Master thesis, 2018-2019

Interventions aimed to increase non-technical skills in multidisciplinary operating teams: a scoping review

Bas Elsendoorn

University of Twente

Bas Elsendoorn

Student Number: s2033666

Faculty Behavioural, Management and Social Sciences, Psychology

First supervisor: Dr. L.M.A Braakman-Jansen

Second supervisor: C. Wrede

Date: 28th of November, 2019

Abstract

There is increasing recognition that non-technical skills (NTS) such as communication and teamwork are a vital part of the toolkit of multidisciplinary surgery teams, and interventions have been developed over the years to improve NTS. There is currently a gap in scientific literature exploring digital interventions that improve NTS, and a lack of clear oversight of the effective ingredients in existing interventions aimed at improving NTS. The objective of this paper is to identify NTS training interventions of health professionals working in multidisciplinary surgical teams, and to analyse components of these interventions in terms of target learning outcomes and behaviours, behaviour change techniques (BCTs) and persuasive sytem design (PSD) principles.

Methods: A scoping review of PsycINFO, Scopus and PubMed was conducted. The PICOC framework was applied to construct the search string and identify inclusion and exclusion criteria. The selected studies were extracted in three tables and a matrix. Quality of selected studies was assessed on the basis of methodological design, and validity and reliability of used measurement instruments. BCTs were identified through of the BCT V1 taxonomy and digital interventions were identified at through the Persuasive System Design Model (PSD).

Results: 14 studies were selected. Intervention type consisted of didactic training, simulation training or checklist implementation, often combined with either individual or group coaching. Eight out of ten studies aimed at improving NTS managed to achieve significant improvements. Only three out of a total of seven studies aimed at improving patient outcomes by either reducing major adverse events or reducing patient mortality managed to improve outcomes. When checklists were implemented as intervention form, the quantity of checklist adherence in studies did not improve significantly in most studies, although the quality of checklist adherence did increase. No digital interventions were found. The most popular BCTs were repetition and substitution, goals and planning and shaping knowledge. Due to the lack of clarification of the contents of the interventions, no effective BCTs that can improve non-technical skills could be identified.

Conclusion: For future studies the exact content of interventions should be explained to enable the identification of effective BCTs. Furthermore, due to a lack of digital interventions, it is recommended that digital forms of interventions are designed and tested in future studies rather than strengthening evidence of current training methods. eHealth has great potential to improve NTS because it focuses on self-empowerment of surgeons that might perceive interventions as a threat to authority and because it can be integrated in to daily activities unlike simulation training and CRM training. Virtual reality (VR) might hold potential to

improve NTS within the operating room due to its potential cost-effectiveness and its capability to be engaging for adult learners. It is recommended that study designs using VR will be explored and cost-effectiveness analyses be made.

Keywords: non-technical skills (NTS), eHealth, interventions, Behaviour Change Techniques (BCT), Persuasive System Design (PSD), scoping review

Introduction

In a modern-day clinical setting, healthcare professionals often work in multidisciplinary teams that have to take care of patients with a complex medical profile (Castel, Ginsburg, Zaheer, & Tamim, 2015) and experience an increasing number of surgical procedures (Brewin et al., 2015). Whilst we expect that surgery teams have the knowledge required to perform these complex procedures correctly, there has been increased recognition that essential non-technical skills such as teamwork and leadership also play an important role during surgery. Non-technical skills differ from technical skills in that the latter refer to all goal-related psychomotor actions of the surgeon, whilst non-technical skills refer to the team and communication skills necessary for successful surgery (Alken, Fluit, Luursema, & Goor, 2018a). Non-technical skills may be divided in to three distinct categories: social (communication, teamwork and leadership), cognitive (decision-making and situational awareness) and personal resources (ability to cope with stress and fatigue) (Ounounou et al., 2019). There has been increasing recognition that non-technical skills are of an equal level of importance as technical skills in the operating theatre: one of the most commonly cited causes of surgical errors is a lack of non-technical skills (Brewin et al., 2015) which can result in patient injury (Greenberg et al., 2007). Apart from the fact that bad non-technical skills might jeopardize the safety of patients, there is evidence that improved non-technical skills lead to an improved team climate (Haller et al., 2008). Therefore much can be gained for both patients and surgical teams when non-technical skills are improved.

Although the realisation that non-technical skills matter in healthcare came fairly recently compared to other high risk-industries such as aviation and the oil industry (Sevdalis, 2013), there are currently two major intervention forms in healthcare to improve non-technical skills. The first one is Crew Resource Management (CRM), stemming from aviation. The defining aspect of CRM is its systematic approach to safety culture rather than focusing on individual failures; CRM aims to identify systematic flaws and uses standardized communication tools to improve process effectiveness and safety (Haerkens et al., 2015). Results with CRM programmes regarding surgery teams look promising: it has positive effects on attitudes, behaviour and learning, as well as on healthcare outcomes (Ricci & Brumsted, 2012). The rationale behind it seems sound: there are many parallels between aviation and healthcare, such as the fact that both pilots and doctors operate in complex environments where teams interact with technology, deal with low-and high risk threats from a variety of sources in the environment and safety being paramount for both professions (Helmreich, 2000). Nevertheless, important drawbacks are the lack of a current international

standard for medical CRM training (Haerkens et al., 2015), the fact that long-term effects still need to be studied (Courtenay, Nancarrow, & Dawson, 2013) and implementation of a CRM approach in healthcare settings requires customisation of tools and techniques for each specific care venue, which comes with considerable cost (Pizzi, Neil, Goldfarb, & Nash, 2001). The second intervention is simulated operating rooms. These simulations are used to train both technical skills and non-technical skills in tandem (Alken et al., 2018a) and can range from high-fidelity simulations in a fully equipped operating room to low-fidelity simulations which use full immersion/distributed simulation simulators instead (Ounounou et al., 2019). Although simulation training has been shown to be effective across multiple surgical specialities there are also important drawbacks including high costs, extensive organisation requirements to compose realistic operating teams, and guidance by trained teachers (Alken et al., 2018a). It is therefore desirable that alternatives are found that are not as expensive, can be standardized and require less organisational resources.

A potential solution for these issues are interventions delivered via electronic means, or eHealth. EHealth is defined as "the transfer of health-related resources and health care by electronic means, including information, support resources, assessments, interventions, and health care records" (Oh, Rizo, Enkin, & Jadad, 2005). There is growing recognition that eHealth has potential for surgeons: there has been a growth in mobile applications for both surgeons and patients that cover a wide range of surgical specialities, including plastic surgery, orthopaedics, neurosurgical, general surgery, cardiac surgery, ophthalmology and urology (Kulendran et al., 2014). EHealth has often been hailed as a way to reduce healthcare costs (Van Gemert-Pijnen, Peters, & Ossebaard, 2013), which can address the costs problem for both CRM and simulation interventions. Furthermore, eHealth might reduce the strain on organisational resources; since eHealth modules can be accessed from multiple locations via the internet on computer or mobile devices, the need for teachers in multiple hospitals will be diminished. EHealth can also have added value when training non-technical skills: as medical professionals perceive requirements to change behaviour often as a threat to their autonomy and authority (Leape & Berwick, 2005), eHealth can help to negate this barrier since eHealth stresses the empowerment of consumers to make their own decisions (Van Gemert-Pijnen et al., 2013), Finally, internet and mobile technologies may be useful for non-technical skills training because interventions using these technologies can be seamlessly integrated into daily activities (Young et al., 2019). As the amount of surgeries conducted continues to rise (Brewin et al., 2015), interventions making use of these techniques can be fit more easily in the schedule of a surgical team than traditional interventions.

Although interventions aimed at improving non-technical skills are important, it is essential that designers of interventions know what determines behaviour regarding non-technical skills and the adherence to it, or lack thereof. Important barriers include that experienced surgeons might not have had non-technical skills training as part of their curriculum, whereas the new generation of surgeons is familiar with non-technical skills training via their education. Furthermore, the view of the practicing surgeons might be skewed when it comes to non-technical skills: they either deem them irrelevant or unnecessary, or believe they already acquired the skill through years of practice whilst the opposite is true (Hollands, 2013). A linear decrease in score on a non-technical skills questionnaire after fellowship has been awarded seems to support this hypothesis (Gostlow et al., 2017). This vision can potentially cause patient harm as these experienced surgeons generally take on positions of leadership during surgery, and other staff members in the operating theatres might not be taking part in the decision-making process. Therefore, although it is encouraged in the philosophy of non-technical skills, other staff is does not speak up about potential concerns (Gostlow et al., 2017). A lack of knowledge and skewed attitudes therefore seem to be important determinants regarding problems with non-technical skills in the operating theatre.

Knowing these determinants, designers of interventions can develop more effective interventions, as these are more likely to be effective when they target casual determinants of behaviour and behaviour change, in other words the theoretical mechanisms of change (Michie, Johnston, Francis, Hardeman, & Eccles, 2008). From this point on, a variety of techniques can be applied to trigger behaviour change. These are called behaviour change techniques (BCTs) and are defined as "an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an "active ingredient"" (Michie et al., 2013). A list of BCTs has been summarized in the BCT taxonomy, which includes 93 distinct BCTs that can be employed to trigger behaviour change (Michie et al., 2013). The BCT taxonomy was used to identify active ingredients in regular interventions in this review, as it has the advantage of being a reliable method for extracting information about intervention content, "thus identifying and synthesizing discrete, replicable, potentially active ingredients (or combinations of ingredients) associated with effectiveness" (Michie et al., 2013).

Whilst eHealth can solve many issues resolving non-technical skills training, one of its biggest problems is getting participants engaged with and adhere to an intervention for a

longer period of time: simply providing an electronic behaviour change intervention is not enough. This is demonstrated by the high level of attrition and low levels of adherence eHealth and mHealth behaviour change interventions struggle with, and there have been calls to design more engaging interventions to address these issues since there is a general consensus that engagement is necessary for intervention effectiveness (Short et al., 2018). In other words, the technology needs to be persuasive in adoption and aiding the user to increase the chances of people using the technology and reaching its goals (Van Gemert-Pijnen, Kelders, Beerlage-de Jong & Oinas-Kukkonen, 2018). Whereas regular interventions implement behaviour change techniques to support users in helping to reach their goals, persuasive health technology can be seen as the digital equivalent of these BCTs (Van Gemert-Pijnen et al., 2018). One framework which is used to design and evaluate persuasive digital designs is the Persuasive Systems Design Model, also known as the PSD model (Oinas-Kukkonen & Harjumaa, 2008). The PSD model uses four principles for designing persuasive health technology to increase uptake and effectiveness: primary task support (techniques aiding the user in achieving their task), dialogue support (techniques supporting man-machine interaction), system credibility (techniques that make the system appear more credible, therefore more persuasive) and social support (techniques using social influence to motivate users) (Räisänen, Lehto, & Oinas-Kukkonen, 2010) The PSD model was used to evaluate existing digital interventions found during this review, as this model has already been successfully used before to evaluate digital designs (Räisänen et al., 2010).

Although reviews regarding interventions to improve non-technical skills have been conducted before (Gordon, Darbyshire, & Baker, 2012; Courtenay et al., 2013; Ounounou et al., 2019) these interventions never listed behaviour change techniques that were used nor the contents of the intervention. The description of the contents of the intervention has been labelled as poor (Gordon et al., 2012). This study aimed to address this issue by mapping out which behaviour change techniques are employed to engage and aid the user in traditional interventions by using the behaviour change taxonomy (Michie et al., 2013) and see what behaviour change techniques are used most frequently. Furthermore, none of these reviews have focused on interventions that make use of eHealth. Considering the potential impact eHealth can have on non-technical skills training, it is worthwhile to map out which digital interventions exist, which are effective and what factors contribute to the effectiveness using the PSD model (Oinas-Kukkonen & Harjumaa, 2008). Considering that the PSD model is used to exclusively design and evaluate digital behaviour change interventions, this model was better tailored to evaluating digital interventions than the BCT taxonomy.

A scoping review was conducted to list interventions that aim to improve non-technical skills amongst multidisciplinary surgery teams working in the operating theatre, whilst also including search terms that specifically look for digital interventions. A scoping review aims at examining the extent, range and nature of the research activity, determine if a systematic review is feasible, summarize and disseminate research findings, and identify gaps in existing literature (Arksey & O'Malley, 2005). Considering that there are no current reviews that highlight and compare digital interventions, a scoping review is the best fit for this paper. The objective of this review was to identify non-technical skills training interventions of health professionals working in multidisciplinary surgical teams, and to analyse components of these interventions in terms of target learning outcomes and behaviours, behaviour change techniques (BCTs) and persuasive design principles (PSD).To achieve this objective three research questions were established:

1. What are the effective interventions, both digital and non-digital, aimed to improve non-technical skills of health professionals in multidisciplinary teams in surgery rooms, and what specific outcomes were found?
2. What BCTs are included in the interventions aimed to improve non-technical skills?
3. What PSD techniques are included in digital interventions aimed at improving non-technical skills?

Methods

PICOC and search strategy

To construct the search string for this review, the PICOC framework was applied. PICOC is an acronym that stands for Population, Intervention, Comparison, Outcome and Context and helps to orient the construction of the bibliographic search, and to rapidly and accurately locate the best scientific information available (Santos, Pimenta, & Nobre, 2007). For the **population** health personnel in a surgery team was chosen. In general, a surgical team consists of surgeons, anaesthesiologists and nurses (He, Ni, Chen, Jiang, & Zheng, 2014), which are also the roles we will be using during our search along with more general terms describing healthcare workers.

The **intervention** is aimed at addressing the non-technical skills within the healthcare setting. Considering that Crew Resource Management (CRM) interventions are deemed promising for improving non-technical skills in healthcare (Courtenay et al., 2013) this term was included in the search string. Furthermore, as one of our research questions is related to digital interventions, terms that are related to eHealth, mHealth and telemedicine were included. Since there is a significant heterogeneity in methods regarding these interventions (Gordon et al., 2012), there was no **comparison** between methods during this literature search.

Outcomes were non-technical skills, patient outcomes and checklist adherence. Since non-technical skills encompass a lot of dimensions (Lindamood, Rachwal, Kappus, Weinstock, & Doherty, 2011; Gordon et al., 2012) for the sake of convenience the terms used by Gostlow and colleagues (2017) were used, as well as the fifteen principles defined by the CRM training programme as terms. These terms included knowledge of the environment, anticipate and planning, calling for help early, exercising of leadership and followership, workload distribution, available resource mobilization, effective communication, the use of all available information, the prevention and managing of fixation errors, double checking, the use of cognitive aids, repeated re-evaluation, having good teamwork, attention allocation, and setting priorities dynamically (Lindamood et al., 2011). Patient outcomes as an outcome measure were included since shortcomings in non-technical skills have been identified as a cause for adverse events in the operating room (Alken et al., 2018b). For the sake of simplicity, these categories were divided into adverse outcomes (length of stay, unplanned readmissions and post-operative complications) and mortality (patient death). Checklist adherence was included since teams complying with the WHO surgical safety checklist (WHO SSC) also have higher mean scores on instruments that measure non-technical skills

(Robertson et al., 2014). Since adverse patient outcomes, patient mortality and checklist adherence are only related with non-technical skills outcomes and do not measure non-technical skills, they were defined as secondary outcome measures.

