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ORIGINAL ARTICLE

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Rating non-technical skills: developing a behavioural marker system for use in anaesthesia

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Abstract Studies of performance in medicine are often based on observation. Videotape provides a valuable tool for recording events from both real environments and simulators. When analysing observational data it is important that robust tools are used, particularly when investigating non-technical (cognitive and social) skills. This paper describes the method used to identify the key non-technical skills required in anaesthesia and to develop a behavioural marker system for their measurement. A prototype taxonomy was designed on the basis of a literature review; an examination of existing marker systems; cognitive task analysis interviews; an iterative development process involving workshops; and cross-checking in theatre. The resulting anaesthetists' non-technical skills (ANTS) system comprises four skill categories (task management, team working, situation awareness, and decision making) that divide into 15 elements, each with example behaviours. Preliminary evaluation using ratings of videotaped scenarios indicated that the skills were observable and could be rated with reasonable agreement.

Keywords Non-technical skills · Behavioural marker system · Anaesthesia · Performance assessment · Cognitive task analysis

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1 Introduction

In work settings such as acute medicine, studies of task performance are often based on observations, and video is a valuable tool for collecting and recording behavioural data for subsequent analysis. Although there have been significant advances in the technology used to videotape behaviour in operating theatres and other hospital settings (Mackenzie and Xiao 2003; Weigner et al. 2004), rather less attention has been devoted to designing robust psychometric tools for the analyses of the resulting data sets (Gaba and Rall 2004). While patient outcome may be the ultimate measure of performance, this does not provide any information about the processes that led to the result (Mackenzie et al. 1999). Since one of the roles of video-based research in complex work environments is to investigate the behaviours that underpin these processes, effective diagnostic measures of behaviour are needed. From a review of the literature on studies of anaesthetists' behaviour (Fletcher et al. 2002), it is clear that a number of different criteria and techniques are being used for performance measurement. These include expert assessment (with or without a checklist), set protocol compliance rates, timing of problem recognition, and questionnaires. Some measures focus on the clinical aspects of performance (Byrne and Jones 1997; Forrest et al. 2002) while others record the behaviours supporting these activities (Manser and Wehner 2002; Seagull et al. 1999).

With a proliferation of psychometric instruments being used by researchers, it can be difficult to make comparisons between studies and to isolate specific factors that are key to the success or failure of overall performance. For any measure of behaviour to be useful and fair, it has to be both valid (measuring the variable it is supposed to measure) and reliable (measuring the variable consistently) (Anastasi and Urbina 1997; Nunnally and Bernstein 1993). Without sound measurement devices, there are risks that different observers/raters

may assess performance in different ways and against ill-defined or non-standardised criteria (Carthey 2003; Klampfer et al. 2001). This could lead to problems in the veracity of data collected from observational studies. While it is accepted that observational research will always be influenced by subjective interpretation, the more robust the measure, the more robust the findings. This means that the observational rating tools used for both videotaped and in vivo research should be systematically developed and carefully tested to ensure they meet necessary psychometric criteria.

When studying professional behaviour, evidence from safety research in other high risk work settings (Salas et al. 2001), as well as medicine (Bogner 2004), shows that in addition to technical or clinical competencies, non-technical skills also need to be considered. The term non-technical skills has been adopted from European aviation (Flin et al. 2003c; JAA 1999); they are also known as crew resource management (CRM) skills. These are cognitive and social skills shown to have a critical role in maintaining safety, especially for individuals working in teams in high risk domains (Weiner et al. 1993).

This paper describes a method to develop a behavioural marker system for rating observations of non-technical skills demonstrated by anaesthetists (anesthesiologists) in day-to-day practice. Behavioural markers are 'observable, non-technical behaviours that contribute to superior or substandard performance within a work environment' (Klampfer et al. 2001, p. 10). While there were already behavioural marker systems available for anaesthesiologists and surgeons, these tended to be for the investigation of team performance (Helmreich et al. 1995) or for crisis management (Gaba et al. 1998). The aim was to produce a tool that could be used to support the measurement of an individual anaesthetist's non-technical skills based on observation of behaviour either in the operating theatre or a simulator, live or from video recordings. The approach was based on psychological research methods widely adopted in aviation for behavioural analysis (Baker and Dismukes 2002; Flin and Martin 2001; Flin et al. 2003c; Seamster and Kaempf 2001; Avermaete and Kriujsen 1998) and the military (Farmer et al. 1999). The process was divided into three main stages: (1) identification of the non-technical skills used by individual anaesthetists in their routine practice, (2) development of a prototype taxonomy/behavioural marker system for these skills, and (3) preliminary evaluation of the prototype using videotaped scenarios.

