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Basic concepts for crew resource management and non-technical skills

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In this paper, we explain the conceptual background to non-technical skills and show how they can influence job performance in anaesthesia. We then describe the taxonomy of anaesthetists' non-technical skills (ANTS) and related systems, such as ANTS-AP for anaesthetic practitioners. We discuss the training courses that have been designed to teach these non-technical skills, which are called crew resource management (CRM), crisis resource management (CRM) or crisis avoidance resource management (CARMA). Finally, we discuss the application of non-technical skills assessment systems.

Introduction

Notwithstanding clinical and technical advances in anaesthesia, there are still risks for patients. One notable example is the English case of Mrs Elaine Bromiley, a 37-year-old mother of two young children, who died in April 2005 as a result of a problem in maintaining her airway during elective endoscopic sinus surgery, in a private clinic. Analyses in industry have indicated that human error can

Abbreviations: ANTS, Anaesthetists' non-technical skills; ANTS-AP, Anaesthetic Non-Technical Skills for Anaesthetic Practitioners; NOTECHS, Non-Technical Skills (for airline pilots); NOTSS, Non-Technical Skills for Surgeons; SPLINTS, Scrub Practitioners' List of Intra-operative Non-Technical Skills.

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be a significant component of accident causation [1], and sometimes a key component is a deficiency in the non-technical skill (NTS) of operational staff. What is relevant about Elaine Bromiley's case is what occurred in the UK as a result of her death. Martin Bromiley, who was her husband, is an airline pilot. In his world of aviation, accidents are taken very seriously and that means they are carefully and systematically investigated by experts to discover not only the technical but also the non-technical causes. He assumed that his wife's unexpected and tragic death would be subjected to this level of scrutiny but he was told unless he pursued a legal case, that would not normally occur. He managed to instigate an independent inquiry by a senior anaesthetist, which revealed a number of deficiencies in NTS during the accident trajectory [2]. He then asked if there was a national clinical human factors group that can advise health-care organisations on the latest developments for NTS training and other human factors interventions. However, in the world of health care, no such group existed. Moreover, very little training in human factors or NTS was provided to health-care staff, unlike the other safety-critical industries.

Therefore, Martin Bromiley set about addressing these deficiencies, by establishing in 2007 the first Clinical Human Factors Group for clinicians and human factors specialists (www.chfg.org). His efforts are now leading to an enhanced awareness of the importance of the role of human factors in health care and patient safety. Human factors science essentially studies the variables that can influence human behaviour in relation to task execution. In a work context, this means the environmental, organisational and job factors, as well as the physiological and psychological characteristics that influence behaviour at work. The largest of the professional organisations is the Human Factors and Ergonomics Society, based in the USA (www.hfes.org), and its members come from various disciplines, such as ergonomics, psychology and engineering, and it hosts specialist meetings on health care. There are similar organisations in other countries.

There are many important applications of human factors science in anaesthesia [3]. One important relevant area concerns the behaviour of anaesthetists in relation to their NTS. In this paper, we explain the conceptual background to non-technical skills and show how they can influence job performance in anaesthesia. We describe the taxonomy of anaesthetists' non-technical skills (ANTS) and ANTS-AP for anaesthetic practitioners, as well as the training courses that have been designed to teach these skills. This type of course can be labelled crew resource management (CRM), crisis resource management (CRM) or crisis avoidance resource management (CARMA). Finally, we discuss the development and application of NTS assessment systems.

Non-technical skills

The term ‘non-technical skills’ was first used by the European civil aviation regulator in relation to airline pilots' behaviour on the flight deck. NTS can be defined as “the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance” (p. 1) [4]. In essence, they enhance workers' technical skills. Poor NTS can increase the chance of error, which in turn can increase the chance of an adverse event. Good NTS (e.g., high vigilance, clear communication and team coordination) can reduce the likelihood of error and consequently of accidents. Analysis of incidents, as well as studies of behaviour during routine work (task analysis), can reveal which workplace behaviours positively or negatively influence job performance and adverse events. A recent study of difficult airway management cases showed how a human factors interview protocol can help to extract additional information from anaesthetists who have experienced these cases [5]. The findings underline the importance of situation awareness, as well as some of the social factors that can impede effective performance. This type of knowledge can help to inform the design of NTS training and competence assessment systems.