The **context** was limited to operating rooms, both in-situ and simulations. Both low-fidelity and high-fidelity simulations were included.

The PICOC framework is summarized below:

- Population: health personnel within a multidisciplinary surgery team consisting of surgeons, anaesthesiologists and nurses
- Intervention: interventions aimed at improving non-technical skills within the surgery setting, either via conventional methods (such as Crew Resource Management), or digital methods (Telemedicine).
- Outcome: Non-technical skills defined as in crew resource management interventions (Lindamood et al., 2011) as well as the terms used by Gostlow and colleagues (2007), patient outcomes and checklist adherence.
- Context: Operating rooms, both in-situ and simulated

Other terms used include synonyms, abbreviations and self-induced search terms. In the case of PubMED and Psycinfo MeSH terms were used. Because Scopus does not allow MeSH terms in its search string, the thesaurus on PubMED was consulted which terms were considered part of MeSH terms, which were written out in full in the Scopus search string.

Selection of studies

An electronic literature search of PubMed, PsycINFO and Scopus was conducted. Given the focus of this review and the high tempo technology develops (Van Gemert-Pijnen et al., 2013), this scoping review only included studies conducted between January 2014 and November 2019. Using the search string (appendix A), studies were selected based on the following steps, as well as the inclusion and exclusion criteria:

1. Title and abstracts were skimmed first and selected on relevance to the research questions, as well as the inclusion and exclusion criteria.
2. Duplicates were removed.

3. The full text of the selected studies was read, and further selected based on the relevance to the research questions, as well as the inclusion and exclusion criteria. The reason for exclusion is mentioned in the flowchart.
4. Studies in reviews were read individually. The same inclusion and exclusion criteria for individual studies were applied for studies that are found in reviews;
5. Last, the reference lists was consulted and promising studies were added to the grey literature. This search technique is known as snowballing and can lead to many studies being included that might not have ended up in the search results. These identifications can form a significant part of the results (Greenhalgh & Peacock, 2005). Studies that met the inclusion criteria during the writing of the introduction of this study and did not show up in the search results were also added to the grey literature.

Inclusion criteria were:

1. Studies with the objective of improving non-technical skills amongst healthcare personnel in surgery rooms;
2. Studies that used either non-technical skills, patient outcomes or both as an outcome measure;
3. Studies that used quantitative measures to measure effects;
4. Studies that used both conventional and digital behaviour change techniques to improve non-technical skills;
5. Studies that were quasi-experimental or experimental in nature;
6. Studies that used randomized or non-randomized populations;
7. Studies that had an abstract available;
8. Studies conducted between 1st of January 2014 and 30th of November 2019;
9. Studies that did not show up in the literature search, but were found during the skimming of the reference lists of selected studies and included based on the aforementioned points and relevance to the research questions (grey literature).;
10. Reviews which identified existing interventions regarding non-technical skills, with the individual studies found in these reviews being included.

Exclusion criteria were;

1. Studies that were conducted before 1st of January 2014;
2. Studies that did not contain the relevant population of healthcare personnel;
3. Studies that used qualitative measures such as interviews or ethnographic studies;
4. Studies that solely relied on self-assessment as outcome measure;

5. Studies that solely measured technical skills;
6. Factor studies that examined a correlation between a certain behaviour and the influence it has on non-technical skills;
7. Studies that did not contain an intervention aimed at improving non-technical skills;
8. Studies that focused on one professional group;
9. Studies that did not describe in detail what elements the intervention consists of;
10. Studies that were not conducted within the operating room or an equivalent, such as a simulation;
11. Studies that were not available in the English or Dutch language;
12. Studies that did not have humans as participants;
13. Proposals for future studies;
14. Studies lacking empirical data;
15. Studies from which the full text was not available;
16. Studies that lack an abstract.

Determining study strength

To determine overall value of the studies, included studies were rated based on methodological design, effectiveness and quality of instruments. For methodological design, the general hierarchy of study designs to answer questions regarding effectiveness (Ryan, Hill, Prictor & Mekenzie, 2013) was applied. This hierarchy ensures that when effects are found, the results are the least likely to be skewed by bias (Ryan et al., 2013). The hierarchy was rated with the following scores:

Table 1. The coding for methodological design.

Methodological design	Score
Randomised controlled trials (RCTs)	1
Non-randomised studies, including quasi-randomised controlled trials, controlled before-and-after studies, and interrupted time series studies	2
Controlled observational studies, including cohort studies, case-control studies and case series	3

To assess the value of the found effects, significant effects with $p < .05$ were marked with an asterisk (*), whilst significant effects with $p < .01$ were marked with two asterisks (**).

Furthermore, instrument reliability and validity was assessed. Although there are many instruments to measure non-technical skills (Cooper, Endacott, & Cant, 2010), one of the most popular is the Oxford Non-Technical Skills Rating System (NOTECHS), and its successor Oxford NOTECHS II. Both instruments measure non-technical skills across five dimensions: leadership and management, teamwork and cooperation, problem-solving and decision making, and situational awareness, which is done by independent raters (Robertson et al., 2014). Research demonstrated that NOTECHS has both a high inter-rater reliability and test-retest reliability in live environments (Robertson et al., 2014) and validity was demonstrated through improved scores of teamwork training (Mishra, Catchpole, & McCulloch, 2009). NOTECHS II builds further upon the original instrument by improving the scalability. Just like its predecessor, NOTECHS II shows good inter-rater reliability, improved face validity compared to its predecessor, and technical skills do not influence the score (Robertson et al., 2014). Considering their psychometric strength, NOTECHS or NOTECHS II will automatically be marked with reliable (+).

If another instrument is used to measure non-technical skills, Cronbach's alpha or coefficient alpha (α) will be used to assess reliability. Cronbach's alpha is used to measure the interrelatedness between items; in other words, the items that are used in the instrument measures the same underlying construct (Cortina, 1993). When a study does not make mention of Cronbach's Alpha, the reference list of the study will be consulted to see if referenced studies mentioned Cronbach's Alpha: if referenced studies do not mention Cronbach's alpha, the instrument will be marked as "NA" (non-applicable). The following cut-offs are applied:

Table 2. The Cronbach's/Coefficient alpha cut-off used to determine reliability of instruments.

Chronbach's/Coefficient alpha (α)	Value
>.70	Determined reliable: +
<.70	Determined unreliable: -

Patient outcomes, checklist adherence or instruments that measure technical skills such as glitch count were not rated for reliability and validity.

Data extraction

Results of the literature search were uploaded in to Endnote X9. Four tables were created for data extraction. Table 3 contains an overview of the studies, including author, year, design and the corresponding methodological quality score, study groups, participants, the sample size and setting. As is in line with the recommendations of the general hierarchy of study designs (Ryan et al., 2013), the studies were listed from top to bottom based on the methodological strength: randomised controlled clinical trials (RCTs) are listed first, followed by controlled clinical trials, uncontrolled clinical trials, experimental designs, quasi-experimental designs, and cohort studies respectively. If both studies used an identical study design, they were ranked based on the sample size (N) with bigger sample sizes listed higher. Studies with bigger sample sizes have a higher methodological quality as they reduce the risk of a type I error (Cohen, 1992). Table 4 includes a description of the interventions, as well as the intervention type, specific skills trained, the overarching objective, the measurement moments, used outcomes measures and the quality of the outcome measure. Table 5 includes found results, using non-technical skills, major adverse events, patient mortality, checklist adherence and other potential measures as outcomes. Table 6 includes the Behavioural Change Techniques used during the intervention. For the identifying of the BCTs, version 1 of the Behaviour Change Taxonomy (Michie et al., 2013) was used (appendix B). Only the main groupings are listed in the matrix. Should the interventions found in the study deliver the intervention via digital means the Persuasive System Design model will be applied to identify BCTs (Oinas-Kukkonen & Harjumaa, 2008). Only the main groupings (primary task support, dialogue support, system credibility support and social support) will be listed in a separate matrix.

Results

Searching Scopus, PubMed and PsycINFO resulted in 526 studies. After searching the titles and abstract and selecting studies based on the inclusion and exclusion criteria, 62 studies remained. Following the selection, duplicates were removed, resulting in 39 studies and seven reviews. The texts of the single studies were read in full, resulting in the inclusion of nine studies. Afterwards, the seven reviews were read, in which 96 studies were identified. After application of the selection criteria, four additional studies from reviews were included. Consulting the reference lists of the included studies resulted in one additional study that was added to the grey literature, resulting in a total of 14 studies included for the review. The flowchart of the selection process is illustrated in figure 1.

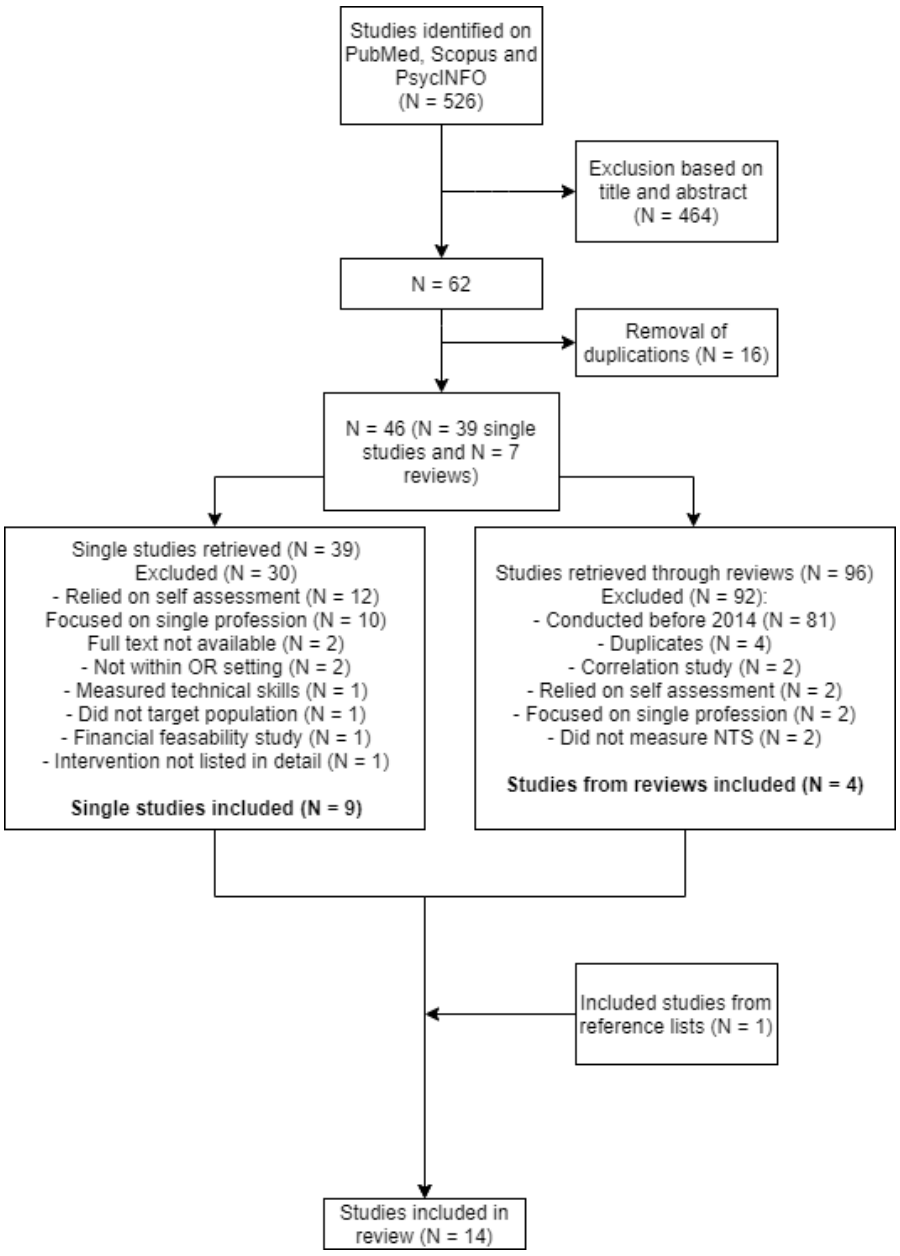

Figure 1. The flowchart of the selection process for the studies.

Description of studies

Table 3 contains the description of the studies, including author, year of publication, design, study groups, participants, setting and the methodological design score. The methodological quality of the selected studies overall can be described as fair, with the majority of the studies being assigned a score of two [3-12]. From the 14 studies selected, only 4 made use of randomization of the population [1-4]. The majority of the studies did report an experimental design, with the non-experimental designs consisting of cohort studies [13, 14]. Interestingly, many studies did not list a sample size for individuals [1-7, 12, 14] instead often opting to list the amount of surgeries observed [2, 3, 5, 7, 14]. Only three studies did not specify sample size [4, 6, 12]. Furthermore, a few studies mentioned the use of specific teams [3, 5, 6], with different teams used for both the experimental and control condition in study 5 and 6. The most recent study dates from 2017, so as of the time of writing not many studies have been recently conducted that tried to examine how non-technical skills can be improved via interventions.

Table 3. Description of selected studies including design, participants, setting and methodological design score.

Author & year of publication	Design	Study groups	Participants	Setting	Methodological design score
[1] (Duclos et al., 2016)	Cluster randomised trial	Intervention and control group; control group received no intervention	Individual N not given; OR teams from 31 hospitals	Training in OR	1
[2] (Haugen et al., 2015)	Cluster randomised controlled trial	5 surgical groups receiving the same intervention, but at different time intervals	Individual N not given; instead the amount of observed surgeries were given pre- and postintervention (N = 2212 and N = 2263, respectively); OR teams within five specialities (cardiothoracic, neurosurgery, orthopaedic, general and urologic)	ORs	1
[3] (Morgan et al., 2015b)	Controlled interrupted time studies	Intervention and control group; control group received no intervention	Individual N not given; instead the amount of observed surgeries were given pre- and postintervention (N = 44 and N = 50, respectively); operating staff within OR	ORs conducting elective orthopedic surgery	2
[4] (Sparks et al., 2017)	Quasi-randomised controlled interventional study	3 intervention groups; 2 intervention groups and 1 control group	N not given; midlevel surgical residents (PGY 2 & 3), anesthesia providers, scrub nurses and circulating nurses	Simulated ORs	2
[5] (Morgan et al., 2015a)	Controlled interventional study	Intervention and control group; control group received no intervention	Individual N not given; instead the amount of observed surgeries were given pre- and postintervention for the intervention condition (N = 26 and N = 25, respectively) and control condition (N = 11 and N = 10, respectively); operating staff within the OR	Orthopedic ORs (intervention) and vascular/general ORs (control)	2

[6] (Robertson et al., 2015)	Controlled interventional study	Intervention and control group; control group received no intervention	N not given; surgeons, anesthetists and nurses	plastic/reconstructive surgery (intervention) and orthopedic ORs (control)	2
[7] (Kleiner et al., 2014)	Uncontrolled interventional study	Single study group receiving intervention	Individual N not given; instead the amount of observed surgeries were given for pre-and postintervention (both N = 160); surgeons, anesthesiologists, certified RN anesthetists, residents, nurses, surgical technicians, and others participating in the surgery	OR	2
[8] (Weller et al., 2016)	Uncontrolled interventional study	Single study group receiving intervention	N = 120; consultant surgeon, surgical resident, consultant anesthetist, anaesthetic fellow, anaesthetic technician and OR nurses	Simulated ORs	2
[9] (Rao et al., 2017)	Uncontrolled interventional study	Single study group receiving intervention	N = 53; general surgery residents, anesthesia residents, OR nurses, Anesthesia techicians		2
[10] (Savage et al., 2017)	Multi-level prospective single case study	Single study group receiving intervention	N = 153; all managers and staff	ORs	2
[11] (Everett et al., 2017)	Single group A-B-A-B experimental design	Single study group receiving intervention	N = 35; surgeons, anaesthetists, nurses	Simulations in OR	2
[12] (Amaya-Arias et al., 2015)	Single group quasi-experimental interventional study	Single study group receiving intervention	N not given (“80 per cent of the population”); surgeons, nurses, anaesthesiologists	Training in OR	2

[13] (Nicksa et al., 2015)	Prospective cohort study	Single study group receiving intervention	N = 43; junior surgical residents (PGY 1 & 2) with other health care professionals (nursing, anesthesia, critical care, medicine, respiratory therapy, and pharmacy)	Various locations; OR, intensive care unit, emergency department, postanesthesia care unit and simulation center	3
[14] (Gitelis et al., 2017)	Retrospective cohort study	Single study group receiving intervention	Individual N not given; instead surgery observation when paper checklist was used (N = 167), and electronic checklist (N = 50); Surgeons, anaesthesiologists, nurses	OR	3

Abbreviations: OR, operating room.