2 Stages in development of a behavioural marker system

2.1 Skills identification

A review of human factors research in anaesthesia established the current state of theoretical and applied knowledge on non-technical skills in anaesthesia (Fletcher et al. 2002). The results from a study of anaesthetists' attitudes to safety and team work (Flin et al. 2003a) were also taken into account. A plan to examine the non-technical skills cited in anaesthetists' incident reports as a primary source of data proved unfeasible due to insufficient detail and limited coding of human factors information. (However, these were used towards the end of the project for checking the developing prototype.) From these sources of information and a survey of medical simulation centres running aviation style crew or crisis resource management courses, six existing behavioural marker systems were identified and analysed to establish exactly which skills they contained and how they were structured. These systems were: (1) operating room checklist (Helmreich et al. 1995), (2) a German version (translated) of the operating room checklist (Department of Anaesthesia, University of Basel-Kantonspital 1997), (3) crisis management behavioural performance markers (Gaba et al. 1998), (4) ACRM principle markers (Howard et al. 1992), which are slightly different from their behavioural performance markers, (5) teamwork behaviour matrix (Small et al. 1999), and (6) categories of behaviour defining aptitude for anaesthesia residents (Altmaier et al. 1997). Component skills were extracted; then listed behaviours from all systems were sorted into groups with common themes at equivalent levels of abstraction. These were used to provide a baseline to guide subsequent data collection activities and to check the prototype.

The second component for determining the content of the behavioural marker system was the semi-structured interview study with expert practitioners, using a cognitive task analysis technique (Klein and Militello 2001). This method has been shown to be effective for eliciting knowledge on non-technical skills (Chipman et al. 2000; Seamster et al. 1997). A grounded theory approach (Charmaz 1995; Strauss and Corbin 1990) was adopted for the analyses of the resulting interview data. This is an inductive rather than a deductive approach that is helpful in exploratory data analysis, for example when a system is being developed. It has previously been found useful in the medical domain (Altmaier et al. 1997; Klemola and Norros 1997).

In total, 29 consultant anaesthetists from across Scotland volunteered to participate and were interviewed by a psychologist with a basic knowledge of the process of conducting and managing an anaesthetic. Each interview was conducted in a private room at the consultant's own hospital and lasted approximately one and a half hours. In the first part of the interview, the anaesthetists were asked to describe their management of a particularly challenging case or critical incident in a process adapted from the critical incident technique (Flanagan 1954) and the critical decision method (Klein et al. 1989). It involved the anaesthetist recounting their event, focussing on the non-technical and management aspects, with minimal interruption from the interviewer. Each interviewee described their case twice, once to

provide a brief overview and the second time to provide the detail. At this time, probe questions were used to gain additional information if necessary. Initially, a large number of probes were developed based on those suggested by Klein et al. (1989) for studying decision making. Other areas of non-technical skills such as resource management, situation awareness, and team working were also incorporated. However, in practice only a few very general questions were required, e.g. *what were you thinking about, was there any one else involved, how did you know what was going on*? These allowed the necessary information to be collected but importantly without leading the interviewees too much or distracting them from the thread of their event. If any issues remained unanswered at the end of this process, some additional questions were used to capture that information. This part of the interview lasted on average 45 min.

In the second part of the interview, participants were asked directly about the non-technical skills they thought were important for good practice in anaesthesia and if these skills were the same or different for normal or crisis situations. They were then asked about training that was currently received for these skills. This approach was based on Klein and Militello's (2000) knowledge audit method. The third part of the interview comprised a sorting task (Rugg and McGeorge 1997) and a rating task using the common themes extracted from the existing anaesthesia behavioural marker schemes. The interviewees were given cards with each of the 19 items written on them and were asked to group them into sets of related items. While participants seemed to find this process interesting, unfortunately the analysis showed that all 19 skills were considered important and did not reveal any real shared framework for grouping the ideas. Consequently these data did not prove helpful for development of the marker system. Whether this was a flaw of the method used or simply reflects the lack of common training and understanding of non-technical skills in anaesthesia remains to be investigated.

