Implementing the Theoretical Domains Framework in Occupational Safety: Development of the Safety Behaviour Change Questionnaire

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Abstract

Understanding the factors that either facilitate or hinder the performance of specific safety behaviours is important in developing effective intervention strategies. A questionnaire to identify determinants of safety behaviours for safety-critical workers does not currently exist. This study reports the development and validation of the Safety Behaviour Change Questionnaire (SBCQ) based on the Theoretical Domains Framework (TDF). Following initial questionnaire development, a 3-stage testing procedure was adopted with three independent rail worker samples (totalling 620 participants), with a focus on three separate specific safety behaviours (removing slip/trip hazards, using PPE, safe tool storage). Explorative factor analysis (EFA) was used for the identification of the underlying structure of the initial set of items. Confirmatory factor analysis (CFA) was undertaken to generate the model of best fit at the calibration and validation stages. The final version of the SBCQ questionnaire consisted of 13 factors and 26 items. Subsequent analysis of psychometric invariance confirmed the stability of the model factor structure across three distinct research sub-samples. These initial results suggest that the SBCQ demonstrates reliable, stable and valid properties, and that it can be utilised by safety managers and practitioners to guide the design of safety interventions for a range of safety behaviours.

Key Words: Safety behaviour change, Theoretical domains framework, Barriers, Determinants, Safety-critical work, Occupational safety, Intervention development

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1. Introduction

Estimates of fatal occupational incidents and diseases worldwide amount to over 2.78 million (ILO, 2017). Additionally, almost 374 million non-fatal work-related injuries and illnesses occur annually worldwide, which result in many instances of extended work absences (Probst, Bettac, & Austin, 2019). These global workplace accident statistics suggest that safety can be further improved for the benefit of both workers and employers. In large safety-critical sectors like the UK rail industry annual accident rates and fatalities remain consistently above zero (Curcuruto, Griffin, Kandola, & Morgan, 2018; Morgan, Abbott, Furness, & Ramsay, 2016). The most common types of accidents experienced by UK rail workers; being hit by a train, on-track plant, or a road rail vehicle; electrocution from overhead power lines or conductor rails; and trips and falls are often preventable (Network Rail, 2017). Understanding the factors that influence injury-related behaviours is the starting point in the development of strategies to improve safety (Chadwick, 2018; Morgan, Reidy, & Probst, 2019). However, safety interventions are typically developed intuitively by supervisors or safety managers rather than utilising theoretical approaches to understand the specific barriers and facilitators for behaviour change (Taylor, Parveen, Robins, Slater, & Lawton, 2013).

The most common intervention strategies adopted by those responsible for managing safety are education, persuasion, or monitoring behaviours and providing feedback. The latter strategy is typified by “Behaviour-Based Safety” (BBS) initiatives which aim to increase “safety behaviours” and decrease “at-risk behaviours” through direct observation of work practices and feedback (Gravina, King, & Austin, 2019; Sulzer-Azaroff & Austin, 2000). BBS programmes, also referred to as ‘safe behaviour,’ ‘behaviour modification’ or ‘behavioural safety’ (Hopkins, 2006), have been criticised due to their lack of theoretical foundation, largely top-down and reductionist implementation procedures. Also, they are characterised by an underlying assumption that behaviour is the sole cause of safety breaches and thus misdirect attention away from the complex role of other multilevel factors (Chadwick, 2018). The narrow focus on behaviour observation and reinforcement has been heavily criticised by academics and union representatives for unfairly blaming workers for accidents, not actively involving employees in the change process (Wiegand, 2007), apart from “ratting” on fellow colleagues for misbehaving (DePasquale & Geller, 1999).