Description of interventions

The description of the interventions including type, intervention form, specific skills trained, objective, measure moments, outcomes as well as the quality of the outcome measure are listed in table 4. Most studies made either use of didactic training [1, 3, 5, 6, 10, 12], simulation training [4, 8, 9, 11, 13] or checklist implementation [2, 10, 11, 14]. This was often combined with coaching [1, 5, 6, 11, 13]. Most studies focused on training in groups [1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13] rather than an individual approach. Most of the studies made use of repeated measures and had no separate control group [7-14]. Although the intervention form was often clear, the exact contents of the intervention such as the specific skills trained were not described in half of the studies [2, 3, 4, 5, 7, 9, 14].

From the selected studies, 10 studies focused on improving non-technical skills [3-13], 8 studies focused on improving patient outcomes [1, 2, 3, 5, 6, 10, 14] and 6 studies focused on improving checklist adherence [1, 3, 5, 6, 10, 14]. It is noteworthy that only one study did a kind of follow-up measure moment [1], meaning that long-term effects should still be studied for these interventions. None of the selected studies made use of digital intervention, although digital tools to deliver a conventional part of the intervention have been used in two studies [12, 14].

The majority of studies that measured non-technical skills employed NOTECHS or its successor NOTECHS II [3, 4, 5, 6, 9, 13], indicating that the majority of the studies are reliable and valid regarding measuring non-technical skills. However, studies that did not use NOTECHS but measured non-technical skills via other questionnaires [8, 10, 11, 12] made no mention of the reliability from the used instrument, with the exception of one study [11]. Reliability was also not found when reference lists of these studies were consulted. This is worrying, as in the case of one study [8] the scores on the used outcome measure (BRMI) seemed to relate to time of day, duration of the case, number of staff in OR, and patient ASA score. This indicates that these instruments could have potentially been unreliable.

Table 4. Description of interventions including intervention type, intervention form, specific skills trained, objective of the study, measure moment, outcomes and outcome quality.

Study	Type	Intervention form	Specific skills trained	Objective	Measure moments	Outcomes
[1]	Didactic group training combined with group coaching	The Intervention consisted of two half-day team training sessions at six-month intervals. First training session included explain the major concepts of CRM with safety principles highlighted in instructional videos. The second consisted of effective implementation in OR by observing behaviour in ORs whilst giving feedback.	Situational awareness, team synergy, interpersonal communication, safety principles, surgical checklist use, preoperative and postoperative debriefing	Improving patient outcomes and checklist adherence	Longtidunal study, Monthly for 19 months	- Major adverse events; operative and postoperative complications, mortality rates - Fufilled surgical safety checklist (unspecified)
[2]	Checklist implementation	There was a baseline three month registration period, followed by an intervention period of eight months. The WHO SSC was implemented in clusters of surgical specialisations in a randomized manner. All specialities received the intervention, but some later than the other due to randomisation. The periods without WHO SSC and with WHO SSC were compared.	*Not mentioned*	Improving patient outcomes	Longitudinal study, Pre-intervention and post-intervention 11 months later	- Complications - Patient death up until 30 days after surgery - Length of stay for patients

[3]	Didactic group training	The intervention consisted of a team training and SOP training. The team training consisted of an off-site interactive lecture training that lasted 1 day with specific attention given to the WHO SSC, SOP training consisted of two off-site half-a-day workshop style sessions	*Not mentioned*	Improving NTS, patient outcomes and checklist adherence	Longitudinal study, Pre-intervention 6 months before the intervention and post-intervention 6 months after the intervention	- NOTECHS II; NTS, including leadership and management, teamwork and cooperation, problem solving, decision making and situational awareness (+) - Glitch count; interruptions, omissions and changes with the potential to reduce quality or speed from the procedure - WHO SSC adherence; attempted time-out and sign out sections - Clinical outcome data; length of stay, percentage of patients without any complications and readmissions
[4]	Group simulation training	The intervention consisted of a one-hour orientation and two training sessions, Participants were divided in to scenarios with a low, medium or high degree of fidelity. Scenarios lasted 10 to 15 minutes. Low fidelity consisted of crisis scenario on SimMan. Medium fidelity was the same scenario on a "synthetic anatomy for surgical tasks" mannequin, high fidelity was the same scenario on a deceased donor. Afterwards a 45-minute debriefing was held where reactions were shared and the instructor leads at the hand of CRM checklist objectives	*Not mentioned*	Improving NTS	Longitudinal study, Pre-intervention and post-intervention immediately after.	- NOTECHS (+) - TAS; trauma management skills - CRM checklist score; team behaviour expectations, score performance of team members and guide for debriefings. - Self-efficacy questionnaire - Participant satisfaction survey

[5]	Didactic group training combined with group coaching	The intervention group received a teamwork training training course consisting of two three-hour interactive classroom teaching with specific attention to WHO SSC compliance. Afterwards coaching was provided for six weeks. The intervention lasted for three months so everyone could attend	*Not mentioned*	Improving NTS, patient outcomes and checklist adherence	Longitudinal study, Pre-interventions 3 months before and post-intervention 3 months after intervention	- NOTECHS II (+) - Glitch count - WHO SSC adherence - Clinical outcome data; length of stay, percentage of patients without any complications and readmissions within 90 days
[6]	Didactic group training combined with group coaching	The intervention consisted of a half – day didactic training explaining the concepts of lean process engineering as well as a half-day didactic teamwork training, followed by 5 days in-theatre coaching spread over six weeks. Intervention lasted for three months	Situational awareness, flat hierarchy, formal communications protocols and checklists.	Improving NTS, patient outcomes and checklist adherence	Longitudinal study, Pre-intervention 3 months before and post-intervention 3 months after intervention.	- NOTECHS II (+) - Glitch count - WHO SSC adherence - Clinical outcome data; complication rate, readmission rate and length of stay

[7]	Group and individual coaching	A retired orthopaedic surgeon provided coaching for four weeks to improve NTS. Coaching included addressing issues identified in the pre intervention observations, discussions with staff after procedures to address what went well and what not, presentations to various OR committees and updates at weekly staff meetings, presenting information, answering questions, encouraging self-reflection and addressing issues after surgery.	*Not mentioned*	Improving NTS	Longitudinal study, Pre-intervention immediately before and post-intervention 2 months after intervention.	- Number of briefings and debriefings before and after the intervention. - CRM Observation Checklist score; quality of communication during briefing and debriefing
[8]	Group simulation training	The training lasted a full day and consisted of three scenarios in a realistic simulated OR environment. Each simulation was followed by a debriefing and presentations on communication strategies, using a structured framework to guide discussion about teamwork, information sharing and communication with special attention to unique information each member had	Briefing skills, information sharing, information inquiry, contingency management, assertion to speak up, vigilance and inter-disciplinary information sharing	Improving NTS	Longitudinal study, Pre-intervention and post-intervention immediately after intervention took place	- BRMI; briefing, information sharing, inquiry, contingency management, assertion and vigilance (“NA”)

[9]	Group simulation training	The intervention consisted of eight sessions of in-situ simulation involving two non-randomized scenarios. Each scenario was followed by a debriefing that consisted of 10 minutes of self-reflection, 10 minutes of guided discussion by the faculty, and 5 minutes to summarize areas of improvement.	*Not mentioned*	Improving NTS	Longitudinal study, Pre-intervention and post-intervention (when not stated)	- NOTECHs II (+) - Participant survey
[10]	Didactic group training combined with risk assessment and checklist implementation	The intervention consisted of a course of didactic seminars lasting four and a half hours, which included group exercises and role-playing. Furthermore, a risk assessment that involved observations and semi-structured interviews to standardize work practices with CRM principles; and the implementation of WHO SSC to develop, implement and refine SOPs	Team formation, closed-loop communication, risk recognition, speaking up with a standardized format, decision making, creating and sustaining a shared mental model, situational awareness.	Improving NTS and patient outcomes	Longitudinal study, Pre-intervention, post-intervention (2 years after) and follow-up (4 years after)	- HOSPC; safety culture perception - MedPACT; NTS including communication, leadership, situation monitoring and mutual support ("NA") - Participant survey - Electronic Medical Records; length of stay, unplanned/acute reoperations and unplanned readmissions

[11]	Group simulation training combined with checklist implementation and group coaching	The intervention consisted of two sessions. Participants were familiarized and coached on how to use the checklists. 4 scenarios were chosen out of a possible 8. The participants could use the checklists in the first and third scenario but not in the second and fourth scenario (the second and fourth scenario serving as control). Scenarios were conducted on a computerised manikin. The duration of the intervention was not stated.	Leadership, teamwork, task management	Improving NTS and checklist adherence	Longitudinal study, Post-intervention and follow-up after an interval of 8 months.	- Checklist adherence to critical event key processes - Team Emergency Assessment Measure (TEAM); NTS of medical emergency teamwork including leadership, teamwork and task management (+) - Participant survey
[12]	Blended didactic teaching	The intervention implementation period lasted two months. The intervention consisted of a multifaceted training with consisting of a four-hour workshop, five digital modules uploaded on a weekly basis, training within the use of the WHO SSC and correct implying of time-outs, and institutional actions	Communication, cooperation/support, leadership, situational awareness	Improving NTS	Longitudinal study, Pre-intervention and post-intervention 1 week after	- OTAS-S; NTS including communication, coordination, cooperation/support, leadership, and supervision/awareness of the situation (“NA”) - Quality of delivery - Overall satisfaction

[13]	Group simulation training combined with individual coaching	The intervention consisted of high-risk simulations lasting 15 to 20 minutes, followed by 30-minute debriefings with real-time feedback. The first ten minutes consisted of individual reflection, followed by twenty minutes of watching video footage in which the simulation team gave feedback, facilitated discussion gave instruction, provided insight and encouraged participant self-reflection.	Communication, leadership, teamwork, problem solving, situational awareness	Improving NTS	Longitudinal study, Pre-intervention and post-intervention immediately after intervention took place	- Modified NOTECHS; NTS including communication, leadership, teamwork, problem solving, situation awareness and confidence in performing emergency procedure (+) - Participant survey
[14]	Checklist implementation within the EHR	Personnel was informed of the upcoming changes during regular meetings. Participants were trained to use EHR correctly and explained why management deemed it important to patient safety. This was followed by technical support two weeks after implementation.	*Not mentioned*	Improving checklist adherence and patient outcomes	Longitudinal study, Pre-intervention about compliance rate began 4 months before the intervention and lasting 4 months. Perception survey was administred 4 months after, compliance rate 8 months after, perioperative risk events 11 months after	- SSC compliance rate - Perio-operative risk events

Abbreviations:
CRM = Crew Resource Management;
OR = operating room;
WHO SSC = World Health Organization Surgical Safety Checklist;
NTS = non-technical skills;
SOP = Standard operating procedures;
NOTECHS = Oxford Non-Technical Skills Scale;
TAS = trauma management skills;
TeamSTEPPS = Team Strategies and Tools to Enhance Performance and Patient Safety;
MORSim = Multidisciplinary Operating Room Simulation;
BRMI = Behavioural Marker Risk Index;
HOSPC = Hospital Survey on Patient Safety Culture;
MedPACT = Medical Performance Assessment Tool for Communication and Teamwork;
PGY = Postgraduate year;
EHR = Electronic Health Record;
OTAS-S = Observational Teamwork Assessment for Surgery;
(+) = instrument of high reliability;
("NA") = reliability of instrument not mentioned

Effective interventions

Table 5 lists the found effects for the outcome measures non-technical skills, adverse patient outcomes, patient mortality, checklist adherence and other measures such as participant attitudes. Overall, in most studies non-technical skills outcome measures showed an improvement [3, 4, 5, 8, 9, 10, 12, 13] with only 2 studies reporting non-significant results [6,11]. Some studies only reported a mean score improvement for non-technical skills such as for NOTECHS or NOTECHS II [3, 4, 5, 9] whilst some reported improvements on specific dimensions of the NOTECHS or NOTECHS II such as communication, leadership, cooperation, situational awareness and co-ordination [12, 13]. The non-significant improvement in study 6 could be due to the concepts of lean process engineering which participants were familiarized with during the training, do not attribute to an improvement in non-technical skills. An explanation for the non-significant effects found in study 11 might be that participants had to adhere to multiple checklists instead of only the WHO SSC as was the case in other studies. The requirement to adhere to so many protocols might have resulted in an increase in cognitive load, which in turn meant that there were no attentional resources remaining to engage in non-technical skills.

The single study [2] that measured patient mortality found no significant reduction after the intervention, and of the seven studies that measured adverse patient outcomes [1, 2, 3, 5, 6, 10, 14] only three studies reported a significant improvement when preventing adverse events [2, 10, 14]. Therefore, the relationship between improved non-technical skills and positive patient outcomes, such as reduced frequency of major adverse events and patient mortality, is not so strong as previously claimed.

When improving checklist adherence was one of the study objectives [1, 3, 5, 6, 11, 14], adherence on checklists did not improve significantly in half of the studies [1, 6, 11]. This can be explained that the adherence to checklist can already be part of the hospital policy. Nevertheless, the quality of adhering to a checklist, such as the quality of time-outs in according with the World Health Organisation Surgical Safety Checklist, did improve [6, 7, 10].

Finally, some studies recorded the attitudes of participants regarding the intervention to improve NTS [4, 9, 11, 12, 13] including usefulness, preference over regular NTS training, and relation to daily experiences. It is noteworthy that participants rated the interventions favourably [4, 9, 11, 12, 13]. This was regardless of intervention form and whether the results found were significant or not. From the results of these participants' surveys it can be

concluded that participants have positive attitudes towards interventions aimed at improving non-technical skills.

Table 5. Effectiveness of interventions on measures including NTS, major adverse events, mortality, checklist adherence and other measures.