Airline pilots, human factors, CRM and NTS

The aviation industry had realised by 1980, from a series of accidents with no primary technical failure, that maintaining high standards of safety was going to require attention to the pilots' NTS and their relation to safe and unsafe behaviours during flight operations [6]. Experienced pilots were interviewed to discover which behaviours constituted ‘good airmanship’. The aviation psychologists

conducted experiments in flight deck simulators and reanalysed accident reports, in order to determine which skill components either contributed to accidents or were effective in preventing adverse events. Having identified these skills, crew resource management (CRM) training courses were designed for pilots to increase understanding of the importance of particular behaviours for safety and to provide opportunities to practise the skills in exercises and simulated flights. In 1989, a *British Midland* plane crashed at Kegworth after the pilots mistakenly shut off the working engine when the other was on fire. This was such a strong demonstration that human error and teamwork failures were contributing to fatal accidents that the UK Civil Aviation Authority took the view that CRM had to be introduced, even though at the time there were only a few scientific studies on its effectiveness. By the 1990s, CRM training for pilots had been widely introduced in aviation, driven by national regulators and the influence of the International Civil Aviation Organisation.

In aviation, pilots are taught and examined in the psychological and physiological factors influencing task performance from the start of their training (human performance limitations courses). They then undertake crew resource management training provided by their employing airline on a regular basis. Consequently, they are very familiar with the cognitive and social skills required for safe and efficient flight operations, as well as how these skills can be influenced by stress and fatigue.

It was not only in aviation where cognitive and social skills were found to contribute to workplace safety; studies of accidents in many other sectors of industry began to reveal the same patterns [4]. Today, CRM (i.e., NTS) training is now widely used for different occupations as a form of safety management and skills development, as a recent report by the Energy Institute (2014) describes [7]. Ab initio courses in medical schools are beginning to introduce the concept of NTS and explain their importance for patient safety. At a number of Scottish medical schools, there are now psychologists employed to lecture on human factors and patient safety and these topics are being embedded throughout the 5-year curriculum [8].

The main categories of NTS are as follows:

- Situation awareness
- Decision-making
- Teamwork
- Leadership
- Coping with stress
- Managing fatigue

These skills are not unfamiliar to anaesthetists but they have not traditionally been taught as part of clinical training. An increasing body of evidence suggests that they are required by anaesthetists to maintain safe performance [9]. Human error cannot be eliminated, but efforts can be made to minimise, catch and mitigate errors by ensuring that people have appropriate NTS to cope with the risks and demands of their work. In the next section, the main categories of NTS and their application to anaesthesia are briefly described.

Categories of NTS for anaesthetists

Situation awareness

Situation awareness is essentially a continuous monitoring of the task, noticing what is going on and detecting any changes in the environment. Almost all aspects of the anaesthetists' intraoperative tasks rely heavily on their vigilance and situation awareness skills. The critical role of situation awareness for anaesthetists has recently been reviewed with implications examined for practice, training, measurement and equipment design [10]. Fioratou et al. [11] pointed out that the anaesthetist needs to distribute their attention across many sources of information and that situation awareness is also shared within the team. This cognitive skill is primarily about gathering and processing information from the anaesthetic work environment and using stored memories and mental models to make sense of it. Research studies have indicated how interruptions and

distractions, both of which are common in operating theatres [12], can disrupt situation awareness [13] and can present risks for prospective memory, that is, remembering to do things in future (e.g., re-administer a drug in 10 min) [14].

Decision-making

Decision-making during work tasks, sometimes called dynamic decision-making, is a cognitive process for reaching a judgement, selecting an option and choosing which action to take to meet the needs of a given situation. In anaesthesia, there is a continuous cycle of monitoring and re-evaluating the task environment, and then taking the appropriate action. Decision-making usually involves more than one method, depending on circumstances. The main types of decision-making are recognition primed (a pattern recognition/intuitive process), rule based, analytical (i.e., comparing optional courses of action) and creative. Conditions for decision-making can vary in relation to time pressure, task demands, feasibility of options and what level of constraint, support and resource exists for the decision-maker. There is surprisingly limited literature on the decision-making skills of anaesthetists, with some notable exceptions [15] given the importance of cognition for safe anaesthesia. There is now a growing literature for on-task decision-making in emergency medicine, especially by Croskerry [16], and also for surgeons' intraoperative decision-making [17].

