Anaesthesiology students’ Non-Technical skills: development and evaluation of a behavioural marker system for students (AS-NTS)

Parisa Moll-Khosrawi1*, Anne Kamphausen1, Wolfgang Hampe2, Leonie Schulte-Uentrop1, Stefan Zimmermann2† and Jens Christian Kubitz1†

Abstract
Background: Non-Technical Skills (NTS) are becoming more important in medical education. A lack of NTS was identified as a major reason for unsafe patient care, favouring adverse events and team breakdown. Therefore, the training of NTS should already be implemented in undergraduate teaching. The goal of our study was to develop and validate the Anaesthesiology Students’ Non-Technical Skills (AS-NTS) as a feasible rating tool to assess students’ NTS in emergency and anaesthesiology education.

Methods: The development of AS-NTS was empirically grounded in expert- and focus groups, field observations and data from NTS in medical fields. Validation, reliability and usability testing was conducted in 98 simulation scenarios, during emergency and anaesthesiology training sessions.

Results: AS-NTS showed an excellent interrater reliability (mean 0.89), achieved excellent content validity indexes (at least 0.8) and was rated as feasible and applicable by educators. Additionally, we could rule out the influence of the raters’ anaesthesiology and emergency training and experience in education on the application of the rating tool.

Conclusions: AS-NTS provides a structured approach to the assessment of NTS in undergraduates, providing accurate feedback. The findings of usability, validity and reliability indicate that AS-NTS can be used by anaesthesiologists in different year of postgraduate training, even with little experience in medical education.

Keywords: Non-technical skills, Simulation, Education

Background
In patient care, both Technical Skills (TS) and Non-Technical Skills (NTS) are necessary to maintain best practice as well as reach a high level of expertise [1]. TS are routinely taught in trainee programs. However, evaluation and assessment of NTS have been missing for a long time [2, 3]. NTS are defined as “the cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance” [4].

Adverse events in high-risk settings often take place due to deficiencies in NTS [5], which has been shown in various fields such as aviation and nuclear energy [6–8] and has also been confirmed for medical care: up to 70% of adverse events are due to human errors [9–11]. In order to reduce medical errors, good NTS and improved teamwork are essential [12].

NTS interventions and mostly feedback on NTS have shown to have positive effects on team performance, concluding that good patient care requires TS and NTS, which have been found to correlate in crew resource
management [13, 14] and to foster improved clinical performance like quicker problem solving in simulated operating theatre environment [15]. The positive effects of NTS also encompass enhanced patient safety. Salas et al. showed in a meta-analysis the positive effects of NTS on team members’ reactions and attitudes related to teamwork safety [16]. Other studies pointed out positive effects of NTS on clinical performance (TS) and on patient outcome like surgical complications and morbidity [17].

Knowledge of necessity and benefits of NTS lead many institutions to emphasize the importance of interpersonal skills [13, 16–21] and these departments implemented crew-resource training programs in their curricula, primarily focusing on NTS during postgraduate training [22].

The training of NTS should not only be focused in postgraduate training - undergraduate curricula and education should already integrate the concept of “patient safety”, directly addressing, teaching and assessing NTS [23, 24]. Only a few studies have investigated the effect of teaching NTS in undergraduates. Hagemann et al. showed that even one brief seminar had positive effects on undergraduates’ NTS [21].

The German Association for Medical Education has acknowledged the repeatedly expressed need of NTS implementation in undergraduate education by publishing a “Learning Objective Catalogue for Patient Safety in Undergraduate Medical Education”, which has the aim to unify the curricular targets in German medical faculties [25]. However, a concrete curriculum, implementation or teaching strategy for NTS in undergraduate education is not given yet. In addition, due to a missing conventional rating tool a structured assessment of NTS in undergraduates is often lacking.

To create and realize an implementation and teaching strategy for NTS in undergraduates, at first the structured assessment of NTS with a robust method is necessary [4], in order to provide specific and formative feedback and to monitor the learning progress in undergraduates.