Despite the criticisms of safety management generated behaviour change strategies, there is some support for their effectiveness (Gravina et al., 2019; Myers, McSween, Medina, Rost, & Alvero, 2010). However, because their theoretical foundation is often unclear, there is a limited body of knowledge about what works, in what situations, for what problems, both within and across sectors (Chadwick, 2018). Behaviour change research evidence suggests that the choice to implement particular interventions techniques should depend on the specific factors (e.g., knowledge, skills, motivation, confidence, environment, social influences) affecting a particular behavioural change (Michie et al., 2005; Michie, Johnston, Francis, Hardeman, & Eccles, 2008). In practice, those tasked with implementing safety behaviour change rarely have access to the aforementioned research evidence. In any case, because there is an abundance of health behaviour theories, often insufficiently specified, they may find it difficult to determine how they might go about identifying and then modifying the factors to be targeted through an intervention (Rothman, 2004; Taylor, Parveen, et al., 2013).

The theoretical domains framework (TDF) was developed using an expert consensus and validation process to make it easier for practitioners to select from the large number of often overlapping theories of behaviour and behaviour change (Atkins et al., 2017). The TDF is a synthesis of 33 theories clustered into 14 (originally 12) domains, specifying the cognitive, affective, social and environmental barriers and levers to change in a range of contexts (see Atkins et al., 2017 for examples). The 14 TDF domains are as follows: Knowledge; skills; social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement; intentions; goals; memory, attention, and decision processes; environmental context and resources; social influences; emotion; behavioural regulation. Atkins et al., (2017, p. 4-5) provided brief definitions for each domain. These are shown in Table 1, below.

Insert Table 1 about here

Application of the TDF has largely been confined to healthcare settings and clinical behaviours. Early applications relied on qualitative interviews to gain a detailed understanding of the factors influencing behaviour change for patients (e.g. Dyson, Lawton, Jackson, & Cheater, 2011) and healthcare workers (e.g., Duncan et al., 2012; French et al., 2012). However, because qualitative methods tend to be time consuming, resource intensive, and are usually only able to collect data from small samples of the population of interest, limiting generalisability, there have been a number of recent attempts to create questionnaires based on the TDF (e.g., Taylor, Lawton, & Conner, 2013; Taylor, Parveen, et al., 2013; Huijg, Gebhardt, Crone, Dusseldorp, & Presseau, 2014; Huijg, Gebhardt, Dusseldorp, et al., 2014). In addition to the potential time and resource savings and increased sample size, the questionnaire approach is also more likely to be adopted by those tasked with facilitating safety behaviour change in their organisation. It is suggested that typically practitioners such as these may lack the knowledge, skills, and time required to use qualitative interviews (Taylor, Parveen, et al., 2013).

Although the TDF has been used to develop and validate questionnaires examining the barriers and enablers of healthcare behaviours, to our knowledge, a questionnaire to understand the factors affecting safety behaviour change for safety-critical workers does not exist in the literature. Given the extensive range of behaviours and behavioural influences associated with ensuring the safety of workers, it was deemed necessary to address this gap in the literature and the criticisms aimed at existing methods of safety behaviour change. Therefore, this study describes the development and validation of the Safety Behaviour Change Questionnaire (acronym: SBCQ). Our aim was to develop and validate a questionnaire to be utilised by health and safety practitioners working in a wide range of safety-critical settings to enable them to identify the facilitators and barriers for specific high-risk safety behaviours. With this aim in mind we adopted a staged development process and cross-validation strategy (Curcuruto et al., 2018). This approach involves a consultation exercise including the academic knowledge base and industry safety experts, resulting in the development of an initial questionnaire prototype. This is followed by the statistical testing of the same questionnaire across factor analysis stages involving independent samples of workers and a focus on three specific safety behaviours. A final stage of psychometric analysis of measurement invariance of the new SBCQ questionnaire tool was conducted on a combined dataset, allowing us to examine its stability across the three distinct independent samples involved in the previous stages, and the validity and consistency of the underlying model structure and measurement assumptions.

4. Method

4.1. Workflow

Our validation study followed the implementation of seven main research steps shown in Figure 1.