Study	Non-technical skills	Major adverse events	Mortality	Checklist Adherence	Other measures
1	N.A.	Major event occurrence: difference between intervention and control hospitals N.S.	N.A.	Intervention hospitals; checklist fulfilled N.S, Control hospitals; checklist fulfilled N.S	N.A.
2	N.A.	Complication rate** Length of stay*[1]	Patient death N.S.	N.A.	N.A.
3	NOTECHS II score*	Glitch count*[1] Patient outcomes N.S.		WHO SSC adherence**	N.A.
4	Medium-fidelity compared to control; NOTECHS*[1] TAS*[1] High fidelity compared to control; NOTECHS*[1] TAS*[1] Difference between high- and medium fidelity N.S.	N.A.	N.A.	CRM score between groups N.S.	Self-efficacy scores between groups N.S. Participants rated the course favourably

5	NOTECHS II score*	Glitch count** Length of stay N.S., Complication rate between groups* but in opposite direction, Readmission rate N.S.	N.A.	WHO SSC adherence**	N.A.
6	NOTECHS II score N.S.	Glitch rate ** Complications between groups N.S. Length of stay between groups N.S. Readmission rate between groups N.S.	N.A.	WHO Time-out attempt N.S. WHO quality of time-out *	N.A.
7	N.A.	N.A.		Number of briefings and debriefings N.S. CRM checklist score briefings* CRM checklist score debriefings**	N.A.
8	BRMI score**	N.A.	N.A.	N.A.	N.A.
9	NOTECHS II score**	N.A.	N.A.	N.A.	Participants rated the course favourably

10	HOSPC; Non-punitive response to errors* Overall safety perception** Teamwork across units** Supervisor expectations and actions* MedPACT; Communciation** Leadership** Mutual support** Situation monitoring**	Unplanned/acurate re-operations* post-intervention period Unplanned readmissions*	N.A.	Team formation** Pre-op huddle (time-out)** Post-up huddle (closing)**	N.A.
11	Overall TEAM Score N.S.	N.A.	N.A.	Medical management N.S.	Participants rated the course favourably
12	Communication** Coordination** Cooperation** Leadership** Situational awareness**	N.A.		N.A.	Participants rated the course favourably

13	PGY-2; Communication* Leadership** Teamwork** Confidence* Decision making N.S. Situational awareness N.S. PGY-1 Communication N.S. Leadership N.S. Teamwork N.S. Confidence N.S. Decision making N.S. Situational awareness N.S.	N.A.	N.A.	N.A.	Participants rated the course favourably
14	N.A.	Overall incidence of perioperative risk events**	N.A.	Overall compliance rate**	N.A.

Abbreviations:
NTS = non-technical skills
NA = not applicable
N.S = non-significant difference
* = p <.05
** = p <.01
*[1] = significant difference but P not specified

Overview of used Behavioural Change Techniques (BCTs)

Table 6 included the matrix with the behaviour change techniques (BCTs) listed per study. The most frequently used BCTs are shaping knowledge 1-6, 10, 11, 12, 13, 14], repetition and substitution [1, 3-5, 8 -13] and goals and planning [3, 4, 6, 7, 8, 9, 11, 12, 13].

Regarding studies that measured non-technical skills [3 - 6, 8, 9 -13], the most frequently used BCTs were repetition and substitution and goals and planning, both used in 9 out of 10 studies. The third most frequently used BCT was shaping knowledge, used in 7 out of 10 studies. The use of repetition and substitution, goals and planning and shaping knowledge seems promising for improving non-technical skills, as most of these studies found a significant improvement. However, the studies that found no significant improvement on non-technical skills [6, 11] also made use of repetition and substitution, goals and planning and shaping knowledge. Shaping knowledge and goals and planning was used in both studies, whilst repetition and substation was only used in study 11. Therefore, even though certain BCTs can be effective and can realise improvements, they do not guarantee an improvement on instruments that measure non-technical skills.

Table 6. List of used behavioural change techniques (BCTs) in studies, along with frequency.

Behavioural Change Technique (BCT)	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]
Comparison of outcomes	x		x		x				x					
Shaping knowledge	x	x	x		x	x				x	x	x	x	x
Repetition and substitution	x		x	x	x			x	x	x	x	x	x	
Feedback and monitoring	x						x				x	x	x	
Comparison of behaviour			x		x					x		x		
Reward and threat			x	x			x							
Goals and planning			x	x		x	x	x	x		x	x	x	
Natural consequences				x		x	x	x				x		x
Social support		x		x		x	x			x	x	x		x

Discussion

The aim of this study was to identify digital and non-digital interventions aimed to improve non-technical skills of health professionals in multidisciplinary surgical teams, and to analyse components of these interventions in terms of target learning outcomes and behaviours, behaviour change techniques (BCTs) and persuasive design principles (PSD). In this scoping review, non-technical skills were improved in the majority of the study making use of a variety of methods. These methods included group didactic training, simulation training and checklist implementation which was often combined with coaching. Although non-technical skills were improved in a majority of studies, checklist adherence did only improve in half of the studies and patient outcomes were improved in a minority of the studies. The most used BCTs are shaping knowledge, behaviour repetition and substitution, and goals and planning. However, the use of these BCTs does not guarantee improvement in non-technical skills, and it seems other factors could be in play when an intervention is delivered. No digital interventions were found.

The frequent use of repetition and substitution as well as goals and planning can be explained by the fact that non-technical skills mostly encompass interpersonal skills (such as teamwork and leadership). It makes sense that these can only be trained by “doing”. Although repetition and substitution, goals and planning and shaping knowledge were the most frequently used BCTs in this study, not all studies that measured non-technical skills reported significant improvements. This can be due to the fact that not only the content of the intervention but also the way in which the intervention is delivered are at least equally important (Kolehmainen & Francis, 2012). Another explanation is that non-technical skills are partially acquired via informal learning situations. Informal learning situations are learning moments in less structured environments which happen partly unconsciously, versus formal learning situations that know a clear start and end point and predefined learning goals (de Feijter, de Grave, Koopmans & Scherpbier, 2013). It is estimated that 80 per cent of general learning occurs in informal learning situations (de Feijter et al., 2013) and it is plausible that non-technical skills are also partly acquired via this method.

Furthermore, whilst earlier scientific research found that patient outcomes such as adverse complications during surgery and patient mortality was correlated with a shortage of non-technical skills (Alken et al., 2018b), this review found no evidence to support this conclusion. The relation between non-technical skills and adverse patient outcomes might therefore be more complex than assumed. Other factors cited to facilitate or hinder patient

outcomes include availability of resources, patient co-operation and socio-demographic variables (Mosadeghrad, 2014). These factors might have a greater share of influence on patient outcomes than non-technical skills. Another explanation is that 50 per cent of complications occur in the perioperative setting (Panesar, Carson-Stevens, Mann, Bhandari & Madhok, 2012), whereas the interventions in this scoping review aimed at surgical teams in the operating room. Earlier research has already hypothesised that a reduction in major adverse events and patient mortality might not occur because the interventions do not target the population largely responsible for these outcomes (Leuschner, Leuschner, Kropf & Niederbichler, 2019).

Study strengths and limitations

The present report is the first review that lists interventions to increase non-technical skills with a focus on digital interventions. Furthermore, this is the first review that attempts to identify behaviour change techniques used during the intervention, with the aim of identifying effective techniques to improve non-technical skills. Nevertheless this review has several limitations. It should be noted that the literature search and classifying of BCTs was only done by the author. Despite the use of theoretical frameworks with the PICOC framework for the literature search and the BCT taxonomy (Michie et al., 2013) for classifying BCTs, the selection and classification remains a matter of subjective interpretation. Furthermore, due to time constraints, only three search engines were consulted. Studies that were relevant for this review were potentially not included as they were not in the database of these three search engines. Moreover, although most of the studies found significant improvement on non-technical skills, improvements in patient outcomes including adverse patient events and patient mortality occurred in a minority of the studies. This could be due to the low incidence of major adverse events and patient mortality in general (Everett et al., 2017). The small sample size in most studies could have resulted in a lower statistical power, which makes it more difficult to measure with adequate precision whether a procedure-specific outcome is found or not (Birkmeyer, Dimick, & Birkmeyer, 2004). During the literature search of this scoping review, no digital interventions were found. This is disappointing, especially as there has been increasing awareness that eHealth has potential to improve the doctor-patient relationship (Felizardo et al., 2014). Despite this increasing awareness, no attention is given to the potential these eHealth applications might have for healthcare workers themselves. Finally, during the classification of the BCTs it became evident that the contents of the intervention such as the exact skills trained, and the exact

content of the instructional courses and videos was often not clear, although BCTs could be identified by the intervention design. This is in line with the findings of Gordon and colleagues (2012), who stated that the description of the interventions is poor. Since the BCT taxonomy also focuses on techniques delivered within the content of the intervention, this review was unable to determine the "effective" ingredients of the contents of the intervention.

Practical implications for further research

The finding that no effective BCTs were found that improved non-technical skills can be useful for developers of interventions; it shows that the mere adoption of BCTs is not enough to guarantee effective interventions aimed at improving non-technical skills. As stated before, the delivery of the intervention might be just as important (Kolehmainen & Francis, 2012). Therefore, it is important that intervention designers do not only consider which BCTs they want to employ, but also how these BCTs are designed within the intervention. Moreover, the findings of this review demonstrate that there are multiple ways in which intervention designers can deliver BCTs as the most popular intervention forms at present – didactic training, simulation training, checklist implementation and coaching. These are all valid methods that can attribute to improved non-technical skills. However, there is still a need for intervention designers to explore the potential of eHealth regarding training of non-technical skills and that interventions using eHealth need to be developed.

Recommendations for further research

As was recommended by Gordon and colleagues (2012), intervention designers of future studies should clarify the exact content of their intervention, more specifically which BCTs were used in the intervention design. Clearly defined intervention content and BCTs might enable more objective forms of reviewing interventions such as fractional factorial design studies. Fractional factorial design studies "allow to study the most important factors or process/design parameters that influence critical quality characteristics" (Antony, 2014). When studies clearly describe which BCTs have been used, fractional factorial design in turn can help identify which BCTs attribute the most to the effectiveness of an intervention. This will help design more cost-effective interventions by removing redundant BCTs that have no effect on the effectiveness.

This scoping review did not find sufficient evidence that interventions aimed at improving non-technical skills also managed to achieve more positive patient outcomes such as a reduction in major adverse events and patient mortality, with only a minority of the

studies measuring patient outcomes reporting improvements. A reason for this could be the low frequency of major adverse events and mortality, which might have resulted in a lower statistical power. It is recommended that future studies re-examine this hypothesis by measuring over a longer period of time and with more participants. It is also worthwhile to examine whether other factors that might facilitate or hinder patient outcomes (Mosadeghrad, 2014) do indeed play a bigger role in influencing patient outcomes than non-technical skills.

Furthermore, this scoping review demonstrates that there is still a lack of studies that explore the possibilities of digital interventions which should be addressed in further research, especially considering the benefits that eHealth can bring (Van Gemert-Pijnen et al., 2013). The cost-effectiveness, the negation of the attitude that intervention changing behaviours are a threat to autonomy due to the focus on self-empowerment, and the easy integration with daily activities have already been discussed. Furthermore, eHealth could be beneficial for improving non-technical skills when eHealth interventions are developed with the user as the focal point (Van Velsen, Wentzel, & Van Gemert-Pijnen, 2013). Whereas CRM and simulation training focus on the surgical group as the unit, surgery teams are often interdisciplinary with multiple professions interacting with one another. Due to the user being consulted during the development of an eHealth application (van Velsen et al., 2013), eHealth has the unique advantage that the intervention can be tailored to match the need of the specific surgical role. An interesting study proposal is exploring the possibilities of virtual reality (VR) when it comes to training of non-technical skills. VR is defined as "computer-generated imagery that emulates a training environment using three-dimensional (3D) graphics, sounds and a sense of touch" (Rafiq, Tamariz, Boanca, Lavrentyev, & Merrell, 2008). Although users are aware that they are not physically located in the virtual space, they might behave and think as if they are (Dargar, Kennedy, Lai, Arikatla, & De, 2015) and it is possible that a VR environment of an operating room might evoke the same responses and therefore learning processes as a fully equipped high-fidelity OR simulation would. One of the advantages that a VR learning environment might have is saving a significant amount of financial resources: instead of supplying the physical space, instruments and patient simulators can all be implemented in the software used for the intervention. Furthermore, when a VR intervention has an online component, surgical teams from all over the world can collaborate to exchange and increase knowledge regarding surgical procedures in an immersive, standardized 3D environment. One of the biggest issues with current simulation training is that it requires significant organisational resources (Alken et al., 2018a): this can be partially solved with a VR intervention that makes use of the internet. Trainees can connect with and learn advanced

skills from surgical experts who work in another hospital, which can also help decrease the strain on resources as in-house experience and material are not required for training. Digital interventions need to be more engaging to increase general effectiveness (Short et al., 2018) and should be persuasive to increase adoption of the intervention and reaching its goal (Van Gemert-Pijnen et al., 2018). VR training might be able to address both these concerns. Virtual reality is unique in that it matches the needs of the adult learner. Adult learners require an engaging task that enables self-directed learning, as well as the capacity to relate the task to previous experiences and immediate outcomes in order to stimulate learning. VR fulfills those needs by allowing learners to interact with the environment and have control over it (Piromchai, Avery, Laopaiboon, Kennedy, & O'Leary, 2015). Moreover, it also gives VR an advantage over didactic training as the student is no longer required to enter the teaching environment with a willingness to learn (Bryan, Kreuter, & Brownson, 2008). In other words, VR creates the motivation instead of requiring it from learners. It is evident that VR has the requirements for an effective digital intervention by being engaging and making the user the focal point of the intervention, and it addresses common barriers of the most popular training methods that were found in previous scientific literature and this scoping review. It is worthwhile for researchers and intervention designers to explore its possibilities to improve non-technical skills in the operating room rather than strengthening current evidence.

Future studies need to test the hypothesis that VR indeed has advantages over didactic and current simulation training as this review suggests. Moreover, as most of the studies employing VR interventions for surgical teams focus on technical skills (Haque & Srinivasan, 2006) there are unanswered questions on how to develop a VR study that is designed to improve non-technical skills. Issues such as whether a computer-controlled or learner-controlled colleagues is more effective, and whether the teacher should be present as an avatar or take the role of an “observer” controlling the environment needs to be addressed. Finally, as eHealth interventions often lack solid business cases preventing implementation (Van Limburg & Van Gemert-Pijnen, 2011), cost analyses with comparison to current interventions is needed. Especially with healthcare costs on the rise (Van Gemert-Pijnen et al., 2013), this question will become more important for intervention designers in the future.

This scoping review with its focus on digital interventions highlights that there is still much to be gained when exploring interventions aimed at improving non-technical skills in the digital field. Whilst non-technical skills have clearly and increasingly been brought to attention in the recent years, not exploring this gap in literature would be a disservice to the

curiosity and the creativity of various researchers and intervention designers, who strive to improve non-technical skills within the operating room.