Several rating tools for assessing NTS in medical professionals are available. They are helpful to provide feedback which is not based on “gut feeling” and to speak “the same language” during the feedback process [26–31]. However, the existing rating tools, such as the Anaesthetists’ Non-Technical Skills (ANTS) [32], are very complex and not designed for undergraduates or junior residents, as ANTS is developed for experienced anaesthesiologists to rate trainees who have reached certain TS, which limits its broad application in undergraduate education. A feasible application is further limited as for raters a two-day training with the rating scheme is required. The use of ANTS delays the feedback loop, as the NTS ratings are based on video clips of the training sessions, which are evaluated after the training [5].

The goal of this study was to develop a rating tool to assess NTS in undergraduate education in emergency medicine and anaesthesiology: Anaesthesiology Students’ Non-Technical Skills (AS-NTS). The tool is supposed to be feasible and easily handled without the necessity for video recording or extended instructions and trainings for the user.

### Methods

#### Study design

This study was performed at the Department of Anaesthesiology in the University Medical Center Hamburg-Eppendorf, Germany. The study was conducted in the period of January 2017 to December 2017. Undergraduates and residents in anaesthesiology participated in this study with a stepwise design in order to develop and validate a rating tool for NTS in undergraduates in anaesthesiology. The development took place in four steps (Table 1), empirically grounded on qualitative and quantitative research methods:

1. Review of published literature (expert group)
2. Focus group and half-structured interviews
3. Field observation
4. Implementation and validation

Table 1 shows a scheme of the conducted developmental steps and underlying research methods.

A detailed explanation of the development is given in the Additional file 1.

#### Study setting: assessment of NTS during emergency and anaesthesiology training sessions

The undergraduate curriculum of the Medical Faculty of Hamburg has implemented emergency training sessions in nearly every semester, in order to experience the students in emergency medicine. We use high fidelity simulators (Rescue Anne Laerdal) which are suitable for training technical skills such as endotracheal intubation, defibrillation or drug administration.

NTS were assessed in four different training sessions (Advanced cardiac life support I, II, III and operation room simulation) of four different semesters. In each training session a pre-existing set of standardized simulation scenarios were used (13 in total, a detailed description of the simulation scenarios is provided in the Additional file 1).

The simulation scenarios are standardised and solely for each type of training session. For example, the training session “Advanced cardiac life support II (ACLS II)”, which is held in the 3rd year of undergraduate education, includes the scenarios: “Hyperkalaemia”, “Hypothermia” and “Aspiration”.

In each training session every student is assigned to a small group which rotates through each simulation scenario.
With each following semester, the simulation scenarios require more advanced TS and NTS. In order to rule out that low NTS skills are due to technical skills not proceduralized we decided to test our rating system in students who had already passed the basic life support training in following training sessions:

- **Advanced cardiac life support I** (ACLS I: 2nd or 3rd year undergraduates, pre-existing simulation scenarios: 2; number of rated simulation scenarios for interrater agreement analysis: 20)
- **Advanced cardiac life support II** (ACLS II: 3rd year undergraduates, pre-existing simulation scenarios: 3; number of rated simulation scenarios for interrater agreement analysis: 24)
- **Advanced cardiac life support III** (ACLS III: 4th year undergraduates, pre-existing simulation scenarios: 5; number of rated simulation scenarios for interrater agreement analysis: 23)
- **Operation room (OR) simulation** (3rd or 4th year undergraduates, pre-existing simulation scenarios: 3; number of rated simulation scenarios for interrater agreement analysis: 31)

In each training session, the undergraduates are divided into groups of three. Each of these groups rotates through the simulation scenarios of the training session. In each simulation scenario one student takes the role of the physician, the other two that of paramedics or anaesthetic co-workers. The student in the role of the physician leads the team and delegates basic tasks such as establishing the monitoring, preparing defibrillation and other required medical procedures to the other team members. Therefore, only this student was evaluated by the two or three supervising anaesthesiologists, using the AS-NTS.

### Raters and interrater reliability

Twenty-one anaesthesiologists (Table 2) conducted the training sessions during the study period. In 67 emergency simulation scenarios two of them rated the students independently, in the 31 operating room simulation scenarios...
three raters were involved. The raters who rated the same simulation scenario, did not discuss their results while rating, in order to rule out cognitive bias.

The rater teams changed frequently based on the teaching schedule. The raters all received a five-minute introduction into the AS-NTS.

The interrater-reliability was investigated using a two-step approach.