Insert Figure 1. about here

4.2. Literature review and selection of domains for the SBCQ

As behavioural frameworks, including the TDF, generally evolve rather than remain stagnant (Cane, O'Connor, & Michie, 2012; Fishbein et al., 2001; Michie et. al., 2005), and because no causal elements are proposed to link theoretical components of the TDF, it was deemed suitable to adapt the framework. Removing TDF domains that are considered less relevant to a target behaviour is something performed in previous research (Amemori, Michie, Korhonen, Murtomaa, Kinnunen, 2011; Taylor, Parveen, et al., 2013) and is recommended in guidance on the use of the TDF, as is the consideration of additional contextually relevant domains (Michie et al., 2005; Atkins et al., 2017). The original 14 TDF domains are as follows: Knowledge, skills; social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement; intentions; goals; memory, attention, and decision processes; environmental context and resources; social influences; emotion; behavioural regulation. In line with previous studies that have modified the framework for the specific behaviour being studied, the safety literature was consulted in order to determine which of the existing TDF domains were most relevant and whether additional determinants should be considered. Consistent with other research, the 'Behavioural Regulation' construct was not considered relevant and therefore omitted from the current framework (Amemori et al., 2011; Huijg, Gebhardt, Crone, et al., 2014). The 'Intentions' domain was also removed because it is similar to ‘Safety Motivation’, commonly treated as an mediator or outcome variable in safety science research (c.f. Griffin & Neal, 2000). The original definition of the TDF domain ‘Environmental Context and Resources’ includes “organisational culture and climate” (Atkins et al., 2017). Safety climate is increasingly recognised as having a strong impact on individual and organisational safety outcomes (Clarke, 2006; Curcuruto et al., 2018). As a consequence, the ‘Environmental Context and Resources’ domain was replaced by safety climate, split into 2 domains according to the findings of previous studies which have identified at least two levels; ‘organisational level safety climate’ (focused on top management) and ‘group level safety climate’ (focused on the immediate supervisor). The final framework developed, therefore, consisted of 13 constructs, 11 of which were directly comparable to the TDF (Michie et. al., 2005; Cane et al., 2012), and two which were indirectly comparable (organisational, and group level, safety climate).

Further information concerning the theoretical foundations and contextual relevance of the chosen domains in relation to safety behaviour is provided below.

Knowledge

Previous research utilising the TDF has found knowledge to be a main influential factor in the performance of behaviours relating to hand-hygiene, recycling and the use of smoking cessation programs in dental practices (Amemori et al., 2011; Dyson et al., 2010; Gainforth, Sheals, Atkins, Jackson, & Michie, 2016). Furthermore, this domain is likely to be particularly important for safety behaviour change, due to a knowledge of safety procedures/policies (safety knowledge) having a strong influence on broad categories of safety behaviour (i.e. compliance and participation) and organisational safety outcomes (see Griffin & Neal, 2000; Christian, Bradley, Wallace, & Burke, 2009).

Skills

This domain has been defined as a professional ability acquired through practice on the job. Organizational research has highlighted the relationship between technical and nontechnical skills (see e.g., Flin & O'Connor, 2017) and prevention of occupational accidents in several industries, such as civil aviation and healthcare. Additionally, safety training has been found to be a key driver of safety behaviours (Sacks, Perlman, & Barak, 2013), and safety skills alongside safety knowledge have been conceptualised as proximal predictors of safety performance (Griffin & Neal, 2000).

Social/Professional Role and Identity

The domain termed social/professional role and identity broadly refers to an individual's self-concept about their professional role and identity based on their experiences, belief system, and values (Ibarra, 1999). Research conducted in the construction industry suggests that workers' social and group identity can play an important role in determining whether they follow safety rules and procedures. Andersen, Karlsen, Kines, Joensson, & Nielsen (2015) found that the way in which individuals identify with social or work groups (such as crews), or the organisation more generally, can either facilitate or hinder safety behaviour depending on their inherent beliefs, norms, and values.

Beliefs About Capabilities

This domain encompasses two important constructs in relation to safety; self-efficacy and job control. The former is defined as a person's judgement about their capability to execute courses of action required to perform satisfactorily (Bandura, 1999), while the latter is defined as the degree to which employees have a say on the pace and characteristics of their daily assignments on the job (Karasek, 1979). Research has shown that both are predictors of safety behaviours (Chen & Chen, 2014; Katz-Navon, Naveh, & Stern, 2007; Turner, Chmiel, & Walls, 2005).