Teamwork

There is no shortage of evidence that teamwork in operating theatres is very important and that this has a major impact on patient safety. The team skills relate to effective communication, task coordination, supporting other team members, negotiating and resolving conflicts. A recent review of what can improve teamwork in the operating theatre by Weller and Boyd [18] identified three main types of intervention that have been shown to be effective. These were structured methods of sharing information within the team (e.g., checklists), team training and organisational adjustments. Anaesthetists can play a significant role in the maintenance of team harmony and performance using both verbal and non-verbal communication. This is an area where there have been a number of research studies into coordination and communication in anaesthesia crews [19], as well as into specific situations such as handovers by anaesthetists to recovery rooms [20] or in anaesthetic emergencies [21].

Leadership

While there is an emerging literature on the intraoperative leadership role of surgeons and how this impacts on task performance in the operating theatre [22], there has been less research on the specific leadership role of the anaesthetist during surgery, although it is clear that they can perform critical leadership tasks, not only in emergencies but also during routine operating conditions. In fact, there can be ambiguity about who should take the leadership role in a theatre team between the senior anaesthetist, the senior surgeon and the senior nurse. This can result in multiple leaders or other equally hazardous situations where apparently no one is fully in charge. While some surgeons assume they have the leadership role, in fact, task leadership is partly about monitoring, managing and supporting the team, so this may be difficult for surgeons when they have total visual focus on the surgical site. In the ANTS system, leadership behaviours for anaesthetists are contained within the element of teamwork. Reader et al. [23] examined leadership in the intensive care unit and found more emphasis on functional behaviours than on behaviours concerned with developing the teams.

Coping with stress

There are two types of work stress and both have implications for worker and patient safety [24]. Occupational or chronic stress relates to ongoing conditions and pressures from the job, co-workers, bosses and the organisation. This type of stress has been extensively studied in a whole range of occupations and is certainly experienced by anaesthetists. In almost all organisations, workers need to

have skills to recognise the causes and effects of occupational stress and to have techniques for dealing with these, as well as knowing what sources of support are available from their employer. In non-technical (CRM) skills training courses, the focus tends to be more on the second type of stress, namely acute stress, which is experienced by workers who have to deal with very high-demand situations, such as emergencies. This is particularly relevant to anaesthetists because of the risks of the patient becoming critically ill, as the case of Elaine Bromiley demonstrated.

Managing fatigue

Anaesthetists need to be able to cope with working at night, working shifts and concentrating for long periods of time with no rest breaks. Fatigue is common in these types of work settings and it is well known to be a pervasive contributing factor to industrial accidents. Hence, the skills for managing fatigue are also required by anaesthetists [25]. The Association of Anaesthetists of Great Britain & Ireland recently published an updated edition of its guidelines, 'Fatigue and Anaesthetists' [26]. It describes current issues relating to fatigue and provides recommendations relating to rest facilities, the management of on-call work (with particular emphasis on the older anaesthetist) and education on fatigue. A key aspect of fatigue management is recognising when one is fatigued, understanding how this impacts cognitive skills such as decision-making and adapting behaviour accordingly. When intercontinental pilots are fatigued after a long flight, they adapt their team coordination behaviours such as using more read-back and checking and taking decisions more systematically [27].