In the first step a classical analysis of interrater-reliability was conducted, analysing data from rating pairs. To rule out agreement by chance, the intraclass correlation (ICC) from six pairs of raters were calculated, which had rated at least six simulation scenarios together. The first analysis included 67 of the total of 98 simulation scenarios. In five of the six pairs the first author (R1) took part (Table 3).

In the second step of the interrater-reliability analysis, the whole data set from the 98 simulation scenarios was analysed. To rule out that either the strong involvement of R1 in the development process of AS-NTS or the medical training had an effect on the interrater reliability, data was aggregated across raters being in the same year of training. This allowed us to investigate the relationship between medical expertise and rating agreement (Table 4).

Table 3 Characteristics of the six pairs of raters

| Pairings | Sex | Age | Experience in medical education | Anaesthesiology training | Number of rated simulation scenarios |
|----------|-----|-----|---------------------------------|---------------------------|--------------------------------------|
| R1/R2    | F/M | 32/27 | High/Low                        | A/2nd year resident       | 17                                   |
| R1/R3    | F/M | 32/27 | High/Middle                     | A/3rd year resident       | 14                                   |
| R1/R4    | F/F | 32/34 | High/High                       | A/5th year resident       | 7                                    |
| R1/R5    | F/M | 32/38 | High/Middle                     | A/A                       | 8                                    |
| R1/R6    | F/F | 32/29 | High/Low                        | A/4th year resident       | 14                                   |
| R7/R8    | M/F | 31/28 | Middle/Low                      | 5th−/3rd year resident    | 7                                    |

Abbreviation: A Attending, R Rater

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics Version 23.0. Intraclass correlation (ICC) was used for ordinally scaled data and Cohens Kappa for nominally scaled data to calculate interrater reliability. We used the one-way random effects model to calculate the ICCs [34]. Values of ICC and kappa below 0.40 are interpreted as poor correlation, between 0.40 and 0.59 as fair correlation, between 0.60 and 0.74 as good correlation and between 0.75 and 1.00 as excellent correlation [35].

Results

Development of the AS-NTS assessment tool

The literature search resulted in 12 different NTS important in anaesthesiology (Table 5). The discussions in the focus- and expert group revealed, that not all of these NTS are highly important for undergraduates. During the field observations some NTS were difficult to observe. Using the results of the focus group discussions we defined new dimensions specifically for undergraduates, symbiosing some pre-defined NTS:

- Planning tasks, prioritising and conducting
- Teamwork: exchanging information and leading the team
- Team orientation

Table 5 displays the created list of the NTS and the further conducted steps which were decisive for the inclusion of each skill. The last column illustrates which NTS is part of ANTS and AS-NTS. Figure 1 displays the definition of the NTS.

The first dimension of AS-NTS: “Planning tasks, prioritizing and problem solving” resulted as a compound, mainly formed by pre-defined NTS dimensions “Decision making” and “Task management” (Fig. 2). The elements that were considered important in undergraduates and therefore created the basis to define the first dimension of AS-NTS are highlighted.

“Coordinating team members”, “communication” and “Leadership” were regarded as highly important in the focus group and performance could be observed in different levels during the field observation, therefore these elements created the basis for dimension two of ANESTHESIOLOGY STUDENTS’ NON-TECHNICAL SKILLS: “Teamwork and leadership”.

Leadership, defined as the skill of directing others, coordinating, managing workload and motivating others...
is often separated into two independent dimensions allowing for the assessment of different leadership styles distinguishing between task orientation and team orientation. In this leadership model, “Task orientation” is closely related to our first two AS-NTS dimensions, therefore we decided to add “Team orientation” as third and final dimension of the AS-NTS. “Teamwork and leadership” emphasizes the collaborative processes to build a team. In contrast to the ANTS, performance is rated on the three dimensions and not on the level of skills. However, the underlying skill structure was used to give behaviorally anchored rating examples to clarify what a “good” or “poor” performance on each dimension might look like in the final AS-NTS assessment tool (Fig. 3), a five-point Likert scale was used for each dimension, although the ANTS system has a four-point scale [32]. Cook et al. could show that, in regard to reliability and interrater reliability, there are no differences in 5- and 9- point scales in mini-clinical evaluation exercise [61].