Optimism

Perceptions of risk or personal susceptibility are key aspects of several models of social and health psychology theories of behaviour. These include the parallel process model (PPM; Leventhal, 1970), the health belief model (HBM; Rosenstock, 1974), protection motivation theory (PMT; Rogers, 1983), the psychometric paradigm (PP; Slovic, 1987), the precaution adoption process model (PAPM; Weinstein, 1988), the extended parallel process model (EPPM; Witte, 1992), and the prototype/willingness model (PWM; Gibbons, Gerrard, Blanton, & Russell, 1998), which assume that risk perception plays an important role in determining behaviour. Low risk perceptions or more specifically ‘unrealistic optimism’, where subjective risk judgments are lower than the objective risk has been shown to be associated with negative health outcomes (Ferrer et al., 2012; Katapodi, Dodd, Lee, & Facione, 2009). Although there is limited research on the role of (unrealistic) optimism in determining occupational safety behaviour, a recent study found that although young adults were comparatively optimistic about their risk of having a household accident they had experienced more accidents than a group of older adults who were comparatively pessimistic about their risk (Morgan, Reidy, and Probst, 2019). Further evidence to support the potential role of optimism as a determinant of safety behaviours comes from studies where unrealistically optimistic participants have been shown to be less likely to engage in risk mitigating health protective behaviours such as planning to, or stopping smoking or consuming alcohol (Dillard, McCaul, & Klein, 2006; Dillard, Midboe, & Klein, 2009).

Beliefs About Consequences

This domain is rooted in the outcome-expectancy theory (Vroom, 1964). This theory predicts that employees will be motivated to comply with safety rules and participate in safety initiatives if they believe that doing so will lead to a valued outcome such as fewer injuries (Neal & Griffin, 2006). Research has found that safety climate can inform behaviour-outcome expectancies, such that a supportive safety climate, in which the priority for safe outcomes (over other competing priorities) is high, is associated with fewer injuries (Beus, Payne, Bergman, & Arthur, 2010).

Reinforcement

The TDF definition of reinforcement is "increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus". The premise that reinforcement can promoting behaviour change originated from the work of behaviourists at the beginning of the 20th century (e.g., Skinner, 1938). Although the approach has been criticised due to its inherent reductionist nature there is some evidence that reinforcement in the form of feedback during structured Behaviour-Based Safety initiatives can be effective in changing safety behaviours (Gravina et al., 2019; Myers, McSween, Medina, Rost, & Alvero, 2010).In addition, in one study involving roofing workers, positive reinforcement in the form of monetary compensation also led to improved safety performance (Austin, Kessler, Riccobono, & Bailey, 1996).

Goals

Setting clear priorities and planning are at the core of this domain. Safety research in high-reliability industries where injury rates are low has shown that a safety management model needs to be based in part on planning and setting goals to improve safety standards before implementation and audit (Foster & Hoult, 2013). Other research has shown that when safety is the main priority, rather than production, safety performance is increased (e.g., Jiang & Probst, 2015).

Memory, Attention, and Decision Processes

Cognitive capabilities and cognitive failures have long been investigated in occupational safety. A cognitive failure is defined as an error on simple tasks that employees should normally be able to complete without fault due to memory, attention, or decision making. Occupational safety research has shown that cognitive failures are associated with higher rates of minor injuries (Simpson, Wadsworth, Moss, & Smith, 2005) as well as accident proneness (Day, Brasher, & Ridger, 2012).