Identifying ANTS

The specific NTS required for a particular occupation need to be determined by a systematic process of identification based on task analysis. While the main skill categories (e.g., decision-making or leadership) are similar across professions, the component elements and examples of good and poor behaviours need to be carefully specified for a given profession and task set. These can be distinctive and clearly vary from one technical setting to another. This is why it is inadvisable to use an NTS set devised for one domain (e.g., aviation) in a different work setting (e.g., health care). In essence, a two-stage process should be employed: first, to identify the skills and related behaviours deemed to influence safe and efficient performance, and, second, to refine the resulting list and to organise it into a concise, hierarchical structure or taxonomy. This skill set can then form the basis not only of NTS training but also of related assessment systems. Gaba and colleagues [28] used a behaviour rating tool as part of their assessments of anaesthetists' performance in crisis management simulations. In Scotland, a research project was started in 1998 to identify anaesthetists' NTS for routine activities, as well as in more challenging situations. The aim was to design a method of rating these skills from observations of behaviour in the anaesthetic room or operating theatre: The resulting ANTS system [29] is shown in Fig. 1.

The ANTS system was developed using a similar design and evaluation process as was used to produce a NTS rating tool (NOTECHS, Non-Technical Skills (for airline pilots)) for European airline pilots [30]. The skill set was derived from data on anaesthetists' behaviour gathered from a literature review, observations, interviews, surveys and incident analysis [10,31,32]. The ANTS rating tool was formulated to meet a set of design criteria, similar to those of NOTECHS, such as suitability for practical use in the operating theatre or a simulation setting. (For detailed reports and papers, see www.abdn.ac.uk/iprc/ants.).

As shown in Fig. 1, the ANTS skills framework has four categories: situation awareness, decision-making, task management and team working, with component elements and examples of good and poor behaviour for each element. Managing stress and coping with fatigue were not included as explicit categories in ANTS, due to the difficulty of judging these states, which can be concealed unless extreme; moreover, they influence other behaviours that can be rated. However, the skills to cope with fatigue and stress should be covered in a CRM/NTS course for anaesthetists. Leadership was not set as a separate category but incorporated into team working, because there are times where the anaesthetist may lead the theatre team.

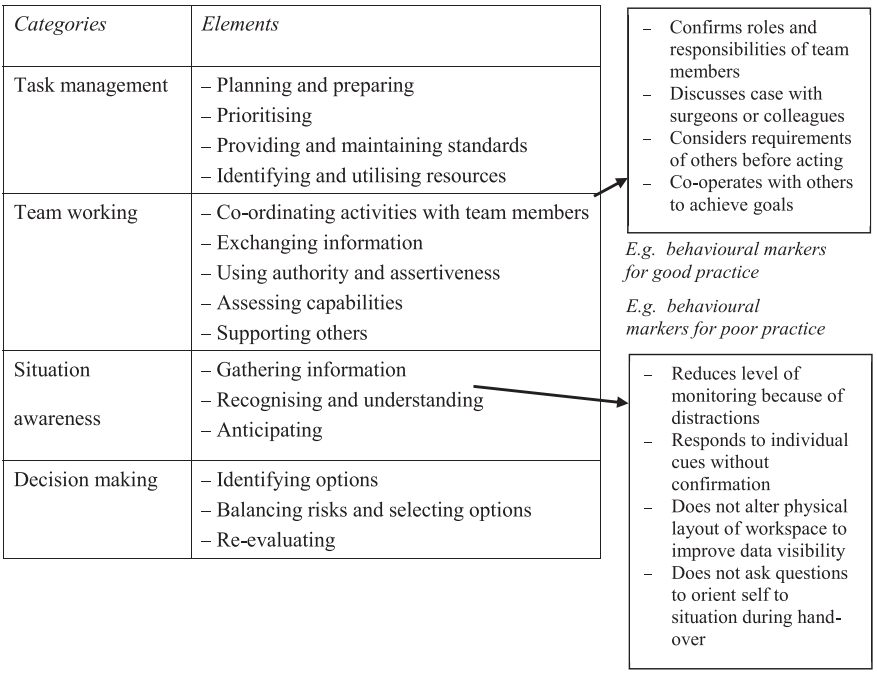

Fig. 1. Anaesthetists' non-technical skills (ANTS).