Feasibility and content validity of the scoring system
The interviews with eight anaesthesiologists in their first year of residency, who used both the AS-NTS and ANTS in simulation training (including video tapings), showed that no further dimension had to be added to the AS-NTS rating tool (step 4). Furthermore, they confirmed the feasibility of AS-NTS and concluded that in undergraduates, as well as in the first 2 years of residency in anaesthesiology, the ANTS system is too complex.

Without video tapings it is nearly impossible to complete ANTS, due to time shortness. This was already pointed out by the developers [5, 32]. The eight anaesthesiologists discovered the rating of the videos to be very time consuming and delaying the feedback loop.

These anaesthesiology trainees decided to continue their postgraduate training curriculum using AS-NTS, rather than ANTS, for their first 2 years of residency.

The results from an additional evaluation questionnaire, completed by 21 anaesthetists, who had used the rating tool at least three times in undergraduate medical education, confirmed that the AS-NTS was feasible and practical (Additional file 1: Table S1). Additionally, they rated the importance of each dimension of AS-NTS.

The content validity index for each dimension was calculated, reflecting the proportion of relevance [62]. The calculated content validity index for the first dimension of AS-NTS was 0.9, for the second dimension 0.95 and for the third dimension 0.8. A content validity index of 0.75 or higher is considered as “excellent” [33].

Interrater reliability
The interrater reliability reached high levels of agreement (Table 6), except for dimension two, in the group of 3rd vs. 5th year residents (fair correlation). The ICC

| Non-Technical Skill | Step 1: Literature | Step 2: Focus group | Step 3: Field Observation | Part of rating tools |
|---------------------|-------------------|---------------------|--------------------------|---------------------|
| Situation awareness | [26, 28, 30, 36–45] | *                   | *                        | * DIMENSION 1: Planning tasks, prioritising and problem solving |
| Prioritising (Planning Tasks) | [12, 31, 46] | *                   | (*)                      | * DIMENSION 2: Teamwork and leadership |
| Decision-making | [12, 28, 41, 42, 47–54] | *                   | (*)                      | * DIMENSION 3: Leadership |
| Maintaining standards | [31, 38, 39, 43, 54] | *                   | (*)                      | * |
| Coordinating team members and activities | [39, 55] | *                   | *                        | * |
| Communication | [12, 22, 26, 28–31, 38, 40, 41, 43–47, 49–51, 53–59] | *                   | *                        | * |
| Leadership | [7, 12, 16, 26, 29–31, 36, 39, 41–44, 46, 47, 55–58] | *                   | *                        | * |
| Using authority and assertiveness | [38, 39, 56] | *                   | (*)                      | * |
| Team-building | [12, 28, 31, 36, 38, 39, 56] | *                   | *                        | * |
| Team orientation/ Teamwork | [12, 28, 29, 31, 36, 38, 39, 45, 46, 56–58] | *                   | *                        | * |
| Resolving conflicts/ problems | [12, 39, 42, 47, 56] | *                   | *                        | * |
| Supporting others | [22, 28, 39, 42] | *                   | *                        | * |

Table 5 Hierarchical mapping of Non-Technical skills and multi-step development of AS-NTS

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| Non-technical skill             | Definition                                                                                                                                 |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Situational awareness         | The skill to develop and maintain an overall dynamic awareness of the situation based on perceiving the elements of the emergency environment: Patient, team, equipment. Understanding what they mean and thinking ahead of what could happen next |
| Prioritising                  | Scheduling tasks, activities, issues, information channels etc., according to importance. Being able to identify key issues and allocate attention to them and avoid being distracted by less important matters |
| Decision making               | The skill of 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 time pressured crisis situations |
| Maintaining standards         | Supporting safety and quality by adhering to accepted principles of anaesthesia, following, where possible, codes of good practice, treatment protocols or guidelines and mental checklists |
| Coordinating team members and activities | Working together with others to carry out tasks, for both physical and cognitive activities; understanding the roles and responsibilities of different team members and ensuring that a collaborative approach is employed |
| Communication                 | The skill to convey and/or share all the ideas and thoughts relevant to the situation. Following all the rules of “good communication” like speaking loud and using closed loop communication |
| Leadership                    | The skill to share the mental model, assigning tasks and sharing information and opinion. Structuring the situation and initiate the necessary working steps |
| Using authority and assertiveness | Leading the team and for the task, accepting a non-leading role when appropriate; adopting a suitable forceful manner to make a point and adapting this for a team and/or situation |
| Team building                 | The skill to involve all the team members and to make them feel as part of one team, each playing an essential role in managing the task/situation. Distributing tasks to every member and asking actively for feedback and results |
| Team work                     | The skill of working with others in a team context, in any role, to ensure effective joint task completion and team satisfaction |
| Resolving problems conflicts/ problems | The skill of realizing interpersonal or technical conflicts and disagreement. Ability to embrace them, rather than avoiding them—in order to gain the best results out of the conflict, contributing to resolve the situation/task. Providing guidance within this process |
| Supporting others             | Providing physical, cognitive or emotional help to other members of the team                                                              |