Social Influences

This domain is defined as the interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours. This includes 'social norms' which, alongside other constructs described by the Theory of Planned Behaviour (TPB; Ajzen, 1991) have consistently been found to play an important role in behaviour change. Social norms are a person's perception of the external pressure to perform a behaviour. To date the majority of research assessing social influences on safety has used intentions to perform unsafe behaviours as the outcome variable. For example, Rowe et al (2016) found that social norms predicted novice motorists' intentions to engage in speeding and mobile phone use while driving. The few occupational safety studies to explore social influences have shown that social norms in work groups can predict both safety intentions, and self-reported unsafe and safe behaviours. For instance, Fogarty and Shaw (2010) found that workgroup norm was both indirectly (through intentions) and directly associated with aircraft maintenance violations. Choi, Ahn, and Lee (2017) found that construction workers safety behaviour (an aggregation of specific self-reported conduct such as wearing safety glasses) was influenced by perceived workgroup norm.

Emotion

The emotion domain encompasses positive and negative affect, mood, stress, and burnout. The effect of emotional state on safety performance has been investigated in a number of research studies. Driving behaviour studies have shown that reckless driving can increase under conditions of specific positive affect (e.g., Taubman-Ben-Ari, 2012) and negative affect (e.g., Eherenfreund-Hager, Taubman–Ben-Ari, Toledo, & Farah, 2017). Morgan, Jones, & Harris (2013) found that specific moods were associated with different levels of risky decision making in a sample of train maintenance engineers. Anxiety was associated with more risky decision making while happiness was associated with less.

Burnout is widely recognized as a workplace stressor and can be described as a syndrome of emotional exhaustion, cynicism, and lack of efficacy (Maslach & Leiter, 2008). In a meta-analysis of over 200 primary studies, Nahrang, Morgeson, and Hofmann (2011) found that safety hazards, physical demands, and system complexity are associated with higher burnout, which in turn is associated with higher rates of accidents, injuries, and unsafe behaviours.

Safety Climate

Although not considered a behaviour change domain in the original TDF model, safety climate has been extensively investigated in organizational psychology since the 1980s. It is a specific form of organizational climate that describes individual perceptions of the value of safety in one’s workplace. Management values, organizational practices, communication, and employee involvement are all important component of safety climate. Several studies and meta-analyses have shown that safety climate predicts safety behaviours (Clarke, 2006; 2010). Consistent with the multilevel literature on safety climate (Curcuruto et al., 2018; Zohar & Luria, 2005), in our conceptualization we distinguish between two sources of safety climate, organisational level safety climate (top management) and the group level safety climate (immediate supervisor).

4.3. Identifying target behaviours

To assess the utility of the developed questionnaire for multiple safety beahviours it was deemed necessary to develop and test the questionnaire using three context-relevant safety behaviours. Identifying specific target behaviour(s) is considered an essential step in the TDF approach, in order to ultimately determine the facilitators and barriers for the enactment of that behaviour (Michie et al., 2005; Atkins et al., 2017). Consistent with recommendations to use different sources of data/information to identify appropriate and worthwhile target behaviour(s) (Atkins et al., 2017), we analysed the previous five years of company accident and incident frequency and severity data (including written reports) in order to ascertain patterns of attributable non-compliance with company guidance on safety working practices during safety-critical activities, e.g., wearing personal protective equipment (PPE).

Two researchers independently trawled the company data identifying and coding any (non-performance of) safety behaviours recorded as being a causal factor in an accident or incident. The two researchers then met to cross check findings. Once a consensus was reached, a weighted calculation was performed that considered the frequency of non-compliance for each identified safety behaviour, as well as the severity of subsequent accident or incident. Based on this analysis, three specific safety behaviours were selected. In line with previous TDF questionnaire development initiatives (e.g., Taylor, Parveen, et al., 2013), stakeholder consultation was also conducted. Feedback from company safety managers supported the decision to target these three safety behaviours due to their association with accidents and incidents and their applicability for a large percentage of workers. The three target safety behaviours were “removing or managing slip/trip hazards at work” (safety behaviour 1), “correctly using all PPE provided for the task” (safety behaviour 2), and “safely storing tools, equipment and materials” (safety behaviour 3).