Designing anaesthetic NTS rating tools

Anaesthetists' non-technical skills

Having identified the basic set of NTS for the practice of safe delivery of anaesthesia (ANTS) and having structured these into a taxonomy, the next stage was to design and test a behavioural rating tool. A four-point scale for ANTS was devised for rating observed behaviours with regard to the elements and categories. The descriptors on the rating scale not only reflect performance levels but also emphasise their relevance for patient safety. The ANTS ratings can be made where anaesthesia is delivered, normally, in the operating room, or the anaesthetic room (or in simulator facilities). The tool was designed to be used by experienced anaesthetists to rate the NTS of another anaesthetist who has achieved basic technical competence.

The first evaluation of the ANTS behaviour-rating method was undertaken with 50 consultant anaesthetists who were given 4 h of training on the system and subsequently rated the NTS of consultant anaesthetists in eight videotaped scenarios. While the amount of training was minimal, the levels of rater accuracy were acceptable and inter-rater reliability approached an acceptable level [29]. The raters had experience in giving feedback on technical skills, but they had no previous experience of behaviour rating and they were given only introductory training in the ANTS system. Therefore, given their limited familiarity and practice with the system, it was concluded that these findings were sufficient to move on to usability trials. The first measures of usability and acceptability from consultants and trainees were promising [32], and so the system was released in 2004 and made available free of charge via the website to anaesthetists for non-commercial use. From the requests we receive for copies and an emerging set of publications, it is apparent that there are anaesthetists in many countries now using or considering use of the ANTS tool. The system has been translated into several languages, including German and Hebrew, and it has been used to evaluate simulator training for anaesthetists in Canada [33] and in Denmark [34]. It is also being used in African countries, such as Rwanda [35].

Tools for anaesthetic practitioners and nurse anaesthetists

Recently, a new tool, Anaesthetic Non-Technical Skills for Anaesthetic Practitioners (ANTS-AP), was developed by John Rutherford, a consultant anaesthetist in Scotland, for the assessment of the anaesthetic nurses and operating department practitioners (ODPs), who assist the anaesthetist. This group of practitioners plays an invaluable role in the safe delivery of anaesthesia. While there was no doubt that they too require cognitive and social skills for safe and effective practice, there is very limited literature on this topic [36]. The ANTS-AP taxonomy and behavioural rating system was designed using the available literature [36], interviews with anaesthetic practitioners (and also with consultant and trainee anaesthetists) [37] and an analysis of an anaesthetic event database. The extracted skills were developed into a structured taxonomy by the research team and a group of experienced anaesthetic practitioners. The prototype rating system was evaluated using video footage recorded in a simulation centre, with 48 anaesthetic practitioners who rated the scenarios using the new tool [38]. This was the design method used previously for ANTS, Non-Technical Skills for Surgeons (NOTSS) for surgeons [39] and Scrub Practitioners' List of Intra-operative Non-Technical Skills (SPLINTS) for scrub practitioners [40]. As shown in Table 1, ANTS-AP has three categories and nine elements with associated behavioural markers for good and poor performance. Further details of ANTS-AP can be found on the website www.abdn.ac.uk/iprc/ants-ap.

Table 1
ANTS-AP system (Rutherford under review) [38].

Category	Element
Situation awareness	Gathering information
	Recognising and understanding
	Anticipating
Teamwork and communication	Coordinating
	Supporting
	Asserting
Task management	Planning and preparing
	Prioritising and problem solving
	Coping with pressure

A similar NTS behavioural rating system has recently been developed in Denmark for nurse anaesthetists by Lyk-Jensen and colleagues [41].

Training ANTS

Anaesthesia has been at the forefront of developments to train NTS in medicine with Gaba and colleagues designing the first anaesthesia crisis resource management (ACRM) courses based on aviation crew resource management [42]; see Lighthall for recent review [43]. In addition to introducing basic theories of human performance limitation, the original course focused on some 'key principles' including the following:

- Anticipate and plan
- Demonstrate leadership
- Utilise all available resources
- Use cognitive aids
- Distribute work appropriately
- Use all available information
- Re-evaluate regularly

There is now considerable interest in adapting CRM training for health-care practitioners [44,45], and there are now a range of NTS courses available, many of which are developed in collaboration with former airline pilots with experience of CRM training. It is evident that courses are sometimes imported from aviation or other industries without adequate training needs analysis or customisation.