Fig. 1 Definition of the NTS. The definitions were extracted from the cited taxonomies in Table 5, mostly the ANTS system

Fig. 2 Underlying NTS for dimension one of AS-NTS
### Planning tasks, prioritising and problem solving

| Level | Description | Good behavioural examples: |
|-------|-------------|---------------------------|
| Very good | | - Conducts the CPR algorithm  
- Takes (all) necessary steps  
- Prioritizes the tasks and structures workflow |
| Good | | |
| Average | | |
| Poor | | - Is distracted by less important tasks |
| Very poor | | |

### Teamwork and leadership

| Level | Description | Good behavioural examples: |
|-------|-------------|---------------------------|
| Very good | | - Gives clear instructions to the team and allocates responsibilities  
- Updates the team about new insights  
- Ensures that the team develops the same understanding of the situation  
- Tells the team members what she/he expects from them to do  
- Leads the team |
| Good | | |
| Average | | |
| Poor | | - Does not integrate the team into the process  
- Does not inform the team, if the planned plot has to be changed  
- Does not reassure if the team members have understood their tasks  
- Confuses the team members |
| Very poor | | |

### Team orientation

| Level | Description | Good behavioural examples: |
|-------|-------------|---------------------------|
| Very good | | - Integrates the team members into the diagnostic process  
- Asks actively the team members which information they need  
- Thinks loudly about her/ his assumption(s)  
- Creates a good team atmosphere |
| Good | | |
| Average | | |
| Poor | | |
| Very poor | | - Does not aim to gather the opinion of the team members  
- Does not take the suggestions of the team into account  
- Devalues the opinion of other team members  
- Does not ensure that the team members alternate in performing the cardiopulmonary resuscitation (prevention of fatigue) |

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Fig. 3 AS-NTS assessment tool (english version; the original German version has been added to the Additional file 1)
indicated a high rater agreement regardless of educational experience, training in anaesthesiology or familiarity with the AS-NTS rating tool.

Discussion

The development of the AS-NTS was performed in a stepwise approach, beginning with a review of pre-existing literature, continuing with focus group analysis and field observation, and ending with implementation and validation.

The steps were processed by means of empirical and qualitative research methods, which have gained a broad application in medical research [63–71].

During the field observations some skills proved to be difficult to observe and excluded from ANAESTHESIOLOGY STUDENTS' NON-TECHNICAL SKILLS, based on developmental guidelines of assessment tools described by Abell et al., who recommend items to be excluded, if they are not observable in at least 50% of field observations [72].

Nonetheless, the excluded skills are part of most existing NTS taxonomies and regarding the importance of these skills, one might argue that they should still be taught and addressed in undergraduate education.

However, acquiring and refining NTS is an individual and ongoing process [73]. Therefore, in undergraduate training pre-cursors of some NTS should be assessed and evaluated. Further, most of the taxonomies from which the NTS list was extracted, are developed for postgraduate training—focussing on specialist level, which makes these skills not one to one transferable to undergraduates.