List of References

Alken, A., Fluit, L., Luursema, J-M., & Goor, H. (2018a). Integrating technical and nontechnical skills in hands-on surgical training. In G. Tsoulfas (Eds.), *Medical and Surgical Education - Past, Present and Future.* London, United Kingdom: IntechOpen.

Alken, A., Luursema, J-M., Weenk, M., Yauw, S., Fluit, C., & van Goor, H. (2018b). Integrating technical and non-technical skills coaching in an acute trauma surgery team training: Is it too much? *The American Journal of Surgery, 216*(2), 369-374. doi:https://doi.org/10.1016/j.amjsurg.2017.08.011

Amaya-Arias, A. C., Idarraga, D., Giraldo, V., & Gómez, L. M. (2015). Effectiveness of a program for improving teamwork in operanting rooms. *Revista Colombiana de Anestesiologia, 43*(1), 68-75. doi: https://doi.org/10.1016/j.rcae.2014.10.002

Antony, J. (2014). Fractional factorial designs. In J. Antony (Eds.), *Design of Experiments for Engineers and Scientists* (2nd ed.), (pp. 87-112). Amsterdam, Netherlands: Elsevier.

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. doi:10.1080/1364557032000119616

Birkmeyer, J. D., Dimick, J. B., & Birkmeyer, N. J. (2004). Measuring the quality of surgical care: structure, process, or outcomes? *J Am Coll Surg, 198*(4), 626-632. doi:10.1016/j.jamcollsurg.2003.11.017

Brewin, J., Tang, J., Dasgupta, P., Khan, M. S., Ahmed, K., Bello, F., . . . Jaye, P. (2015). Full immersion simulation: validation of a distributed simulation environment for technical and non-technical skills training in urology. *BJU International, 116*(1), 156-162. doi:10.1111/bju.12875

Bryan, R. L., Kreuter, M. W., & Brownson, R. C. (2008). Integrating adult learning principles into training for public health practice. *Health Promotion Practice, 10*(4), 557-563. doi:10.1177/1524839907308117

Castel, E. S., Ginsburg, L. R., Zaheer, S., & Tamim, H. (2015). Understanding nurses' and physicians' fear of repercussions for reporting errors: clinician characteristics, organization demographics, or leadership factors? *BMC Health Services Research, 15*(1), 326. doi:10.1186/s12913-015-0987-9

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159. doi:10.1037/0033-2909.112.1.155

Cooper, S., Endacott, R., & Cant, R. (2010). Measuring non-technical skills in medical emergency care: a review of assessment measures. *Open Access Emergency Medicine: OAEM, 2*, 7-16. doi:10.2147/oaem.s6693

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*(1), 98-104. doi:10.1037/0021-9010.78.1.98

Courtenay, M., Nancarrow, S., & Dawson, D. (2013). Interprofessional teamwork in the trauma setting: a scoping review. *Human Resources for Health, 11*(1), 57. doi:10.1186/1478-4491-11-57

Dargar, S., Kennedy, R., Lai, W., Arikatla, V., & De, S. (2015). Towards immersive virtual reality (iVR): A route to surgical expertise. *J Comput Surg, 2*. doi:10.1186/s40244-015-0015-8

de Feijter, J.M., de Grave, W.S., Koopmans, R.P., & Scherpbier, A.J.J.A. (2013). Informal learning from error in hospitals: what do we learn, how do we learn and how can informal learning be enhanced? A narrative review. *Adv in Health Sci Educ, 18*, 787-805. doi:10.1007/s10459-012-9400-1

Duclos, A., Peix, J. L., Piriou, V., Occelli, P., Denis, A., Bourdy, S., . . . Colin, C. (2016). Cluster randomized trial to evaluate the impact of team training on surgical outcomes. *Br J Surg, 103*(13), 1804-1814. doi:10.1002/bjs.10295

Everett, T. C., Morgan, P. J., Brydges, R., Kurrek, M., Tregunno, D., Cunningham, L., . . . Tarshis, J. (2017). The impact of critical event checklists on medical management and teamwork during simulated crises in a surgical daycare facility. *Anaesthesia, 72*(3), 350-358. doi:10.1111/anae.13683

Felizardo, V., Sousa, P., Sabugueiro, D., Alexandre, C., Couto, R., Garcia, N., & Pires, I. (2014). E-health: Current status and future trends. In E. Kajan, D. Randjelovic, B. Stojanovic, C. Dolicanin, & E. Dolianin (Eds.), *Handbook of Research on Democratic Strategies and Citizen-Centered E-Government Services (Advances in Electronic Government, Digital Divide, and Regional Development)*, (pp. 302-326). Hershey, PA: IGI Global.

Gitelis, M. E., Kaczynski, A., Shear, T., Deshur, M., Beig, M., Sefa, M., . . . Ujiki, M. (2017). Increasing compliance with the World Health Organization Surgical Safety Checklist - A regional health system's experience. *Am J Surg, 214*(1), 7-13. doi:10.1016/j.amjsurg.2016.07.024

Gordon, M., Darbyshire, D., & Baker, P. (2012). Non-technical skills training to enhance patient safety: a systematic review. *Med Educ, 46*(11), 1042-1054. doi:10.1111/j.1365-2923.2012.04343.x

Gostlow, H., Marlow, N., Thomas, M. J. W., Hewett, P. J., Kiermeier, A., Babidge, W., . . . Maddern, G. (2017). Non-technical skills of surgical trainees and experienced surgeons. *British Journal of Surgery, 104*(6), 777-785. doi: https://doi.org/10.1002/bjs.10493

Greenberg, C. C., Regenbogen, S. E., Studdert, D. M., Lipsitz, S. R., Rogers, S. O., Zinner, M. J., & Gawande, A. A. (2007). Patterns of communication breakdowns resulting in injury to surgical patients. *J Am Coll Surg, 204*(4), 533-540. doi:https://doi.org/10.1016/j.jamcollsurg.2007.01.010

Greenhalgh, T., & Peacock, R. (2005). Effectiveness and efficiency of search methods in systematic reviews of complex evidence: audit of primary sources. *BMJ, 331*(7524), 1064-1065. doi:10.1136/bmj.38636.593461.68

Haerkens, M. H. T. M., Kox, M., Lemson, J., Houterman, S., van der Hoeven, J. G., & Pickkers, P. (2015). Crew Resource Management in the intensive care unit: a prospective 3-year cohort study. *Acta Anaesthesiol Scand, 59*(10), 1319-1329. doi:10.1111/aas.12573

Haller, G., Garnerin, P., Morales, M.-A., Pfister, R., Berner, M., Irion, O., . . . Kern, C. (2008). Effect of Crew Resource Management training in a multidisciplinary obstetrical setting. *International Journal for Quality in Health Care, 20*(4), 254-263. doi:10.1093/intqhc/mzn018

Haque, S., & Srinivasan, S. (2006). A meta-analysis of the training effectiveness of virtual reality surgical simulators. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society, 10*, 51-58. doi:10.1109/TITB.2005.855529

Haugen, A. S., Søfteland, E., Almeland, S. K., Sevdalis, N., Vonen, B., Eide, G. E., . . . Harthug, S. (2015). Effect of the World Health Organization Checklist on patient outcomes: a stepped wedge cluster randomized controlled trial. *Ann Surg, 261*(5), 821-828. doi:10.1097/sla.0000000000000716

He, W., Ni, S., Chen, G., Jiang, X., & Zheng, B. (2014). The composition of surgical teams in the operating room and its impact on surgical team performance in China. *Surg Endosc, 28*(5), 1473-1478. doi:10.1007/s00464-013-3318-4

Helmreich, R. L. (2000). On error management: lessons from aviation. *BMJ, 320*(7237), 781-785. doi:10.1136/bmj.320.7237.781

Hollands, M. J. (2013). Providing non-technical skills for surgeons. *Med J Aust, 198*(8), 400-401.

Kleiner, C., Link, T., Maynard, M. T., & Halverson Carpenter, K. (2014). Coaching to improve the quality of communication during briefings and debriefings. *Aorn j, 100*(4), 358-368. doi:10.1016/j.aorn.2014.03.012

Kolehmainen, N., & Francis, J. J. (2012). Specifying content and mechanisms of change in interventions to change professionals' practice: an illustration from the Good Goals study in occupational therapy. *Implementation Science, 7*(1), 100. doi:10.1186/1748-5908-7-100

Kulendran, M., Lim, M., Laws, G., Chow, A., Nehme, J., Darzi, A., & Purkayastha, S. (2014). Surgical smartphone applications across different platforms: their evolution, uses, and users. *Surgical Innovation, 21*(4), 427-440. doi:10.1177/1553350614525670

Leape, L. L., & Berwick, D. M. (2005). Five years after to err is human: What have we learned? *JAMA, 293*(19), 2384-2390. doi:10.1001/jama.293.19.2384

Leuschner, S., Leuschner, M., Kropf, S., & Niederbichler, A.D. (2019). Non-technical skills training in the operating theatre: a meta-analysis of patient outcomes. *The Surgeon, 17*(4), 233-243. doi: https://doi.org/10.1016/j.surge.2018.07.001

Lindamood, K., Rachwal, C., Kappus, L., Weinstock, P., & Doherty, E. (2011). Development of a neonatal intensive care multidisciplinary Crisis Resource Training program. *Newborn and Infant Nursing Reviews, 11*, 17-22. doi:10.1053/j.nainr.2010.12.011

Michie, S., Johnston, M., Francis, J., Hardeman, W., & Eccles, M. (2008). From theory to intervention: mapping theoretically derived behavioural determinants to behaviour change techniques. *Applied Psychology: An International Review, 57*(4). 660-680. doi:10.1111/j.1464-0597.2008.00341.x

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., . . . Wood, C. E. (2013). The Behavior Change Technique Taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine, 46*(1), 81-95. doi:10.1007/s12160-013-9486-6

Mishra, A., Catchpole, K., & McCulloch, P. (2009). The Oxford NOTECHS System: reliability and validity of a tool for measuring teamwork behaviour in the operating theatre. *Qual Saf Health Care, 18*(2), 104-108. doi:10.1136/qshc.2007.024760

Morgan, L., Hadi, M., Pickering, S., Robertson, E., Griffin, D., Collins, G., . . . New, S. (2015a). The effect of teamwork training on team performance and clinical outcome in elective orthopaedic surgery: a controlled interrupted time series study. *BMJ Open, 5*(4), e006216. doi:10.1136/bmjopen-2014-006216

Morgan, L., Pickering, S. P., Hadi, M., Robertson, E., New, S., Griffin, D., . . . McCulloch, P. (2015b). A combined teamwork training and work standardisation intervention in operating theatres: controlled interrupted time series study. *BMJ Qual Saf, 24*(2), 111-119. doi:10.1136/bmjqs-2014-003204

Mosadeghrad, A. M. (2014). Factors affecting medical service quality. *Iran J Public Health, 43*(2), 210-220. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4450689/

Nicksa, G. A., Anderson, C., Fidler, R., & Stewart, L. (2015). Innovative approach using interprofessional simulation to educate surgical residents in technical and nontechnical skills in high-risk clinical scenarios. *JAMA Surg, 150*(3), 201-207. doi:10.1001/jamasurg.2014.2235

Oh, H., Rizo, C., Enkin, M., & Jadad, A. (2005). What is eHealth (3): a systematic review of published definitions. *Journal of Medical Internet research, 7*(1), e1. doi:10.2196/jmir.7.1.e1

Oinas-Kukkonen, H., & Harjumaa, M. (2008). A systematic framework for designing and evaluating persuasive systems. In H. Oinas-Kukkonen, P. Hasle, M. Harjumaa, K. Segerståhl, P. Øhrstrøm (Eds.), *Persuasive Technology. PERSUASIVE 2008. Lecture Notes in Computer Science*, vol 5033. Berlin/Heidelberg, Germany: Springer.

Ounounou, E., Aydin, A., Brunckhorst, O., Khan, M. S., Dasgupta, P., & Ahmed, K. (2019). Nontechnical skills in surgery: a systematic review of current training modalities. *J Surg Educ, 76*(1), 14-24. doi:10.1016/j.jsurg.2018.05.017

Panesar, S.S., Carson-Stevens, A., Mann, B.S., Bhandari, M., & Madhok, R. (2012). Mortality as an indicator of patient safety in orthopaedics: lessons from qualitative analysis of a database of medical errors. *BMC Musculoskeletal Disorders, 13.* doi:10.1186/1471-2474-13-93

Piromchai, P., Avery, A., Laopaiboon, M., Kennedy, G., & O'Leary, S. (2015). Virtual reality training for improving the skills needed for performing surgery of the ear, nose or throat. *Cochrane Database of Systematic Reviews,* (9). doi:10.1002/14651858.CD010198.pub2

Pizzi, L., Neil, P., Goldfarb, I., & Nash, D. (2001). Crew Resource Management and its application in medicine. In K.G Shojanja, B.W. Duncan, K.M McDonald & R.M. Wachter (Eds.), *Making Health Care Safer: A Critical Analysis of Patient Safety Practices. Evidence Report/Technology Assessment*. Rockville, MD: AHRQ.

Rafiq, A., Tamariz, F., Boanca, C., Lavrentyev, V., & Merrell, R. C. (2008). Objective assessment of training surgical skills using simulated tissue interface with real-time feedback. *J Surg Educ, 65*(4), 270-274. doi:https://doi.org/10.1016/j.jsurg.2008.05.012

Räisänen, T., Lehto, T., & Oinas-Kukkonen, H. (2010). Practical findings from applying the PSD model for evaluating software design specifications. In T. Ploug, P. Hasle, & H. Oinas-Kukkonen (Eds.), *Persuasive Technology. PERSUASIVE 2010. Lecture Notes in Computer Science*, vol 6137. Berlin/Heidelberg, Germany: Springer.