Course design should optimally be tailored to pre-training needs analysis, although this is not always carried out [46]. Courses that focus on behavioural aspects of performance should allow the learner to reflect on their own behaviours and simulation offers a safe and realistic environment in which to achieve this. Weller et al. [47] recently showed that the communication patterns of anaesthesia teams in the simulator are similar to those in real cases. The use of video allows learners to reflect on the strengths and weaknesses of their own performance, and the use of effective debriefing helps learners to identify performance gaps and agree on a learning plan to address such deficiencies. Creating the opportunity for practice with further feedback and regular rehearsal thereafter allows learners to develop and maintain skills. Such regular and recurrent training is provided in the environment of civil and military aviation; unfortunately, this is still not common in health care.

The use of simulation in training is now increasing, particularly in a number of acute specialities, including anaesthesia. It is no longer considered acceptable to carry out practical procedures on patients without first developing those skills in a simulated environment and therefore the focus of simulation training is often on development of practical skills or rehearsal of management of uncommon but serious conditions such as malignant hyperpyrexia or anaphylaxis.

It is widely accepted that good scenario design should tailor each scenario to address two to three key learning objectives. These are often focussed on technical aspects of performance; however, scenarios designed to address behavioural aspects of performance should similarly be designed to address key behavioural skills. An event-based approach to training (EBAT) and measurement has been described for training and assessing teamwork skills in emergency medicine residents [48]. A similar technique has been applied to the development of a simulation-based course addressing NTS for anaesthetists (CARMA). The underpinning theory and concepts of cognitive (situation awareness and decision-making) and social (task management and team working) skills is first introduced using a formal presentation and small group exercises. Following this, participants undertake scenarios of varying length, which are designed to address key categories or elements within the framework. Scenarios are designed to highlight particular NTS categories. An example of a scenario addressing cognitive skills is illustrated in Box 1.

Box 1
Cognitive skills scenario.

The surgeon (played by confederate) causes damage to the aorta during laparoscopic procedure but is unable to see free blood in the peritoneum on laparoscopy as blood loss is contained in the retroperitoneal space. The patient displays clear physiological signs of hypovolaemia (falling BP and $ETCO_2$, increasing heart rate on monitor and increased capillary refill time). The anaesthetist must establish SA through information gathering, recognition and understanding and anticipation, and use appropriate authority and assertiveness to convey concern to the surgeon and develop a shared understanding of the possible diagnosis. This emphasises the importance of systematic information gathering and asking open questions to avoid fixation; thinking aloud' helps to share one's mental model with other members of the team and to consider alternative diagnoses.

Debriefing of scenarios is carried out using ANTS as a framework for discussion. This allows participants to identify effective and less effective behaviours at the element level within the scenario. Video replay is an essential component to allow participants to reflect on the effectiveness of their actions. At the conclusion of debriefing, each participant will have clearly identified what they consider to be effective behaviours, which they might try to test or develop during further scenarios. Participation in further scenarios allows comparison of effectiveness of different skills across varying 'clinical' contexts and allows individuals to develop and rehearse skills throughout the course. Participants will also develop familiarity with the ANTS taxonomy while watching performances of fellow participants and making behavioural observations using the framework. At the conclusion of the course, each participant will have developed insight into their personal strengths and weaknesses in NTS and have

produced a clear personal development plan of behaviours they wish to develop. The course is positively evaluated and participant follow-up indicates that most will continue to utilise the ANTS taxonomy for personal reflection and development; however, this has not been formally tested in Scotland.

Yee and colleagues [33] were able to demonstrate an improvement in NTS in anaesthetic trainees on repeat exposure to the simulator after they had been debriefed with feedback using the ANTS framework following their first exposure to the simulator. ANTS has been utilised in a number of other simulation studies, for example, Bruppacher et al. [49] who used ANTS to evaluate performance before and after training for weaning from cardiopulmonary bypass. Marshall and Mehra [50] recently reported an experimental study with a sample of 64 experienced clinicians (mainly anaesthetists), who were divided into a control group and an intervention group (who had a cognitive aid present). They were presented with a simulated 'can't intubate, can't oxygenate' crisis. Observers (blinded to the group) analysed each participant's NTS using the ANTS rating system as well as technical performance. The results showed that there was no difference in technical scores but the group with the cognitive aid showed higher ANTS scores.