Those skills should be focused in more advanced educational levels, mostly in postgraduate training. Nevertheless, the aim of the study was to include as many NTS as possible into the ANAESTHESIOLOGY STUDENTS’ NON-TECHNICAL SKILLS, in order to assess them in undergraduates to provide accurate feedback, enhancing the learning process. [74] For this goal, skills were redefined during the development of ANAESTHESIOLOGY STUDENTS’ NON-TECHNICAL SKILLS, symbiosing some pre-defined NTS and focusing more on pre-cursors and underlying elements of skills. This adaptation process was not solely based on the expert- and focus groups—but was supported by literature and resulted in the new dimensions of ANAESTHESIOLOGY STUDENTS’ NON-TECHNICAL SKILLS, specifically designed for undergraduates. The adaptation step was necessary, as some NTS are highly important but not fully developed in undergraduates.

Transferred to the first dimension of ANAESTHESIOLOGY STUDENTS’ NON-TECHNICAL SKILLS, two main dimensions of described NTS (“Decision making” and “Task management”) were symbiosed to the first AS-NTS dimension “Planning tasks, prioritizing and problem solving”.

This might lead to the assumption a specific assessment of these skills is not possible, as they are assessed in the same dimension of performance and in pre-existing rating tools, they are separately assessed.

This objection can be warded by focusing on the developmental rational and existing literature:

| Table 6 | Interrater reliability of the six pairs of raters and of all data (98 rated simulation scenarios) |
|---------|-------------------------------------------------------------------------------------------------|
| Raters  | ICC D.1 | ICC D.2 | ICC D.3 | ICC Overall | Cohen's Kappa D.1 | Cohen's Kappa D.2 | Cohen's Kappa D.3 | Cohen's Kappa Overall |
| R1/R2   | 0.925   | 0.955   | 0.882   | 0.922       | 0.95            | 0.90             | 0.92             |
| R1/R3   | 0.897   | 0.856   | 0.945   | 0.886       | 0.89            | 0.87             | 0.88             |
| R1/R4   | 0.855   | 0.825   | 0.874   | 0.837       | 0.833           | 0.853            | 0.837            |
| R1/R5   | 0.943   | 0.949   | 1       | 0.976       | 1               | 0.87             | 0.78             |
| R1/R6   | 0.905   | 0.978   | 0.943   | 0.945       | 0.893           | 0.98             | 0.94             |
| R7/R8   | 0.706   | 0.706   | 0.706   | 0.681       | 0.67            | 0.67             | 0.67             |

Interrater reliability of the 67 emergency simulation scenarios after data aggregation across raters'anaesthesiology training

| Year     | ICC D.1 | ICC D.2 | ICC D.3 | ICC Overall | Cohen's Kappa D.1 | Cohen's Kappa D.2 | Cohen's Kappa D.3 | Cohen's Kappa Overall |
|----------|---------|---------|---------|-------------|-----------------|-----------------|-----------------|------------------|
| A./2nd year | 0.880   | 0.893   | 0.830   | 0.868       | 0.87            | 0.8             | 0.82            | 0.87             |
| A./3rd year | 0.915   | 0.900   | 0.950   | 0.917       | 0.90            | 0.89            | 0.95            | 0.92             |
| A./4th year | 0.871   | 0.937   | 0.884   | 0.897       | 0.91            | 0.96            | 0.88            | 0.86             |
| A./5th year | 0.811   | 0.787   | 0.834   | 0.805       | 0.85            | 0.77            | 0.87            | 0.78             |
| 4th/3rd year | 0.729   | 0.767   | 0.722   | 0.733       | 0.77            | 0.75            | 0.71            | 0.74             |
| 5th/3rd year | 0.650   | 0.500   | 0.680   | 0.624       | 0.73            | 0.48            | 0.68            | 0.63             |

Interrater reliability of the 31 OR simulation scenarios with 3 raters per each simulation scenario

| ICC Dimension one | ICC Dimension two | ICC Dimension three | ICC overall |
|-------------------|-------------------|---------------------|-------------|
| 0.737             | 0.780             | 0.684               | 0.738       |

Abbreviations: A. Attending, R. Rater, Year Year of anaesthesiology training
“Decision making” is a complex skill which is divided into subskills and rated separately by some behavioral taxonomies [28, 29, 32]. Flowerdew et al. pointed out that it is not only making the decision which is of great importance, but also following the effects caused by the decision [38]. Here, “Decision making” is directly linked to the dimension “Task management”, which includes the elements: “Planning and preparing, prioritizing, providing and maintaining standard, identifying and utilizing resources”. Conducting the elements of “Task management” is the following consequence after “a decision is made”.