Rao, R., Caskey, R. C., Owei, L., O'Connor, K., Riddle, E., Dempsey, D. T., . . . Dumon, K. (2017). Curriculum using the in-situ operating room setting. *J Surg Educ, 74*(6), e39-e44. doi:10.1016/j.jsurg.2017.09.024

Ricci, M. A., & Brumsted, J. R. (2012). Crew Resource Management: Using aviation techniques to improve operating room safety. *Aviation, Space, and Environmental Medicine, 83*(4), 441-444. doi:10.3357/ASEM.3149.2012

Robertson, E. R., Hadi, M., Morgan, L. J., Pickering, S. P., Collins, G., New, S., . . . Catchpole, K. C. (2014). Oxford NOTECHS II: a modified theatre team non-technical skills scoring system. *PLoS ONE, 9*(3), e90320-e90320. doi:10.1371/journal.pone.0090320

Robertson, E. R., Morgan, L., New, S., Pickering, S., Hadi, M., Collins, G., . . . McCulloch, P. (2015). Quality improvement in surgery combining lean improvement methods with teamwork training: a controlled before-after study. *PLoS ONE, 10*(9), e0138490. doi:10.1371/journal.pone.0138490

Ryan, R., Hill, S., Prictor, M., & McKenzie J. (2013). Cochrane Consumers and Communication Review Group. *Study Quality Guide*. Retrieved from https://cccrg.cochrane.org/

Santos, C. M. d. C., Pimenta, C. A. d. M., & Nobre, M. R. C. (2007). The PICO strategy for the research question construction and evidence search. *Revista Latino-Americana de Enfermagem, 15*, 508-511. doi: http://dx.doi.org/10.1590/S0104-11692007000300023

Savage, C., Gaffney, F. A., Hussain-Alkhateeb, L., Olsson Ackheim, P., Henricson, G., Antoniadou, I., . . . Pukk Harenstam, K. (2017). Safer paediatric surgical teams: A 5-year evaluation of crew resource management implementation and outcomes. *Int J Qual Health Care, 29*(6), 853-860. doi:10.1093/intqhc/mzx113

Sevdalis, N. (2013). *Non-technical skills and the future of teamwork in healthcare settings*. Retrieved from https://www.researchgate.net/publication/264622634_Non-technical_skills_and_the_future_of_teamwork_in_healthcare_settings

Short, C. E., DeSmet, A., Woods, C., Williams, S. L., Maher, C., Middelweerd, A., . . . Crutzen, R. (2018). Measuring engagement in eHealth and mHealth behavior change interventions: viewpoint of methodologies. *Journal of medical Internet research, 20*(11), e292. doi:10.2196/jmir.9397

Sparks, J. L., Crouch, D. L., Sobba, K., Evans, D., Zhang, J., Johnson, J. E., . . . Hildreth, A. (2017). Association of a surgical task during training with team skill acquisition among surgical residents: the missing piece in multidisciplinary team training. *JAMA Surg, 152*(9), 818-825. doi:10.1001/jamasurg.2017.1085

van Gemert-Pijnen, L. J. E. W. C. ., Kelders, S. M., Beerlage-de Jong, N., & Oinas-Kukkonen, H. (2018). Persuasive health technology. In L. van Gemert-Pijnen, S. M. Kelders, H. Kip, & R. Sanderman (Eds.), *eHealth Research, Theory and Development: A Multi-Disciplinary Approach.* London, United Kingdom: Routledge.

van Gemert-Pijnen, L. J. E. W. C., Peters, O., & Ossebaard, H. C. (2013). *Improving ehealth*. The Hague: Eleven International Publishing.

van Limburg, M. A. H., & van Gemert-Pijnen, J. E. W. C. (2011). Introducing eHealth business modelling instruments for implementing eHealth technologies based on a integrated approach with human-centered design. In L. van Gemert-Pijnen, H. C. Ossebaard, & P. Hämäläinen (Eds.), *eTELEMED 2011, The Third International Conference on eHealth, Telemedicine, and Social Medicine* (pp. 134-139). (eTELEMED, The International Conference on eHealth, Telemedicine, and Social Medicine; Vol. 2011). IARIA/Thinkmind.

van Velsen, L., Wentzel, J., & van Gemert-Pijnen, J.E.W.C. (2013). Designing eHealth that matters via a multidisciplinary requirements development approach. *JMIR Res Protoc, 2*(1), e21. doi:10.2196/resprot.2547

Weller, J. M., Cumin, D., Civil, I. D., Torrie, J., Garden, A., MacCormick, A. D., . . . Merry, A. F. (2016). Improved scores for observed teamwork in the clinical environment

following a multidisciplinary operating room simulation intervention. *N Z Med J, 129*(1439), 59-67.

Young, C., Campolonghi, S., Ponsonby, S., Dawson, S. L., O'Neil, A., Kay-Lambkin, F., . . . Jacka, F. N. (2019). Supporting engagement, adherence, and behavior change in online dietary interventions. *Journal of Nutrition Education and Behavior, 51*(6), 719-739. doi:10.1016/j.jneb.2019.03.006

Appendix

Appendix A: search strings used.

PubMed:

(Health Personnel[Mesh] OR surgeon OR anesthesiologist OR nurse OR surgical team OR operating team OR operation team OR “healthcare staff” OR “operating room staff”) AND (“behavioral change techniques” OR BCT OR “digital behavioural change interventions” OR Crew Resource Management OR CRM OR Telemedicine[Mesh] OR Electronic medicine OR electronic health OR eCoaching OR simulations OR training OR program* OR strategy OR virtual reality[Mesh]) AND (“non-technical skills” OR non-technical* OR Nontechnical* OR Social Skills[Mesh] OR leadership OR communication OR decision making OR “situational awareness” OR teamwork OR environment knowledge OR anticipation and planning OR “call for help early” OR workload distribution OR resource mobilization OR effective communication OR information usage OR information utilization OR fixation error prevention OR fixation error management OR “cross check” OR “use cognitive aids” OR attention allocation OR dynamic priority setting OR “exercise leadership and followership” OR “re-evaluate repeatedly”) AND (Operating Room[Mesh] OR “surgery rooms” OR “operating theatre” OR “operation room”) NOT (qualitative OR subjective OR Interview OR Study proposal OR Correlation) AND "last 5 years"[PDat] AND Humans[Mesh])) AND English[lang])

Psycinfo:

(Health Personnel[Mesh] OR surgeon OR anesthesiologist OR nurse OR surgical team OR operating team OR operation team OR “healthcare staff” OR “operating room staff”) AND (“behavioral change techniques” OR BCT OR “digital behavioural change interventions” OR Crew Resource Management OR CRM OR Telemedicine[Mesh] OR Electronic medicine OR electronic health OR eCoaching OR simulations OR training OR program* OR strategy OR virtual reality[Mesh]) AND (“non-technical skills” OR non-technical* OR Nontechnical* OR Social Skills[Mesh] OR leadership OR communication OR decision making OR “situational awareness” OR teamwork OR environment knowledge OR anticipation and planning OR “call for help early” OR workload distribution OR resource mobilization OR effective communication OR information usage OR information utilization OR fixation error prevention OR fixation error management OR “cross check” OR “use cognitive aids” OR

attention allocation OR dynamic priority setting OR “exercise leadership and followership” OR “re-evaluate repeatedly”) AND (Operating Room[Mesh] OR “surgery rooms” OR “operating theatre” OR “operation room”) NOT (qualitative OR subjective OR Interview OR Study proposal OR Correlation)

Scopus:
TITLE-ABS-KEY ("Health Personnel" OR "Personnel, Health" OR "Health Care Providers" OR "Health Care Provider" OR "Provider, Health Care" OR "Providers, Health Care" OR "Healthcare Workers" OR "Healthcare Worker" OR surgeon OR anesthesiologist OR nurse OR "Surgical Team" OR "Operating Team" OR "Operation Team" OR "Healthcare Staff" OR "Operating Room Staff") AND TITLE-ABS-KEY ("behavioral change techniques" OR bct OR "digital behavioural change interventions" OR "Crew Resource Management" OR crm OR telemedicine OR "Mobile Health" OR "Health, Mobile" OR mhealth OR telehealth OR ehealth OR "Electronic Medicine" OR "Electronic Health" OR ecoaching OR simulations OR training OR program* OR strategy OR "Virtual Reality" OR "Reality, Virtual" OR "Virtual Reality, Educational" OR "Educational Virtual Realities" OR "Educational Virtual Reality" OR "Reality, Educational Virtual" OR "Virtual Realities, Educational" OR "Virtual Reality, Instructional" OR "Instructional Virtual Realities" OR "Instructional Virtual Reality" OR "Realities, Instructional Virtual" OR "Reality, Instructional Virtual" OR "Virtual Realities, Instructional") AND TITLE-ABS-KEY ("non-technical skills" OR non-technical* OR nontechnical* OR "Social Skills" OR "Skill, Social" OR "Skills, Social" OR "Social Skill" OR "Social Abilities" OR "Abilities, Social" OR "Ability, Social" OR "Social Ability" OR "Interpersonal Skills" OR "Interpersonal Skill" OR "Skill, Interpersonal" OR "Skills, Interpersonal" OR "Social Competence" OR "Competence, Social" OR leadership OR communication OR "Decision Making" OR "Situational Awareness" OR teamwork OR "Environment Knowledge" OR "Anticipation and Planning" OR "Call for help early" OR "Workload Distribution" OR "Resource Mobilization" OR "Effective Communication" OR "Information Usage" OR "Information Utilization" OR "Fixation error prevention" OR "Fixation error management" OR "cross check" OR "use cognitive aids" OR "Attention allocation" OR "Dynamic priority setting" OR "Exercise leadership and followership" OR "re-evaluate repeatedly") AND TITLE-ABS-KEY ("Operating Room" OR "Room, Operating" OR "Rooms, Operating" OR "Surgery Rooms" OR "Operating

Theatre" OR "Operation Room") AND NOT ("qualitative" OR "subjective" OR "Interview" OR "Study proposal" OR "Correlation") AND (LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014))

Appendix B: the BCT taxonomy v1 used for the classification of BCts, by Michie and colleagues (2013).

BCT Taxonomy (v1): 93 hierarchically-clustered techniques

Page	Grouping and BCTs
1	**1. Goals and planning**
	1.1. Goal setting (behavior) 1.2. Problem solving 1.3. Goal setting (outcome) 1.4. Action planning 1.5. Review behavior goal(s) 1.6. Discrepancy between current behavior and goal 1.7. Review outcome goal(s) 1.8. Behavioral contract 1.9. Commitment
3	**2. Feedback and monitoring**
	2.1. Monitoring of behavior by others without feedback 2.2. Feedback on behaviour 2.3. Self-monitoring of behaviour 2.4. Self-monitoring of outcome(s) of behaviour 2.5. Monitoring of outcome(s) of behavior without feedback 2.6. Biofeedback 2.7. Feedback on outcome(s) of behavior
5	**3. Social support**
	3.1. Social support (unspecified) 3.2. Social support (practical) 3.3. Social support (emotional)
6	**4. Shaping knowledge**
	4.1. Instruction on how to perform the behavior 4.2. Information about Antecedents 4.3. Re-attribution 4.4. Behavioral experiments
7	**5. Natural consequences**
	5.1. Information about health consequences 5.2. Salience of consequences 5.3. Information about social and environmental consequences 5.4. Monitoring of emotional consequences 5.5. Anticipated regret 5.6. Information about emotional consequences
8	**6. Comparison of behaviour**
	6.1. Demonstration of the behavior 6.2. Social comparison 6.3. Information about others' approval
9	**7. Associations**
	7.1. Prompts/cues 7.2. Cue signalling reward 7.3. Reduce prompts/cues 7.4. Remove access to the reward 7.5. Remove aversive stimulus 7.6. Satiation 7.7. Exposure 7.8. Associative learning
10	**8. Repetition and substitution**
	8.1. Behavioral practice/rehearsal 8.2. Behavior substitution 8.3. Habit formation 8.4. Habit reversal 8.5. Overcorrection 8.6. Generalisation of target behavior 8.7. Graded tasks
11	**9. Comparison of outcomes**
	9.1. Credible source 9.2. Pros and cons 9.3. Comparative imagining of future outcomes
12	**10. Reward and threat**
	10.1. Material incentive (behavior) 10.2. Material reward (behavior) 10.3. Non-specific reward 10.4. Social reward 10.5. Social incentive 10.6. Non-specific incentive 10.7. Self-incentive 10.8. Incentive (outcome) 10.9. Self-reward 10.10. Reward (outcome) 10.11. Future punishment
15	**11. Regulation**
	11.1. Pharmacological support 11.2. Reduce negative emotions 11.3. Conserving mental resources 11.4. Paradoxical instructions
16	**12. Antecedents**
	12.1. Restructuring the physical environment 12.2. Restructuring the social environment 12.3. Avoidance/reducing exposure to cues for the behavior 12.4. Distraction 12.5. Adding objects to the environment 12.6. Body changes
17	**13. Identity**
	13.1. Identification of self as role model 13.2. Framing/reframing 13.3. Incompatible beliefs 13.4. Valued self-identify 13.5. Identity associated with changed behavior
18	**14. Scheduled consequences**
	14.1. Behavior cost 14.2. Punishment 14.3. Remove reward 14.4. Reward approximation 14.5. Rewarding completion 14.6. Situation-specific reward 14.7. Reward incompatible behavior 14.8. Reward alternative behavior 14.9. Reduce reward frequency 14.10. Remove punishment
19	**15. Self-belief**
	15.1. Verbal persuasion about capability 15.2. Mental rehearsal of successful performance 15.3. Focus on past success 15.4. Self-talk
19	**16. Covert learning**
	16.1. Imaginary punishment 16.2. Imaginary reward 16.3. Vicarious consequences

BCT Taxonomy (v1): 93 hierarchically-clustered techniques

Note for Users

The definitions of Behavior Change Techniques (BCTs):

i) contain verbs (e.g., provide, advise, arrange, prompt) that refer to the action(s) taken by the person/s delivering the technique. BCTs can be delivered by an 'interventionist' or self-delivered

ii) contain the term **"behavior"** referring to a single action or sequence of actions that includes the performance of **wanted** behavior(s) and/or **inhibition** (non-performance) of **unwanted** behavior(s)

iii) note alternative or additional coding where relevant

iv) note the technical terms associated with particular theoretical frameworks where relevant (e.g. 'including implementation intentions)

No.	Label	Definition	Examples
1. Goals and planning			
1.1	***Goal setting (behavior)***	Set or agree on a goal defined in terms of the behavior to be achieved *Note: only code goal-setting if there is sufficient evidence that goal set as part of intervention; if goal unspecified or a behavioral outcome, code **1.3, Goal setting (outcome)**; if the goal defines a specific context, frequency, duration or intensity for the behavior, also code **1.4, Action planning***	Agree on a daily walking goal (e.g. 3 miles) with the person and reach agreement about the goal Set the goal of eating 5 pieces of fruit per day as specified in public health guidelines
1.2	***Problem solving***	Analyse , or prompt the person to analyse, factors influencing the behavior and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes '**Relapse Prevention**' *and '***Coping Planning***'*) *Note: barrier identification without solutions is not sufficient. If the BCT does not include analysing the behavioral problem, consider **12.3, Avoidance/changing exposure to cues for the behavior, 12.1, Restructuring the physical environment, 12.2, Restructuring the social environment,** or **11.2, Reduce negative emotions***	Identify specific triggers (e.g. being in a pub, feeling anxious) that generate the urge/want/need to drink and develop strategies for avoiding environmental triggers or for managing negative emotions, such as anxiety, that motivate drinking Prompt the patient to identify barriers preventing them from starting a new exercise regime e.g., lack of motivation, and discuss ways in which they could help overcome them e.g., going to the gym with a buddy

Back to index page

1.3	***Goal setting (outcome)***	Set or agree on a goal defined in terms of a positive **outcome** of wanted behavior *Note: only code guidelines if set as a goal in an intervention context; if goal is a behavior, code **1.1, Goal setting (behavior)**; if goal unspecified code **1.3, Goal setting (outcome)***	Set a weight loss goal (e.g. 0.5 kilogram over one week) as an outcome of changed eating patterns
1.4	***Action planning***	Prompt detailed planning of performance of the behavior (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive) (includes '**Implementation Intentions**') *Note: evidence of action planning does not necessarily imply goal setting, only code latter if sufficient evidence*	Encourage a plan to carry condoms when going out socially at weekends Prompt planning the performance of a particular physical activity (e.g. running) at a particular time (e.g. before work) on certain days of the week
1.5	***Review behavior goal(s)***	Review behavior goal(s) jointly with the person and consider modifying goal(s) or behavior change strategy in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of (or in addition to) the first, or no change *Note: if goal specified in terms of behavior, code **1.5, Review behavior goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behavior and goal***	Examine how well a person's performance corresponds to agreed goals e.g. whether they consumed less than one unit of alcohol per day, and consider modifying future behavioral goals accordingly e.g. by increasing or decreasing alcohol target or changing type of alcohol consumed
1.6	***Discrepancy between current behavior and goal***	Draw attention to discrepancies between a person's current behavior (in terms of the *form, frequency, duration, or intensity* of that behavior) and the person's previously set outcome goals, behavioral goals or action plans (goes beyond self-monitoring of behavior) *Note: if discomfort is created only code **13.3, Incompatible beliefs** and not **1.6, Discrepancy between current behavior and goal**; if goals are modified, also code **1.5, Review behavior goal(s)** and/or **1.7, Review outcome goal(s)**; if feedback is provided, also code **2.2, Feedback on behaviour***	Point out that the recorded exercise fell short of the goal set