Whilst simulation clearly provides the optimal environment in which to develop an understanding of the effect of behavioural aspects of practice, it is through use in the clinical environment that non-technical behavioural marker systems are most likely to gain widespread acceptance. Early attempts to introduce ANTS into clinical practice proved challenging – not least because the concepts and terminology around cognitive skills (situation awareness and decision-making) in particular were unfamiliar to trainers and trainees alike [51]. However, a decade on from the development of ANTS, these concepts are more readily accepted. As colleges and universities begin to integrate the World Health Organization patient safety curriculum into undergraduate training [52], junior health-care professionals are likely to enter the clinical environment with a greater awareness of these concepts and need to develop these skills for safe practice. The promotion of patient safety as a priority, and endorsement of safety-related skills and training by professional bodies such as colleges and speciality associations, is vital to encouraging established health-care practitioners to engage with training and development. The widespread sharing of patient stories, such as that of the death of Elaine Bromiley due to failure of effective airway management [2], has highlighted the importance of NTS in safe anaesthetic practice and encouraged most anaesthetists to be more conversant with the key concepts of situation awareness, decision-making and team working.

Both the Royal College of Anaesthetists (RCoA) and The Royal College of Surgeons of Edinburgh (RCSEd) now run regular courses to equip professionals with the skills required to observe, rate and give feedback on NTS in the clinical environment using the ANTS and NOTSS tools. The Royal Australasian College of Surgeons incorporated NOTSS into its professional framework and also runs NTS training courses. Both courses use a similar methodology introducing psychological concepts through lectures and group sessions, followed by use of scripted videos to allow participants to observe and classify behaviours at the category and element levels. These courses are most commonly attended by educational facilitators who, in turn, are then equipped to utilise the framework to provide feedback to trainees in clinical practice. The first modules on NTS for surgical residents in the USA were released on November 2014 as part of the national curriculum for general surgery, implemented by the Surgical Council on Resident Education (SCORE, www.score.org). These are on cognitive skills (situation awareness, decision-making) and social skills (communication and teamwork, leadership) [53].

Assessing anaesthetists' NTS with ANTS

With regard to assessment, ANTS has been used in practice in hospital anaesthetic departments, as well as in simulation centres, which is typically for formative purposes [51]. Rall and Gaba [54, p3088] considered the ANTS system and concluded, "On the whole, the ANTS system appears to be a useful tool to further enhance assessment of nontechnical skills in anaesthesia, and its careful derivation from a current system of nontechnical assessment in aviation (NOTECHS) may allow for some interdomain comparisons." They also outlined some of the general issues inherent in both technical and non-technical performance assessment, including criterion thresholds, rating fluctuating performance and inter-rater reliability.

Both ANTS and NOTSS taxonomies were designed to make observations as objective and the rating methods as straightforward as possible to use. However, this apparent simplicity belies the challenge of observing multiple different behaviours, which will commonly vary in effectiveness over time. In contrast to making observations of technical skills (DOPS – direct observation of practical skills) or discussions to probe understanding of a case (case-based discussion), where 'acceptable' standards are agreed, the observation of behavioural skills may feel less definitive.

Graham et al. [55] carried out an evaluation study where a cohort of anaesthetists in Australia were given a short training session on using ANTS in the morning following which they rated five videotapes each of anaesthetists in the operating theatre. The participants were positive about the content validity, and the internal reliability (Cronbach's alpha) scores at the category level were acceptable; however, they found low inter-rater reliability at the element level. This was unsurprising given the short period of familiarisation with the system. In aviation, both trainers and examiners of pilots' NTS require to be specially trained and formally qualified for these tasks, as recent guidelines from the UK Civil Aviation Authority show [56]. For those beginning to use behavioural markers systems for the first time, an expert group (led by the late Professor Helmreich) recommended a minimum of two full days of training – that is, four times as long as in the above evaluation study (see Ref. [4] for details).