4.4. Initial development of the SBCQ questionnaire items

Initial item development involved reviewing published TDF questionnaires, interview schedules and safety research. Such research was used as a template in the development of safety-specific items that relate to our TDF domains. Such an approach reflects recommendations (Michie et al., 2005; Atkins et al., 2017) and the development of other validated TDF questionnaires (Amemori et al., 2011; Huijg, Gebhardt, Crone, et al., 2014; Huijg, Gebhardt, Dusseldorp, et al., 2014; Taylor et al., 2013; Taylor, Parveen, et al. 2013; Smith et al., 2019). In line with previous TDF questionnaires the majority of items were positively worded so low scores represented more of a barrier for behavioural enactment. To reduce the number of items in the scale (aiding in validity), subject matter experts were consulted in a process like that conducted by Huijg, Gebhardt, Dusseldorp, et al., (2014). Health and safety experts were provided with conceptual definitions of constructs and tasked with allocating items to a domain they deemed most relevant. Data relating to interrater reliability from this task, along with conceptual relevance and item distinctiveness was used to identify items to remove or retain. Ultimately, 52 items were retained for data-collection purposes across the 13 constructs (4 items per construct). Following each episode of data collection the negatively worded items were reversed scored before data analysis. Table 2 reports examples of items for the scales developed at this stage, with references to the original literature sources.

Insert Table 2 about here

4.5. Participants and data collection procedure

In total, 620 workers from a UK safety critical rail infrastructure organisation were recruited across three separate samples. These workers are typically involved in a variety of safety-critical activities, such as the maintenance and repair of rail track, overhead lines, power systems, and signaling systems. The participant samples ranged in size from 153-287, with each group completing a questionnaire relating to one of the three safety behaviours most relevant for their work (see above). Demographic information for participants in each of the three samples can be seen in Table 3.

Insert Table 3. about here

Numerous specific ‘safety stand-down’ events, designed to communicate and involve workers in safety initiatives, were utilised as opportunities for data-collection. Such events were deemed suitable as they provided the opportunity for the collection of data en-mass, while allowing for participation during work time (rather than personal time). Following an initial briefing at the ‘safety stand-down’ event that described the study and the purpose of it, workers were given the opportunity to voluntarily participate. Volunteers were then asked to complete a single questionnaire in which the items referenced one of the three safety behaviours. One research team member (MS) attended all sessions to give the briefing, administer and collect questionnaires, and answer any questions. Ethical approval for the study was received prior to data collection from the first author’s institution.

4.5.1 Sample allocation for validation steps

The choice of which participant data sample to utilise at each stage of the validation process was principally driven by the salience and the representativeness of each associated target behaviour for the broader field of safety research, utilising the most general target behaviour in early stages and later more specific.

Sample 1, characterized by the target behaviour “removing or managing slip/trip hazards at work” (safety behaviour 1) was used for the Explorative Factor Analysis Stage. This is because this target behaviour is considered to be one of the most common causes of accidents and injuries across many safety-critical work sectors (Probst & Graso, 2013). Choosing a target behaviour generalizable across a broad range of working situations is considered to be appropriate given the nature of explorative factor analysis (identifying an underlying factor structure for the associations between the SBCQ questionnaire items).

Sample 2, characterized by “correctly using all PPE provided for the task” (safety behaviour 2) as the salient target behaviour, was utilised for the calibration analysis stage with CFA. This choice was justified because enactment of this target behaviour is the key component of safety regulation systems in almost all high-risk industries, for almost all work performed in safety critical contexts. Given the scope of model calibration (the adjustment of model parameters, forcing them within the margins of uncertainties to obtain a model representation), conducting the calibration of the SBCQ questionnaire utilising a universally necessary target behaviour like “PPE Usage” was considered the most appropriate methodological choice.