Using a grounded theory approach, each de-identified interview transcript was examined to identify any non-technical issues, which included references to skills, behaviours, and knowledge. A sample of five randomly selected transcripts was also cross-coded by two additional psychologists from the project team to ensure the identification process was being conducted consistently and comprehensively. Items from each interview were grouped into common themes and obvious duplications removed; the data from all the interviews were then combined and sorted to produce a list of 116 non-technical items. At this stage, the derived skill list deliberately included items at different levels of abstraction, some possible duplications and some explanations. These items were structured into eight broad categories: leadership, team working, communication, task management and planning, situation assessment, situation awareness and recognition, decision making, and personal factors.

2.2 System development

To guide development of the system, design criteria were produced by the project team (three psychologists and three subject matter experts (SMEs)—consultant anaesthetists with experience in training and simulation). These were:

1. The skills should be observable.
2. The system should have a hierarchical structure to make it easy and versatile to use.
3. The system should be simple and usable with minimal training.
4. It should be complementary to the competency-based approach being adopted in medical education in the UK.

To establish a suitable structure for the system, it was decided to adopt the format of the European behavioural marker system for rating pilots' non-technical skills—NOTECHS (Avermaete and Kruijsen 1998; Flin et al. 2003c). This has a tri-level hierarchical structure of skill categories, elements, and behavioural examples or markers, which has been shown to be effective for rating pilots' non-technical skills in an operational context (O'Connor et al. 2002).

During workshop discussions with the project team, a prototype skills taxonomy was developed from the derived skills list. The process during the workshop was to discuss each of the eight category sets (e.g. decision making) in turn, removing items that would not be observable or were not actually skill-based. They were then sorted according to their level of abstraction e.g. 'team working' is at category level, 'exchanging information' is at the element level, and 'discusses case with colleagues' is at the behavioural level. The resulting prototype was then refined and condensed iteratively by (1) making observations in theatre, (2) re-coding a sample of interview transcripts, and (3) reviewing 200 anaesthesia incident reports to cross-check that all the non-technical issues associated with them could be explained. Any alterations and adaptations made to the prototype during this phase were agreed by the project team and noted in a tracking document. Having produced a final prototype, examples of good and poor behaviours were selected for each skill. These exemplars were gathered from the project SMEs and other sources described previously. Each example was written as an action statement either describing directly observable behaviour for a skill, or behaviours from which use of the skill can be legitimately inferred, such as a communication describing a risk judgement. In combination with the skills taxonomy, these example behaviours form the basis of anaesthetists' non-technical skills (ANTS) system, see Tables 1, 2, and 3 below.

Table 1 ANTS system prototype—category definitions

Category label	Definition
Task management	Managing resources and organising tasks to achieve goals, be they individual case plans or longer term scheduling issues
Team working	Working with others in a team context, in any role, to ensure effective joint task completion and team satisfaction; focus is particularly on the team rather than the task
Situation awareness	Developing and maintaining an overall dynamic awareness of the situation based on perceiving the elements of the theatre environment: patient, team, time, displays, equipment, understanding what they mean and thinking ahead about what could happen in the near future
Decision making	Making decisions to reach a judgement or diagnosis about a situation, or to select a course of action, based on experience or new information under both normal conditions and in time-pressured crisis situations

Table 2 ANTS system prototype—categories and elements

Category	Elements
Task management	Planning and preparing
	Prioritising
	Providing and maintaining standards
	Identifying and utilising resources
Team working	Co-ordinating activities with team members
	Exchanging information
	Using authority and assertiveness
	Assessing capabilities
	Supporting others
Situation awareness	Gathering information
	Recognising and understanding
	Anticipating
Decision making	Identifying options
	Balancing risks and selecting options
	Re-evaluating