Back to index page

1.7	***Review outcome goal(s)***	Review outcome goal(s) jointly with the person and consider modifying goal(s) in light of achievement. This may lead to re-setting the same goal, a small change in that goal or setting a new goal instead of, or in addition to the first *Note: if goal specified in terms of behavior, code **1.5, Review behavior goal(s)**, if goal unspecified, code **1.7, Review outcome goal(s);** if discrepancy created consider also **1.6, Discrepancy between current behavior and goal***	Examine how much weight has been lost and consider modifying outcome goal(s) accordingly e.g., by increasing or decreasing subsequent weight loss targets
1.8	***Behavioral contract***	Create a written specification of the behavior to be performed, agreed on by the person, and witnessed by another *Note: also code **1.1, Goal setting (behavior)***	Sign a contract with the person e.g. specifying that they will not drink alcohol for one week
1.9	***Commitment***	Ask the person to affirm or reaffirm statements indicating commitment to change the behavior *Note: if defined in terms of the behavior to be achieved also code **1.1, Goal setting (behavior)***	Ask the person to use an "I will" statement to affirm or reaffirm a strong commitment (i.e. using the words "strongly", "committed" or "high priority") to start, continue or restart the attempt to take medication as prescribed
2. Feedback and monitoring			
2.1	***Monitoring of behavior by others without feedback***	Observe or record behavior with the person's knowledge as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given, code only **2.2, Feedback on behavior**, and not **2.1, Monitoring of behavior by others without feedback**; if monitoring outcome(s) code **2.5, Monitoring outcome(s) of behavior by others without feedback**; if self-monitoring behavior, code **2.3, Self-monitoring of behaviour***	Watch hand washing behaviors among health care staff and make notes on context, frequency and technique used

Back to index page

2.2	***Feedback on behavior***	Monitor and provide informative or evaluative feedback on performance of the behavior *(e.g. form, frequency, duration, intensity)* *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and not* ***2.2, Feedback on behavior****; if feedback is on* ***outcome(s)*** *of behavior, code* ***2.7, Feedback on outcome(s) of behavior****; if there is no clear evidence that feedback was given, code* ***2.1, Monitoring of behavior by others without feedback****; if feedback on behaviour is evaluative e.g. praise, also code* ***10.4, Social reward***	Inform the person of how many steps they walked each day (as recorded on a pedometer) or how many calories they ate each day (based on a food consumption questionnaire).
2.3	***Self-monitoring of behavior***	Establish a method for the person to monitor and record their behavior(s) as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if monitoring of outcome of behavior, code* ***2.4, Self-monitoring of outcome(s) of behavior****; if monitoring is by someone else (without feedback), code* ***2.1, Monitoring of behavior by others without feedback***	Ask the person to record daily, in a diary, whether they have brushed their teeth for at least two minutes before going to bed Give patient a pedometer and a form for recording daily total number of steps
2.4	***Self-monitoring of outcome(s) of behavior***	Establish a method for the person to monitor and record the **outcome(s)** of their behavior as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code ; if monitoring behavior, code* ***2.3, Self-monitoring of behavior****; if monitoring is by someone else (without feedback), code* ***2.5, Monitoring outcome(s) of behavior by others without feedback***	Ask the person to weigh themselves at the end of each day, over a two week period, and record their daily weight on a graph to increase exercise behaviors
Back to index page			

2.5	***Monitoring outcome(s) of behavior by others without feedback***	Observe or record outcomes of behavior with the person's knowledge as part of a behavior change strategy *Note: if monitoring is part of a data collection procedure rather than a strategy aimed at changing behavior, do not code; if feedback given, code only* ***2.7, Feedback on outcome(s) of behavior****; if monitoring behavior code* ***2.1, Monitoring of behavior by others without feedback****; if self-monitoring outcome(s), code* ***2.4, Self-monitoring of outcome(s) of behavior***	Record blood pressure, blood glucose, weight loss, or physical fitness
2.6	***Biofeedback***	Provide feedback about the body *(e.g. physiological or biochemical state)* using an external monitoring device as part of a behavior change strategy *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and not* ***2.2, Feedback on behavior*** *or* ***2.7, Feedback on outcome(s) of behaviour***	Inform the person of their blood pressure reading to improve adoption of health behaviors
2.7	***Feedback on outcome(s) of behavior***	Monitor and provide feedback on the outcome of performance of the behavior *Note: if Biofeedback, code only* ***2.6, Biofeedback*** *and not* ***2.7, Feedback on outcome(s) of behavior****; if feedback is on* ***behavior*** *code* ***2.2, Feedback on behavior****; if there is no clear evidence that feedback was given code* ***2.5, Monitoring outcome(s) of behavior by others without feedback;*** *if feedback on behaviour is evaluative e.g. praise, also code* ***10.4, Social reward***	Inform the person of how much weight they have lost following the implementation of a new exercise regime
3. Social support			
3.1	***Social support (unspecified)***	Advise on, arrange or provide social support *(e.g. from friends, relatives, colleagues,' buddies' or staff)* or non-contingent praise or reward for performance of the behavior. It includes encouragement and counselling, but only when it is directed at the **behavior** *Note: attending a group class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned; if practical, code* ***3.2, Social support (practical)****; if emotional, code* ***3.3, Social support (emotional)*** (includes '**Motivational interviewing**' and **'Cognitive Behavioral Therapy'**)	Advise the person to call a 'buddy' when they experience an urge to smoke Arrange for a housemate to encourage continuation with the behavior change programme Give information about a self-help group that offers support for the behaviour

Back to index page

3.2	***Social support (practical)***	Advise on, arrange, or provide **practical** help *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behavior *Note: if emotional, code **3.3, Social support (emotional)**; if general or unspecified, code **3.1, Social support (unspecified)** If only restructuring the physical environment or adding objects to the environment, code **12.1, Restructuring the physical environment** or **12.5, Adding objects to the environment;** attending a group or class and/or mention of 'follow-up' does not necessarily apply this BCT, support must be explicitly mentioned.*	Ask the partner of the patient to put their tablet on the breakfast tray so that the patient remembers to take it
3.3	***Social support (emotional)***	Advise on, arrange, or provide **emotional** social support *(e.g. from friends, relatives, colleagues, 'buddies' or staff)* for performance of the behavior *Note: if practical, code **3.2, Social support (practical)**; if unspecified, code **3.1, Social support (unspecified)***	Ask the patient to take a partner or friend with them to their colonoscopy appointment
4. Shaping knowledge			
4.1	***Instruction on how to perform a behavior***	Advise or agree on how to perform the behavior (includes '**Skills training**') *Note: when the person attends classes such as exercise or cookery, code **4.1, Instruction on how to perform the behavior, 8.1, Behavioral practice/rehearsal** and **6.1, Demonstration of the behavior***	Advise the person how to put a condom on a model of a penis correctly
4.2	***Information about antecedents***	Provide information about antecedents (*e.g. social and environmental situations and events, emotions, cognitions)* that reliably predict performance of the behaviour	Advise to keep a record of snacking and of situations or events occurring prior to snacking
4.3	***Re-attribution***	Elicit perceived causes of behavior and suggest alternative explanations *(e.g. external or internal and stable or unstable)*	If the person attributes their over-eating to the frequent presence of delicious food, suggest that the 'real' cause may be the person's inattention to bodily signals of hunger and satiety

Back to index page

4.4	***Behavioral experiments***	Advise on how to identify and test hypotheses about the behavior, its causes and consequences, by collecting and interpreting data	Ask a family physician to give evidence-based advice rather than prescribe antibiotics and to note whether the patients are grateful or annoyed
5. Natural consequences			
5.1	***Information about health consequences***	Provide information (e.g. written, verbal, visual) about health consequences of performing the behavior *Note: consequences can be for any target, not just the recipient(s) of the intervention; emphasising importance of consequences is not sufficient; if information about emotional consequences, code* ***5.6, Information about emotional consequences****; if about social, environmental or unspecified consequences code* ***5.3, Information about social and environmental consequences***	Explain that not finishing a course of antibiotics can increase susceptibility to future infection Present the likelihood of contracting a sexually transmitted infection following unprotected sexual behavior
5.2	***Salience of consequences***	Use methods specifically designed to **emphasise** the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences) *Note: if information about consequences, also code* ***5.1, Information about health consequences****,* ***5.6, Information about emotional consequences*** *or* ***5.3, Information about social and environmental consequences***	Produce cigarette packets showing pictures of health consequences e.g. diseased lungs, to highlight the dangers of continuing to smoke
5.3	***Information about social and environmental consequences***	Provide information (e.g. written, verbal, visual) about social and environmental consequences of performing the behavior *Note: consequences can be for any target, not just the recipient(s) of the intervention; if information about health or consequences, code* ***5.1, Information about health consequences****; if about emotional consequences, code* ***5.6, Information about emotional consequences****; if unspecified, code* ***5.3, Information about social and environmental consequences***	Tell family physician about financial remuneration for conducting health screening Inform a smoker that the majority of people disapprove of smoking in public places
5.4	***Monitoring of emotional consequences***	Prompt assessment of **feelings** after attempts at performing the behavior	Agree that the person will record how they feel after taking their daily walk

Back to index page

5.5	***Anticipated regret***	Induce or raise awareness of expectations of future regret about performance of the unwanted behavior *Note: not including* ***5.6, Information about emotional consequences****; if suggests adoption of a perspective or new perspective in order to change cognitions also code* ***13.2, Framing/reframing***	Ask the person to assess the degree of regret they will feel if they do not quit smoking
5.6	***Information about emotional consequences***	Provide information (e.g. written, verbal, visual) about emotional consequences of performing the behavior *Note: consequences can be related to emotional health disorders (e.g. depression, anxiety) and/or states of mind (e.g. low mood, stress); not including* ***5.5, Anticipated regret****; consequences can be for any target, not just the recipient(s) of the intervention; if information about health consequences code* ***5.1, Information about health consequences****; if about social, environmental or unspecified code* ***5.3, Information about social and environmental consequences***	Explain that quitting smoking increases happiness and life satisfaction
6. Comparison of behaviour			
6.1	***Demonstration of the behavior***	Provide an observable sample of the performance of the behaviour, directly in person or indirectly e.g. via film, pictures, for the person to aspire to or imitate (includes '**Modelling**'). *Note:* if advised to practice, also code, ***8.1, Behavioural practice and rehearsal;*** *If provided with instructions on how to perform, also code* ***4.1, Instruction on how to perform the behaviour***	Demonstrate to nurses how to raise the issue of excessive drinking with patients via a role-play exercise
6.2	***Social comparison***	Draw attention to others' performance to allow comparison with the person's own performance *Note: being in a group setting does not necessarily mean that social comparison is actually taking place*	Show the doctor the proportion of patients who were prescribed antibiotics for a common cold by other doctors and compare with their own data
6.3	***Information about others' approval***	Provide information about what other people think about the behavior. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do	Tell the staff at the hospital ward that staff at all other wards approve of washing their hands according to the guidelines

Back to index page

7. Associations			
7.1	***Prompts/cues***	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behavior. The prompt or cue would normally occur at the time or place of performance *Note: when a stimulus is linked to a specific action in an if-then plan including one or more of frequency, duration or intensity also code* ***1.4, Action planning****.*	Put a sticker on the bathroom mirror to remind people to brush their teeth
7.2	***Cue signalling reward***	Identify an environmental stimulus that reliably predicts that reward will follow the behavior (includes ***'*****Discriminative cue'**)	Advise that a fee will be paid to dentists for a particular dental treatment of 6-8 year old, but not older, children to encourage delivery of that treatment (the 6-8 year old children are the environmental stimulus)
7.3	***Reduce prompts/cues***	Withdraw gradually prompts to perform the behavior (includes ***'*****Fading'**)	Reduce gradually the number of reminders used to take medication
7.4	***Remove access to the reward***	Advise or arrange for the person to be separated from situations in which unwanted behavior can be rewarded in order to reduce the behavior (includes ***'*****Time out'**)	Arrange for cupboard containing high calorie snacks to be locked for a specified period to reduce the consumption of sugary foods in between meals
7.5	***Remove aversive stimulus***	Advise or arrange for the removal of an aversive stimulus to facilitate behavior change (includes ***'*****Escape learning'**)	Arrange for a gym-buddy to stop nagging the person to do more exercise in order to increase the desired exercise behaviour
7.6	***Satiation***	Advise or arrange repeated exposure to a stimulus that reduces or extinguishes a drive for the unwanted behavior	Arrange for the person to eat large quantities of chocolate, in order to reduce the person's appetite for sweet foods
7.7	***Exposure***	Provide systematic confrontation with a feared stimulus to reduce the response to a later encounter	Agree a schedule by which the person who is frightened of surgery will visit the hospital where they are scheduled to have surgery

Back to index page

7.8	***Associative learning***	Present a neutral stimulus jointly with a stimulus that already elicits the behavior repeatedly until the neutral stimulus elicits that behavior (includes **'Classical/Pavlovian Conditioning'**) *Note: when a BCT involves reward or punishment, code one or more of:* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Present repeatedly fatty foods with a disliked sauce to discourage the consumption of fatty foods
8. Repetition and substitution			
8.1	***Behavioral practice/ rehearsal***	Prompt practice or rehearsal of the performance of the behavior one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill *Note: if aiming to associate performance with the context, also code* ***8.3, Habit formation***	Prompt asthma patients to practice measuring their peak flow in the nurse's consulting room
8.2	***Behavior substitution***	Prompt substitution of the unwanted behavior with a wanted or neutral behavior *Note: if this occurs regularly, also code* ***8.4, Habit reversal***	Suggest that the person goes for a walk rather than watches television
8.3	***Habit formation***	Prompt rehearsal and repetition of the behavior in the same context repeatedly so that the context elicits the behavior *Note: also code* ***8.1, Behavioral practice/rehearsal***	Prompt patients to take their statin tablet before brushing their teeth every evening
8.4	***Habit reversal***	Prompt rehearsal and repetition of an alternative behavior to **replace** an unwanted habitual behavior *Note: also code* ***8.2, Behavior substitution***	Ask the person to walk up stairs at work where they previously always took the lift
8.5	***Overcorrection***	Ask to repeat the wanted behavior in an exaggerated way following an unwanted behaviour	Ask to eat only fruit and vegetables the day after a poor diet
8.6	***Generalisation of a target behavior***	Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation	Advise to repeat toning exercises learned in the gym when at home

