reliable data is collected, the likelihood of skills based error (slips and lapses) can be predicted, but not the timing. ....Predicability is further hampered by individual differences, the unique contribution of each individual makes to any given situation. Error rates can also be influenced by stress, fatigue, distraction and the like. Therefore, in investigating an accident/incident it is necessary to examine the role of both Immediate Causes and Basic Causes." (Murphy 1994)
What this means is that we need to look beyond the error to the reason that the error occured.
In absolute terms, the opportunity for skills based errors are greatest, followed by rule based error. Knowledge based errors occur least frequently overall due to a lower rate of overall usage. However, errors are more likely to occur because of the greater effort involved. Therefore, the error rate is higher relative to actual usage.(Murphy 1994)
There are a variety of factors or "basic causes" that influence the likelihood of a error occurring. "*It has been estimate that, if a person Is doing a well learned physical tasks requiring hand eye coordination to get the task done correctly the first time without injury, the failure rate could be as low as one in a million... A person with adequate task skills, a knowledge of the process and who is well motivated can be said to be reliable providing that the task characteristics (task demand and task type) remain static and predictable. The error rate for the same person when faced with sudden, unexpected changes to the task characteristics can be as high as one in three" (Cartlon 1996).*
From above it is clear that there are a number of factors that can increase or decrease the likelihood of a error including: stress, fatigue, distractions, task skills, knowledge of process, motivation, task characteristics, predicability of task characteristics etc. The basic caused for errors will vary from situation to situation.
Slips can be broken into subcategories.

- Capture errors - person mixes in a similar sequence
- Description errors - applying the correct function on the wrong object
- Data driven errors - information from the environment intruding into action sequence
- Associate activation errors - blending actions
- Loss of activation errors - decay in information
- Mode errors - person applies the wrong mode

This breakdown will tell us something about the sorts of reasons for the type of slip. For example similarity in a number procedures may lead to capture errors, interruptions and distractions may lead to data driven errors etc.
Another way to classify error is that described by Calton 1996.
"Classified ... as errors of omission or commission. In the former, the task or a step in a process is omitted altogether and in the latter, the task is performed out of sequence (a sequence error), at the wrong time (a timing error), or there was an error of quantity (too little or too much)." Again the type of error may provide clues to the basic causes of the error.
All of these classification systems provide us with some information about the types of error that a person can make. The type or error provides clues as to the basic causes of the error. From a practical perspective what this tells us is that all situations where a error occurs are not the same and on standard solution can not be applied. More training for a person who is already able to correctly perform the task at a skill based or subconscious level will have little effect. However if is a person is applying a incorrect rule training may be effective.
Calton 1996 made comments. Errors
"... occur in what appears, to many managers, to be safe work places so it is possible that they then assume the error was a result of faulty behaviour and prescribe more training or incentives to correct the behaviour. But there are many questions to be asked in relation to the second part of the human error definition, 'a cue or stimulus', that should provide a more logical reason for the error. These questions relate to a large range of interrelated performance shaping factors. Some of these are;

- man-machine interface characteristics; visual, audio and tactile stimuli requiring specific responses, various instructional and procedural characteristics,
- various instructional and procedural characteristics,
- ask demand characteristics; required time for response, duration, frequency, receptiveness and critically,

- task type characteristics; physical, mental, perceptual, and physical environmental characteristics; heat, vibration, noise, etc.

All or any combination of these must be considered as a possible reason for a missing or inappropriate response (by definition, human error) that may lead to an event. The risk control approach, if applied correctly, would include consideration of these at the task level.

CONTROLS TO REDUCE ERRORS

Based on the concept that people use the least mental effort possible and avoid knowledge based thinking they will tend to prefer to use skill based thinking (automatic behaviours) and if this is not possible processes and tend to rule based thinking (rules and procedures available). This leads to design considerations of equipment and processes becomes apparent.

In a situation people will revert to their learnt behaviour and stereotypes on how things work eg driving on the left side of the road, turning a knob clockwise increases etc. When designing equipment or processes the design needs to be consistent to stereotypes and between similar pieces of equipment. For example if two pieces of similar machinery have different layouts of displays and controls people will tend to apply the same rules to both and therefor the likelihood of error increases.

The second consideration is to select preventative controls to suit the level of thinking a person is working at. The following table from Murphy 1994 is one approach.

Level of Cognitive Control	Error type	Example	Corrective Action
Skills-based	Slips, lapse	Pressing wrong button on Café Bar Crashing plane	redesign
Rule-based	mistake	Weak pot of tea Three mile Island Chernobyl	clear instructions clear reasons given frequent revision of training over learning of basic safety procedures redundancy of information
Knowledge-based	mistake	Double coffee from Café Bar Collapsing a petrol tanker	simulation train to diagnose unforseen elements competence testing

Table 1 Levels of Cognition, Error and Propose Action

For example: How do we control "speeding" at each cognitive level:

- Knowledge based : Explain how gears, accelerator, speed limits etc work - explain knowledge behind how things work and why
- Rule based : Ensure the person knows the correct rules and procedure for working the accelerator and brake to control speed, practice and supervision, reminding of "rules", and minimise distractions/interruptions
- Skills-based : Speed alert alarms, cruise control, and other methods to alert a person if they move outside desired behaviour boundaries

In mining there are many examples of the last put onto equipment to prevent slips in automatic behaviours (unconscious error);

- interlocks so access stairs cannot be lowered unless park break is on.
- interlocks so truck can not be put into gear without lowering tray.
- alarms so that drill stem is drawn up before drill walks.

Minimise these errors look for opportunities to design;

- displays and controls to match stereotypes and consistent across equipment
- displays and controls in logical sequence or layout
- routines that are consistent
- signals, alarms or reminders.

WHAT THIS MEANS IN ACCIDENT/ INCIDENT INVESTIGATION?

Persons who perform the investigation require training in understanding;

- human behaviour
- psychological and cognitive processes

The human behaviour is to understand why a person might "choose" to intentionally accept risk. Appropriate control measures can then be used to modify behaviour ie reinforce desired behaviours and extinguish undesired behaviours.
The second is to understand human error and again how to minimise errors whether it be equipment design, job design, training or other means.
Some questions investigators need to ask to look at human error;

- Rule and knowledge based questions : check if the person knew what the appropriate actions should have been.
  - Have you performed this task previously?
  - Can you describe for me the steps you go through to do correctly?
  - Do you know why you do step....?
- Look for knowledge of correct rules and procedures and when they should be applied.
  - Also look for understanding of reasoning behind rule and procedures. If no rules or procedures are known to apply to situation check the persons problem solving approach and knowledge base.
- Skill based questions to find out what might have interrupted or prevented the automatic behaviour.
  - What were you thinking when......?
  - If you know...... what happened when you were about to do that step?

Look for different types of slips and reasons eg two similar procedures and mixing up which is being applied., interruption and loss of place in sequence, controls and displays which do not fit stereotypes or are inconsistent with each other, procedures that are inconsistent

CONCLUSION

Calton 1996 provides a concise summary of the approach I believe we need to adopt in incident investigation "*.....The risk control approach, with its focus on hazards and their associated risks to people, if appropriately applied should remove any attempts to blame the injured person. The main emphasis of this approach is on control, rather than cause, and is naturally pro-active. To design and implement effective risk controls, we need to consider all of the relevant human performance shaping characteristics at the task level. If done correctly, it is possible to eliminate 'human error' according to the definition and improve human reliability and therefore, human performance by orders of magnitude."*
If we investigate incidents with the aim of identifying ways to control risk we need to examine all the contributing factors and this includes human error - causes are identified so that they can be controlled and risk eliminated.

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