2.3 Preliminary evaluation

The next stage for developing the behavioural marker system was to conduct a preliminary investigation into the observability of the skills, the completeness of the system, and its usability for rating non-technical performance (Fletcher et al. 2003). The method was based on that used in an earlier project to evaluate the NOTECHS framework for European airline pilots (O'Connor et al. 2002). For the pilot study, eleven consultant anaesthetists (who were also simulator instructors) were given an hour and a half of introductory training in the ANTS system, consisting of a didactic presentation and scenario rating practice (see Klampfer et al. 2001; Baker et al. 2001). Following this, they were asked to watch six video scenarios, all approximately 10 min long, showing a trainee managing a potentially challenging anaesthetic situation during simulator training. (The trainees concerned gave written consent for their tapes to be used in this study.) After each scenario, participants rated the non-technical skills of the target trainee using the prototype and a simple three point scale (poor, average, good) and a not observed option. Finally they completed an evaluation questionnaire that asked about the content and structure of the ANTS system and opinions regarding its use for training and assessment in anaesthesia. The results were analysed using descriptive statistics and content review.

The findings from this pilot study were encouraging. None of the participants identified any major omissions from the skills taxonomy or thought that any elements were superfluous. With regards to use of the ANTS system, i.e. its fitness for purpose, the main requirements were that the skill elements were observable and could be rated on the scale provided. The results indicated that it was possible to identify all the skills in at least one scenario, if not more. Rating of the skills was more varied but given the limited amount of training provided for the task, there was a reasonable level of rater agreement and accuracy. The need for comprehensive training and practice to use the tool was clear.

The design of the rating scale was also considered. The three-point scale was found to be rather limited for rating low levels of performance. It was felt that the 'distance' from average to poor (described as endangering or potentially endangering patient safety) was too great. There was evidence of behaviour that fell below an average level but that was not sufficiently weak to be regarded as poor. A four-point scale is now provided, see Table 4.

This level of granularity has been found by other researchers to be practical and effective when measuring non-technical performance (Williams et al. 1997). An additional rating option of 'not observed' is also provided for when the skills cannot be observed in a particular situation. No other problems were identified with the scale and rating process, and assessment could be carried out at both element and category levels. The comments section on the rating form allowed the participants to take notes and make justifications for their ratings and also provide feedback for the evaluation.

The provisional indications from the preliminary evaluation were that the prototype appeared to address the main non-technical skills required by anaesthetists and it was possible to rate these items through observation of behaviour. Minor alterations were recommended to ensure the language in some element titles was more meaningful and to lengthen the rating scale to accommodate a more diagnostic range of performance.

3 Discussion

The ANTS system has been designed primarily for use as an assessment tool to allow feedback to be given to

Table 3 ANTS system prototype—element and behavioural markers

Co-ordinating activities with team members	
Behavioural markers for good practice	Behavioural markers for poor practice
Confirms roles and responsibilities of team members	Does not co-ordinate with surgeon/s and other groups
Discusses case with surgeons or colleagues	Relies too much on familiarity of team for getting things done
Considers requirements of others before acting	Assumes things, takes things for granted
Co-operates with others to achieve goals	Intervenes without informing/involving others
	Does not involve team in tasks

Table 4 ANTS rating scale

Rating options	Descriptor
4—good	Performance was of a consistently high standard, enhancing patient safety; it could be used as a positive example for others
3—acceptable	Performance was of a satisfactory standard but could be improved
2—marginal	Performance indicated cause for concern, considerable improvement is needed
1—poor	Performance endangered or potentially endangered patient safety, serious remediation is required
Not observed	Skill could not be observed in this scenario

trainees on key observable non-technical skills needed by anaesthetists in both routine and non-routine situations. Performance can be rated at both the category and element levels depending on the purpose of the assessment and the amount of feedback detail required. The elements represent the main working level of the system, as it is at this level that enough detail is provided for trainers and trainees to focus on the development of specific skills and components of performance. The behavioural markers are intended to help users recognise the types of behaviour associated with good and poor performance of each skill element. The full ANTS system is provided with user guidance, which outlines the origin of the system, describes the concepts and terminology, and includes instructions for its use as an assessment tool (available at http://www.abdn.ac.uk/iprc/ants, cited 16 March 2004). This guidance highlights the requirement for users of the system to be properly trained in a basic understanding of human factors, as well as the mechanics of the system in question and in the principles of using psychometric tools to rate performance (Baker et al. 2001; Klampfer et al. 2001).

