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The two-fold path to human error analysis: TRACEr *lite* retrospection and prediction

By Steve Shorrock

The Human Error Struggle

The topic of 'human error' is as newsworthy as ever, with the media highlighting human and organisational failings in medicine, aviation, rail, military, banking, etc., on a daily basis. So why is it that so little effort is spent applying approaches to identify, classify and analyse actual or potential human errors that could impact system safety and operation? The Health and Safety Executive (HSE) is seeing "very little evidence of use of human error prediction methods in COMAH [Control Of Major Accident Hazards] reports" and yet expects "that the part that foreseeable human failings play in initiating major accidents and the human reliability of safeguards to be understood and addressed with proportionally the same degree of rigour as for process and engineering issues" [1]. Where system development is concerned, it has been claimed that human reliability approaches have had little impact in many industries [2]. So again why, despite widespread development of approaches and techniques, has HEA met such resistance, and had relatively little impact?

An honest inventory of the problems facing HEA would highlight several problems, e.g.:

1. *Complexity of human behaviour and system interactions* - complexity can seem overwhelming, leading to a conclusion that attempts to identify errors are fruitless.
2. *Usability and methodological support* - the starting point is not always clear to new users, who may also be put off by jargon or lack of structure. Existing users might not be using a technique as the developer intended. Few techniques are clearly and concisely documented, and many are not publicly available.
3. *Analyst subjectivity* - even 'experts' disagree on what constitutes an error in retrospection, or credible errors in prediction, and there are different understandings of pertinent latent conditions.
4. *Analytical burden* - burdensome supporting analyses and excessive 'resolution' (of context, error types, etc.) can be off-putting to users. The Pareto principle may be relevant to HEA, though this will depend on the level of risk.
5. *Demonstrable added value* - there can be a perception that the costs are not justified, that no practical output will emerge, or that a safety case will address all HF issues.
6. *Validity in the context of the application domain* - should a technique be a 'Jack of all trades' or a 'master of one'? The choice will influence uptake.
7. *Applicability* - some methods are restricted to small-scale systems/products, individual operator systems, particular life-cycle stages, or types of human performance.

Some issues are outside the scope of a technique, and others have more of an organisational slant, such as acceptance that there is a problem or solution. Denial of a problem can run deep until a disaster occurs, or problems might be assigned to individuals or idiosyncratic circumstances. There may be a belief that 'to err is human', and so nothing can really be done.

A notable problem of interest to this paper is the limited focus of some techniques on particular stages of the system lifecycle. Predictive methods (human error identification, HEI) can be used at any lifecycle stage, but are used with best effect during the design stages. Retrospective approaches (incident analysis) analyse errors that have occurred, normally in operation. Both approaches share a need to analyse human error, and yet each has often taken a separate path to development and application. While those involved in the management of safety are using different (or, worse, incompatible) methods and language to address the same reality, safety margins, organisational learning opportunities and operational efficiencies are being lost.

One effect of all these problems, where they exist, is that potential end-users and customers are left on the starting blocks. Some good, well-known techniques have been applied in a range of domains. But many more approaches exist that have not received widespread attention or use. And all too often, applications are one-off studies, so the (general) HEA approach does not become accepted and standardised. The problems of HEA must be addressed before we can expect widepread use, and a number of criteria must be tackled [3]. This may entail some changes to techniques (e.g. context-recognition, jargon reduction, simplification, etc.), better support, free access, value promotion, and other measures.

From TRACEr to TRACEr *lite*

One technique that has tried to harmonise active and reactive approaches to HEA in the realm of Air Traffic Management (ATM) is 'TRACEr' - Technique for the Retrospective and Predictive Analysis of Cognitive Errors [see Ref. 4]. TRACEr has been used by National Air Traffic Services (NATS) to provide feedback on organisational performance before and after unwanted events. This has been termed the 'the Janus perspective' after the Roman god who was often depicted with two faces because he could look into the past and the future at the same time. It was realised that for the potential of TRACEr to be realised more fully, it had to be simplified and made more accessible to designers, operational incident investigators, trainers, and procedure writers, as well as ergonomists. A reduced-scope version was developed, called 'TRACEr *lite*' [described in Ref. 3].

For predictive use, the analyst first scopes the analysis, then conducts a task analysis. TRACEr *lite* then operates on the task analysis, helping the analyst to determine what could go wrong. For retrospective use, a number of domain-relevant 'task errors' are used as prompts to identify where errors have occurred in incidents, in conjunction with any error definitions within a company's safety management system. TRACEr *lite* comprises a number of inter-related taxonomies (see Table 1), and classifying identified errors is represented as four steps for retrospective or predictive use (see later).