Back to index page

8.7	***Graded tasks***	Set easy-to-perform tasks, making them increasingly difficult, but achievable, until behavior is performed	Ask the person to walk for 100 yards a day for the first week, then half a mile a day after they have successfully achieved 100 yards, then two miles a day after they have successfully achieved one mile
9. Comparison of outcomes			
9.1	***Credible source***	Present verbal or visual communication from a **credible source** in favour of or against the behavior *Note: code this BCT if source generally agreed on as credible e.g., health professionals, celebrities or words used to indicate expertise or leader in field and if the communication has the aim of persuading; if information about health consequences, also code* ***5.1, Information about health consequences****, if about emotional consequences, also code* ***5.6, Information about emotional consequences****; if about social, environmental or unspecified consequences also code* ***5.3, Information about social and environmental consequences***	Present a speech given by a high status professional to emphasise the importance of not exposing patients to unnecessary radiation by ordering x-rays for back pain
9.2	***Pros and cons***	Advise the person to identify and compare reasons for wanting (pros) and not wanting to (cons) change the behavior (includes '**Decisional balance'***)* *Note: if providing information about health consequences, also code* ***5.1, Information about health consequences****; if providing information about emotional consequences, also code* ***5.6, Information about emotional consequences****; if providing information about social, environmental or unspecified consequences also code* ***5.3, Information about social and environmental consequences***	Advise the person to list and compare the advantages and disadvantages of prescribing antibiotics for upper respiratory tract infections
9.3	***Comparative imagining of future outcomes***	Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged behaviour	Prompt the person to imagine and compare likely or possible outcomes following attending versus not attending a screening appointment

Back to index page

10. Reward and threat			
10.1	***Material incentive (behavior)***	Inform that money, vouchers or other valued objects ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes **'Positive reinforcement'**) *Note: if incentive is social, code **10.5, Social incentive** if unspecified code **10.6, Non-specific incentive,** and not **10.1, Material incentive (behavior)**; if incentive is for **outcome,** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that a financial payment will be made each month in pregnancy that the woman has not smoked
10.2	***Material reward (behavior)***	Arrange for the delivery of money, vouchers or other valued objects if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: If reward is social, code **10.4, Social reward**, if unspecified code **10.3, Non-specific reward**, and not **10.1, Material reward (behavior)**; if reward is for **outcome**, code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money that would have been spent on cigarettes if and only if the smoker has not smoked for one month
10.3	***Non-specific reward***	Arrange delivery of a reward if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if reward is material, code **10.2, Material reward (behavior)**, if social, code **10.4, Social reward**, and not **10.3, Non-specific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Identify something (e.g. an activity such as a visit to the cinema) that the person values and arrange for this to be delivered if and only if they attend for health screening

Back to index page

10.4	***Social reward***	Arrange verbal or non-verbal reward if and only if there ***has been*** effort and/or progress in performing the behavior (includes '**Positive reinforcement**') *Note: if reward is material, code **10.2, Material reward (behavior)**, if unspecified code **10.3, Non-specific reward**, and not **10.4, Social reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Congratulate the person for each day they eat a reduced fat diet
10.5	***Social incentive***	Inform that a verbal or non-verbal reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if incentive is material, code **10.1, Material incentive (behavior)**, if unspecified code **10.6, Non-specific incentive**, and not **10.5, Social incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform that they will be congratulated for each day they eat a reduced fat diet
10.6	***Non-specific incentive***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in performing the behavior (includes '**Positive reinforcement'**) *Note: if incentive is material, code **10.1, Material incentive (behavior)**, if social, code **10.5, Social incentive** and not **10.6, Non-specific incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Identify an activity that the person values and inform them that this will happen if and only if they attend for health screening

Back to index page

10.7	***Self-incentive***	Plan to reward self in future if and only if there has been effort and/or progress in performing the behavior *Note: if self-reward is material, also code **10.1, Material incentive (behavior)**, if social, also code **10.5, Social incentive**, if unspecified, also code **10.6, Non-specific incentive**; if incentive is for **outcome** code **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Encourage to provide self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet
10.8	***Incentive (outcome)***	Inform that a reward ***will be*** delivered if and only if there has been effort and/or progress in achieving the behavioural **outcome** (*includes **'Positive reinforcement'***) *Note: this includes social, material, self- and non-specific incentives for outcome; if incentive is for the **behavior** code **10.5, Social incentive**, **10.1, Material incentive (behavior)**, **10.6, Non-specific incentive** or **10.7, Self-incentive** and not **10.8, Incentive (outcome).** If reward is delivered also code one of: **10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Inform the person that they will receive money if and only if a certain amount of weight is lost
10.9	***Self-reward***	Prompt self-praise or self-reward if and only if there ***has been*** effort and/or progress in performing the behavior *Note: if self-reward is material, also code **10.2, Material reward (behavior)**, if social, also code **10.4, Social reward**, if unspecified, also code **10.3, Non-specific reward**; if reward is for **outcome** code **10.10, Reward (outcome).** If informed of reward in advance of rewarded behaviour, also code one of: **10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Encourage to reward self with material (e.g., new clothes) or other valued objects if and only if they have adhered to a healthy diet

Back to index page

10.10	***Reward (outcome)***	Arrange for the delivery of a reward if and only if there ***has been*** effort and/or progress in achieving the behavioral **outcome** (includes '**Positive reinforcement**') *Note: this includes social, material, self- and non-specific rewards for outcome; if reward is for the* ***behavior*** *code* ***10.4, Social reward, 10.2, Material reward (behavior), 10.3, Non-specific reward*** *or* ***10.9, Self-reward*** *and not* ***10.10, Reward (outcome).*** *If informed of reward in advance of rewarded behaviour, also code one of****: 10.1, Material incentive (behaviour); 10.5, Social incentive; 10.6, Non-specific incentive; 10.7, Self-incentive; 10.8, Incentive (outcome)***	Arrange for the person to receive money if and only if a certain amount of weight is lost
10.11	***Future punishment***	Inform that future punishment or removal of reward will be a consequence of performance of an unwanted behavior (may include fear arousal) (includes ***'Threat'***)	Inform that continuing to consume 30 units of alcohol per day is likely to result in loss of employment if the person continues
11. Regulation			
11.1	***Pharmacological support***	Provide, or encourage the use of or adherence to, drugs to facilitate behavior change *Note: if pharmacological support to reduce negative emotions (i.e. anxiety) then also code* ***11.2, Reduce negative emotions***	Suggest the patient asks the family physician for nicotine replacement therapy to facilitate smoking cessation
11.2	***Reduce negative emotions*** [b]	Advise on ways of reducing negative emotions to facilitate performance of the behavior (includes '**Stress Management**') *Note: if includes analysing the behavioural problem, also code* ***1.2, Problem solving***	Advise on the use of stress management skills, e.g. to reduce anxiety about joining Alcoholics Anonymous
11.3	***Conserving mental resources***	Advise on ways of minimising demands on mental resources to facilitate behavior change	Advise to carry food calorie content information to reduce the burden on memory in making food choices
11.4	***Paradoxical instructions***	Advise to engage in some form of the unwanted behavior with the aim of reducing motivation to engage in that behaviour	Advise a smoker to smoke twice as many cigarettes a day as they usually do Tell the person to stay awake as long as possible in order to reduce insomnia

Back to index page

12. Antecedents			
12.1	***Restructuring the physical environment***	Change, or advise to change the **physical** environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments) *Note: this may also involve* ***12.3, Avoidance/reducing exposure to cues for the behavior****; if restructuring of the social environment code* ***12.2, Restructuring the social environment;*** *if only adding objects to the environment, code* ***12.5, Adding objects to the environment***	Advise to keep biscuits and snacks in a cupboard that is inconvenient to get to Arrange to move vending machine out of the school
12.2	***Restructuring the social environment***	Change, or advise to change the **social** environment in order to facilitate performance of the wanted behavior or create barriers to the unwanted behavior (other than prompts/cues, rewards and punishments) *Note: this may also involve* ***12.3, Avoidance/reducing exposure to cues for the behavior****; if also restructuring of the physical environment also code* ***12.1, Restructuring the physical environment***	Advise to minimise time spent with friends who drink heavily to reduce alcohol consumption
12.3	***Avoidance/reducing exposure to cues for the behavior***	Advise on how to avoid exposure to specific social and contextual/physical cues for the behavior, including changing daily or weekly routines *Note: this may also involve* ***12.1, Restructuring the physical environment*** and/or ***12.2, Restructuring the social environment***; if the BCT includes analysing the behavioral problem, only code ***1.2, Problem solving***	Suggest to a person who wants to quit smoking that their social life focus on activities other than pubs and bars which have been associated with smoking
12.4	***Distraction***	Advise or arrange to use an alternative focus for attention to avoid triggers for unwanted behaviour	Suggest to a person who is trying to avoid between-meal snacking to focus on a topic they enjoy (e.g. holiday plans) instead of focusing on food

Back to index page

12.5	***Adding objects to the environment***	Add objects to the environment in order to facilitate performance of the behavior *Note: Provision of information (e.g. written, verbal, visual) in a booklet or leaflet is insufficient. If this is accompanied by social support, also code **3.2, Social support (practical)**; if the environment is changed beyond the addition of objects, also code **12.1, Restructuring the physical environment***	Provide free condoms to facilitate safe sex Provide attractive toothbrush to improve tooth brushing technique
12.6	***Body changes***	Alter body structure, functioning or support **directly** to facilitate behavior change	Prompt strength training, relaxation training or provide assistive aids (e.g. a hearing aid)
13. Identity			
13.1	***Identification of self as role model***	Inform that one's own behavior may be an example to others	Inform the person that if they eat healthily, that may be a good example for their children
13.2	***Framing/reframing***	Suggest the deliberate adoption of a perspective or new perspective on behavior (e.g. its purpose) in order to change cognitions or emotions about performing the behavior (includes '**Cognitive structuring**'); *If information about consequences then code **5.1, Information about health consequences, 5.6, Information about emotional consequences** or **5.3, Information about social and environmental consequences** instead of **13.2, Framing/reframing***	Suggest that the person might think of the tasks as reducing sedentary behavior (rather than increasing activity)
13.3	***Incompatible beliefs***	Draw attention to discrepancies between current or past behavior and self-image, in order to create discomfort (includes ***'*Cognitive dissonance'**)	Draw attention to a doctor's liberal use of blood transfusion and their self-identification as a proponent of evidence-based medical practice
13.4	***Valued self-identity***	Advise the person to write or complete rating scales about a cherished value or personal strength as a means of affirming the person's identity as part of a behavior change strategy (includes ***'*Self-affirmation'**)	Advise the person to write about their personal strengths before they receive a message advocating the behavior change
13.5	***Identity associated with changed behavior***	Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behavior'	Ask the person to articulate their new identity as an 'ex-smoker'

Back to index page

14. Scheduled consequences			
14.1	***Behavior cost***	Arrange for withdrawal of something valued if and only if an unwanted behavior is performed (includes '**Response cost'**). Note if withdrawal of contingent reward code, ***14.3, Remove reward***	Subtract money from a prepaid refundable deposit when a cigarette is smoked
14.2	***Punishment***	Arrange for aversive consequence contingent on the performance of the unwanted behavior	Arrange for the person to wear unattractive clothes following consumption of fatty foods
14.3	***Remove reward***	Arrange for discontinuation of contingent reward following performance of the unwanted behavior (includes **'Extinction'**)	Arrange for the other people in the household to ignore the person every time they eat chocolate (rather than attending to them by criticising or persuading)
14.4	***Reward approximation***	Arrange for reward following any approximation to the target behavior, gradually rewarding only performance closer to the wanted behavior (includes **'Shaping'**) *Note: also code one of* ***59-63***	Arrange reward for any reduction in daily calories, gradually requiring the daily calorie count to become closer to the planned calorie intake
14.5	***Rewarding completion***	Build up behavior by arranging reward following final component of the behavior; gradually add the components of the behavior that occur earlier in the behavioral sequence (includes **'Backward chaining'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Reward eating a supplied low calorie meal; then make reward contingent on cooking and eating the meal; then make reward contingent on purchasing, cooking and eating the meal
14.6	***Situation-specific reward***	Arrange for reward following the behavior in one situation but not in another (includes **'Discrimination training'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for eating at mealtimes but not between meals
14.7	***Reward incompatible behavior***	Arrange reward for responding in a manner that is incompatible with a previous response to that situation (includes **'Counter-conditioning'**) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for ordering a soft drink at the bar rather than an alcoholic beverage

Back to index page

14.8	***Reward alternative behavior***	Arrange reward for performance of an alternative to the unwanted behavior (includes ***'Differential reinforcement'***) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome);*** *consider also coding* ***1.2, Problem solving***	Reward for consumption of low fat foods but not consumption of high fat foods
14.9	***Reduce reward frequency***	Arrange for rewards to be made contingent on increasing duration or frequency of the behavior (includes ***'Thinning'***) *Note: also code one of* ***10.2, Material reward (behavior); 10.3, Non-specific reward; 10.4, Social reward, 10.9, Self-reward; 10.10, Reward (outcome)***	Arrange reward for each day without smoking, then each week, then each month, then every 2 months and so on
14.10	***Remove punishment***	Arrange for removal of an unpleasant consequence contingent on performance of the wanted behavior (includes ***'Negative reinforcement'***)	Arrange for someone else to do housecleaning only if the person has adhered to the medication regimen for a week
15. Self-belief			
15.1	***Verbal persuasion about capability***	Tell the person that they can successfully perform the wanted behavior, arguing against self-doubts and asserting that they can and will succeed	Tell the person that they can successfully increase their physical activity, despite their recent heart attack.
15.2	***Mental rehearsal of successful performance***	Advise to practise imagining performing the behavior successfully in relevant contexts	Advise to imagine eating and enjoying a salad in a work canteen
15.3	***Focus on past success***	Advise to think about or list previous successes in performing the behavior (or parts of it)	Advise to describe or list the occasions on which the person had ordered a non-alcoholic drink in a bar
15.4	***Self-talk***	Prompt positive self-talk (aloud or silently) before and during the behavior	Prompt the person to tell themselves that a walk will be energising
16. Covert learning			
16.1	***Imaginary punishment***	Advise to imagine performing the **unwanted** behavior in a real-life situation followed by imagining an unpleasant consequence (includes ***'Covert sensitisation'***)	Advise to imagine overeating and then vomiting

Back to index page

16.2	***Imaginary reward***	Advise to imagine performing the **wanted** behavior in a real-life situation followed by imagining a pleasant consequence (includes ***'Covert conditioning'***)	Advise the health professional to imagine giving dietary advice followed by the patient losing weight and no longer being diabetic
16.3	***Vicarious consequences***	Prompt observation of the consequences (including rewards and punishments) for others when they perform the behavior *Note: if observation of health consequences, also code **5.1, Information about health consequences**; if of emotional consequences, also code **5.6, Information about emotional consequences**, if of social, environmental or unspecified consequences, also code **5.3, Information about social and environmental consequences***	Draw attention to the positive comments other staff get when they disinfect their hands regularly
Back to index page			

[a]Notes are provided underneath most BCTs to help distinguish them from similar techniques

[b]An additional technique 'Increase positive emotions' will be included in BCT Taxonomy v2