ANTS has now been incorporated into training curricula for anaesthesia in the UK [57] and across Europe [58]. Elements of the taxonomy have been incorporated into workplace-based assessment instruments in the UK. Gale and colleagues have used elements of the ANTS taxonomy to rate NTS in trainees for selection into anaesthesia and demonstrated good predictive validity [59].

As the focus on revalidation and relicensing in the UK grows, it seems likely that assessment of NTS will feature, particularly in doctors identified as having difficulties in clinical practice through other means.

Practical application of ANTS

Training in identification and use of NTS behavioural marker systems is key to effective utilisation. Regular use, training and calibration are necessary to ensure high inter-rater reliability where the tool might be used for summative assessment. However, the introduction of NTS rating systems in clinical practice may be assisted by concentrating on an individual category (such as situation awareness or task management) for the duration of a case. Alternatively, breaking the task down into phases (such as induction of anaesthesia) allows the trainer to focus attention on the importance of NTS during one discrete part of the anaesthetic (see Fig. 2).

Gathering information	• Engages fully with 'time out' • Systematically gathers information from monitors prior to allowing skin incision • Awareness of what other members of the team are doing, and stage of preparation e.g. hearing scrub nurse counting • Scans monitor and anaesthetic machine and theatre (equipment, surgeons and theatre staff) • Increases vigilance/monitoring during knife to skin

Fig. 2. Preparation for start of surgery – information gathering.

Asking new learners to list the behaviours used at different phases of the anaesthetic (for example, prior to extubation) under each of the elements can be a useful way of introducing the framework and encouraging observation of skills and effective behaviours. This technique is used with all novice anaesthetic trainees in one Scottish hospital. Trainees should then be encouraged to use these same

skills during low-fidelity simulation training (skills for drills). Asking trainees to observe the effective (and indeed ineffective) behaviours of supervisors using the framework may also be a non-threatening way in which to allow trainees to become familiar with the taxonomy but also to recognise and describe effective skills which they may want to emulate.

Summary/future developments

NTS are the cognitive and social skills set that support the application of knowledge and practical skills to safe anaesthetic practice. These skills are not new and are observable in expert practitioners; however, until recently, such skills were not explicitly described or discussed. Investigation of adverse events often highlights the important part played by failures in NTS of individuals and within teams.

Over the last decade, the explicit description of NTS through taxonomies such as ANTS, NOTSS, SPLINTS and ANTS-AP have allowed identification of skills at the individual level within the operating theatre. Increasingly, these skills are being incorporated into curricula for postgraduate training in anaesthesia and surgery. Feedback in the simulator environment allows learners to reflect on their own practice and understand their strengths and weaknesses. Continued, regular feedback and reinforcement in clinical practice should allow learners to further develop effective skills. Although such systems appear easy to use, achievement of good inter-rater reliability requires considerable rater training and calibration [60] and important lessons in this regard can still be learnt from the airline industry.

Incorporation of human factors and NTS teaching from the earliest phases of undergraduate training makes it likely that, over the next decade, we will see a generation for whom the theoretical concepts and behaviours are a fundamental part of the skills set of a new doctor and therefore that NTS will be an integral part of postgraduate speciality selection, training and assessment.

Practice points

- Behavioural marker systems such as ANTS allow objective observation of nontechnical skills to be used for feedback in simulated or clinical environments.
- Where simulation is used for non-technical skills training, scenario learning objectives should be designed to address specific non-technical skills.
- Applying the ANTS taxonomy to discrete phases of the anaesthetic, such as induction, improves usability in the early stages of implementation.
- Although deceptively simple in appearance, rating non-technical skills is prone to greater variation than assessment of knowledge or practical skills.
- Rating of non-technical skills for the purposes of assessment requires rater training in order to improve inter-rater reliability.
- The importance of non-technical skills is acknowledged by recent incorporation into undergraduate medical and postgraduate speciality curricula.

Research

- Time-effective techniques for rater training and calibration.
- Analysis of anaesthetic team performance using both ANTS and ANTS-AP.
- Low-fidelity simulation methods for enhancing non-technical skills.
- Optimum methods to integrate non-technical skills training into undergraduate curricula.

Conflict of interest

The authors have no conflicts of interest to declare.

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