Table 1. TRACEr lite taxonomies

Name and Description	Retrospective /Predictive	Example categories
Task error The error described in terms of the controller or pilot task that was not performed satisfactorily.	*Retrospective*	Radar monitoring error; Co-ordination error; Flight progress strip use error; Aircraft transfer error.
External error The observable manifestation of the actual or potential error, based on logical outcomes of erroneous actions, in terms of timing, sequence, selection and quality. External errors are context-free and independent of cognitive processes (e.g. intention).	*Predictive*	Omission; Wrong action on right object; Mis-ordering; Information not sought / obtained.
Error Domains Not a taxonomy, but the organising structure for internal errors (modes and mechanisms).	*Retrospective and predictive*	Perception; Memory; Decision Making; Action.
Internal error (modes) The cognitive function that failed or could fail, and in what way.	*Retrospective and predictive*	Mis-see; Forget information; Poor decision/pan; Selection error.
Internal error (mechanisms) The psychological nature of the error modes; the cognitive biases that are known to affect performance.	*Retrospective and predictive*	Expectation; Confusion; Mind set; Variability.
Information The subject matter or topic of the error. Relate to error modes. E.g., what was misperceived, forgotten, misjudged, or miscommunicated?	R*etrospective*	Flight Level; Heading; Destination; Runway.
Performance Shaping Factors (PSFs) Factors that influenced or could influence the controller's performance, aggravating the occurrence of errors, or perhaps assisting error recovery.	*Retrospective and predictive*	Traffic complexity; RT workload; Alertness/fatigue; Handover/takeover.
Recovery Description of error detection and correction opportunities.	*Predictive*	(No categories *lite* version, but specification of task steps / activities.)

The four steps for retrospective or predictive analysis are as follows:
TRACEr *lite RETRO*:
Step 1 - Task Error
Step 2 - Internal Error (Modes and Mechanisms)
Step 3 - Information
Step 4 - Performance Shaping Factors (PSF)

TRACEr *lite PREDICT*:
Step 1 - Performance Shaping Factors (PSF)
Step 2 - External Error
Step 3 - Internal Error (Modes and Mechanism)
Step 4 - Recovery

TRACEr *lite*'s modular structure allows the user to describe the error at a level for which there is supporting evidence. For example, if the error mechanism cannot be determined, the user can describe the task error and (internal) error mode. When strung together, the classifications form a multi-layered picture of the situation, recognising the roots of 'error' in the task context and offering clues regarding potential strategies to educe errors and their negative effects.

A prototype version of TRACEr *lite* has been represented using Microsoft Excel, integrating both *'RETRO'* and *'PREDICT'* versions. This contains hyperlinks for navigation and pop-up contextual examples of categories.

Future Developments
TRACEr *lite RETRO* is being used by incident investigators at Manchester Area Control Centre. NATS have developed a post-incident checklist and interview protocol for use at the London Terminal Control Centre and London Area Control Centre to record information based on the structure and simplified content of TRACEr *lite*.

TRACEr *lite* has linked with, and used to populate, a safety model for ATM to analyse future ATM technology impacts. Meanwhile, an adaptation of the original TRACEr is flourishing in European ATM, and being tried in U.S. ATM [the 'Janus' technique, Ref. 5]. TRACEr *lite* will be adapted for potential use in the rail sector in the UK, and is open to potential adaptation for other sectors. TRACEr and TRACEr *lite* are currently being tested in an evaluation study to and user consensus and opinion.

A website is currently under construction at www.tracer-lite.co.uk, and expected to be on-line during autumn-winter 2002. The technique may be implemented using a database platform. In the meantime, interested readers should contact the author for a copy of TRACEr *lite*.

Conclusions
Human Error Analysis must change to survive. Increasingly complex models and techniques may widen the reality gap. It is time to think again if methods are to see widespread use by incident investigators, designers, trainers, risk analysts, procedure writers and ergonomists. More attention to contextual validity, flexibility, resource efficiency, and usability will bear fruits in terms of real impact. Techniques also need to adopt a 'Janus perspective', using a common framework and shared taxonomies for prospective and retrospective use, if maximum use is to be made of organisational feed-forward and feedback loops. The possibility of a panacea in HEA techniques is probably both unlikely and undesirable. This article describes one attempt to find a reasonable approach in the ATM domain.

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