One of the main difficulties when developing the ANTS system has been to provide enough detail in the system so it can be used for skills development whist avoiding producing a long and unwieldy tool that cannot be used by practitioners. Furthermore, because of the inevitable overlap between non-technical skills, (e.g. where does the boundary lie between situation awareness and decision making), and the requirement to focus on observable behaviour, a fairly pragmatic approach was needed when designing the system. The main requirements for the ANTS system were that it should describe the non-technical skills needed for anaesthetic practice in such a way that would be meaningful to anaesthetists and easy to use (i.e. it was not designed for psychologists). Moreover, these skills must be observable in normal practice (routine or otherwise). For these reasons, the ANTS system does not contain all possible non-technical skills required for high performance and which should be covered in training. For example, a category relating to 'stress management' was omitted because associated elements such as maintaining control of emotions could not be easily and objectively detected through observation. For the cognitive skills in situation awareness and decision making, it is not possible to directly observe an individual's cognition but in a team situation their behaviour and communication with others should indicate that certain cognitions have taken place. The reliance of the ANTS system on communication to detect the skill elements means that the ANTS system does not contain 'communication' as a separate category or element level. Thus communication is not excluded because it is considered unimportant in anaesthetists' tasks but rather because it is so important for good practice that it is integral to each of the four skill categories. A similar design philosophy had been found to be effective and acceptable with the aviation behavioural marker system NOTECHS (Avermaete and Kruijsen 1998; Flin et al. 2003c).

Therefore, items in the ANTS system were included on the basis of their importance to anaesthetic practice in that their presence was associated with good outcomes and their absence can endanger patient safety. The grouping of related elements into categories makes their relationships clearer and makes using the system easier (Seamster and Edens 1993). The rationale for grouping elements as shown was based on the interview data and the literature on non-technical skills. For example, the situation awareness elements identified from the data mapped strongly onto findings from other research into this process (Endsley 1995; Gaba et al. 1995; Muniz et al. 1998). Similarly the team working elements found in the interviews have strong links to skills identified in more

extensive research on teamwork in both military (Cannon-Bowers et al. 1995) and medical domains (Xiao and Mackenzie 1998; Xiao et al. 1996).

Clearly, it is critical that the items included in a behavioural marker system are those that relate to the construct being measured. While construct validity for a measurement tool can be inferred from method of development such that in principle its content is theoretically sound, criterion validity needs to be tested in a proper evaluation process. As demonstrated in other industries, unless the behavioural marker system is valid and reliable it can provide little value for scoring behaviour (Baker and Dismukes 2002; Klampfer et al. 2001). Furthermore, if a system is impractical and not well accepted by users, it is unlikely to become a successful tool for facilitating non-technical skills research and training in medicine. While the design process used in this study should ensure that the skills included are those needed by anaesthetists, whether these skills really can be observed in behaviour and used to differentiate performance in theatre or in the simulator needs to be investigated further. The pilot study evaluation indicated that the basic design philosophy and contents were acceptable to an anaesthetic population. These preliminary findings have now been supplemented with a video-based experimental study involving 50 consultant anaesthetists (Fletcher et al. 2003) and more practically oriented user trials data from observations in theatre, which have indicated acceptable usability (Flin et al. 2003b). Future studies of the ANTS system will test its psychometric properties and will demonstrate how it can best be used to support measurement of non-technical skills in video-based research and in-theatre observations.

4 Concluding remarks

This study adopted a 'bottom-up' approach to develop a tool to support observation-based assessment of non-technical skills in anaesthetist performance. First the skills were identified from empirical data, and then they were constructed into a behavioural marker system that reflects the roles and practices of the anaesthetists who will be using it. While this tool has limitations, primarily that it only addresses skills that can be detected through observation, its availability should help support research into anaesthetists' performance. The approach adopted for developing the ANTS system could also be used to develop similar behavioural rating systems for video-based research in other work domains both within and beyond healthcare. A similar tool is currently being designed for rating observations of surgeons' non-technical skills in the operating theatre (Flin et al. 2004).

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