The comprehensiveness of “Decision making” and “Task management” regarding the training level of undergraduates was pointed out repeatedly, leading to the exclusion of these dimensions and focusing on some elements of these skills.

The elements of “Decision making” are: Identifying options, balancing risks, selecting options and re-evaluating [7, 20, 32, 56, 75].

Identifying options is necessary to solve a problem - in the decision making loop the risks and benefits of the solving strategy are re-evaluated – this concept of decision making is applicable in more complex scenarios than in undergraduate simulation training. Therefore, the focus group discussed and agreed to include “problem solving” as a less complex proxy of decision making into the first dimension of AS-NTS.

The strength of this study was scrutinizing the interrater reliability from different viewpoints. The interrater reliability was not only defined by a few designated raters, as in classical approaches. A two-step approach was chosen to analyse rater agreement, simultaneously examining if personal background (a.e. year of anaesthesiology training or experience in medical education) might influence ratings. First, agreement of rater pairs were analysed with a sufficient number of ratings, excluding agreement by chance, then data aggregation of the full sample was conducted based on anaesthesiology training, to calculate the interrater reliability. AS-NTS achieved excellent Interrater reliability, only within the group of 5th year vs. 3rd year anaesthesiology residents, the ICC and Cohens Kappa were “good” and only “fair” for dimension two of AS-NTS.

Data aggregation in the full sample, supports the result that the rating agreement is detached from anaesthesiology training and experience in medical education, fostering the usability of AS-NTS.

The strong involvement of Rater 1 in the assessment of the interrater reliability might lead to the assumption one rater could influence all the other raters. Regarding our results, this is not the case, as data aggregation across all raters, in which Rater 1 is not represented predominantly, showed high agreement on ratings as well.

The dimensions of the final version of AS-NTS achieved excellent content validity indexes according to a guideline for evaluating standardized assessment instruments [35]. However, one weakness of the study is that the calculation of the content validity index was only calculated from the evaluation of twenty-one anaesthesiologists. Although there is no predefined sample size required to establish content validity [76], the effect of agreement by chance is higher in a small sample.

The AS-NTS has high potential to improve NTS assessment in undergraduate education and ultimately patient safety, because a lack of NTS leads to adverse events in high-risk settings [5]. A recent study by Hagemann et al. showed that NTS in undergraduate students are improved after only one seminar [21]. Due to its good feasibility, the AS-NTS could be applied to all students as a standardised assessment and feedback tool.

Limitations
The AS-NTS has only been tested in German language at one institution with a limited number of teachers. Further studies should be conducted to establish the validity, reliability and feasibility of the English version.

Conclusion
AS-NTS provides a structured approach to the assessment of NTS in undergraduates, providing accurate feedback. The findings of usability, validity and reliability indicate that the AS-NTS can be used by anaesthesiologists in different year of postgraduate training, even with little experience in medical education.

Additional file

Additional file 1: AS-NTS. (DOCX 93 kb)

Abbreviations
ANTS: Anaesthesiology Non-Technical Skills; AS-NTS: Anaesthesiology Students’ Non-Technical Skills; CVI: Content Validity Index; ICC: Intraclass correlation; NTS: Non-Technical skills; TS: Technical skills

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Authors’ contributions
PMX made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data. She has been involved in drafting the manuscript and given final approval of the version to be published. She agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. AK made substantial contributions to acquisition of data. She has been involved in revising the manuscript critically for important intellectual content and has given final approval of the version to be published. She agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. WH made
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**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**

The assessment of NTS in simulation scenarios in undergraduate education was performed after approval by the local ethics committee in January 2017 (Ethikkommission der Arztekammer Hamburg, Hamburg, Germany; Correspondence PV5563). Written informed consents were obtained from the participants.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that there are no competing interests.

**Author details**

1. Department of Anaesthesiology, University Medical Center Hamburg-Eppendorf, Martinistr. 52, 20246 Hamburg, Germany.
2. Institute of Biochemistry and Molecular Cell Biology, University Medical Center Hamburg-Eppendorf, Martinistr. 52, 20246 Hamburg, Germany.

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