Sample 3, whose target safety behaviour was “safely storing tools, equipment and materials” (safety behaviour 3), was utilised for the last factor analysis stage, namely, model validation with CFA analyses. After allocating two relatively ubiquitous safety behaviours (Removing Fall/Slip Hazards; PPE Usage) to the exploratory and the calibration analysis stages, for the subsequent validation step we selected a target safety behaviour which, although not uncommon across safety-critical contexts, was identified as particularly important for the rail worker population sampled in the present study. This methodological decision was made in part for practical reasons, however, it was considered justified because in the field of occupational safety research a model validation is not finalised once and for all, but always requires further verification for other worker samples, contexts and conditions (Curcuruto, Conchie, & Griffin, 2019; Griffin & Curcuruto, 2016; Keiser & Payne, 2018; Zohar, 2010).

4.6. Data analysis

4.6.1 Explorative factor analyses (EFAs) on SBCQ prototype

Utilising data from the first sample of workers where the target safety behaviour was “removing or managing slip/trip hazards at work” (safety behaviour 1), exploratory factor analyses (EFAs) were conducted to test the dimensionality of the SBCQ domain scales derived from step a) and b). EFA is commonly used in the creation and validation of a new psychometric tools, in order to identify complex interrelationships among items and to group items that are part of unified concepts. When using EFA, the researcher makes no a priori assumptions about relationships among the items included in the psychometric tool. Given that the TDF had not used previously in the field of occupational safety research, we considered it sensible to conduct this exploratory analysis step.

For each domain scale identified in the earlier research step, we chose to conduct separate EFAs, using principal axis factoring (PAF) with direct oblimin as the statistical strategy for the extraction and the rotation of the latent factors. This analysis strategy allowed us to identify the least number of factors which could account for the common variance (correlation) of the identified set of items for each domain, considering also the possibility of potential correlations between multiple latent factors for each given set of items. According with this statistical approach EFAs allowed us to verify the effective dimensionality of each scale, and if necessary, empirical indications to exclude those items presenting a low statistical association with the rest of the scale. All EFA analyses were conducted using SPSS software (version 24) (IBM, 2016).

4.6.2 SBCQ overall measurement model calibration with CFAs

After the identification of unidimensional factor versions for each dimension of the SBCQ the next validation stage used a series of confirmatory factor analyses (CFAs) to test the overall goodness of the measurement model of the questionnaire. These analyses were conducted on a second sample of workers where the identified target behaviour was "correctly using all PPE provided for the task" (safety behaviour 2).

First all the questionnaire items were included in a single CFA model to test both the quality of the overall structural model and the item composition of the measurement scales. At this stage we aimed to iteratively refine the model using the information provided by modification indices (MIs). MIs are statistic indices that may be used to modify a model to improve its fit. After each modification a CFA was conducted to assess the revised measurement model. Following previous TDF questionnaire validation studies using this calibration approach (Taylor et al., 2013; Taylor, Parveen, et al. 2013). For model estimation, the maximum likelihood method was applied. For model evaluation, several fit indices were adopted in the current study, including: the ratio of model $\chi 2$ to the degrees of freedom ($\chi 2$/df), the comparative fit index (CFI), the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR). AMOS 25 (Arbuckle, 2017) was used to conduct all CFA analyses. Below, these indices are briefly introduced, together with thresholds recommended in literature.

The first index, the $\chi2$ value is a first 'absolute index' for evaluating the model fit to the data and assesses the magnitude of discrepancy between the sample and fitted covariance matrices (Hu and Bentler, 1999). In this study, we used the $\chi2$ ratio to the degree of freedom ($\chi2$/df) because this corrected form of $\chi2$ minimises the impact of sample size on the index. $\chi2$/df values less than 5 indicates an acceptable model fit to the data, with a value less than 3 being considered good.

The second index, the CFI value is a 'relative' fit index which compares the $\chi2$ for the hypothesized model to one from a 'null model' (or 'baseline'), in which all of the variables are uncorrelated (Hu & Bentler, 1999). CFI values between .90 and .95 are generally considered acceptable, while values higher than .95 are considered good.

SRMR and RMSEA indices are two 'absolute indices' providing information of the statistical error related to the model in respect to the data (Hu & Bentler, 1999). Past studies showed that SRMR is more sensitive to misspecifications in covariances (Nye & Drasgow, 2011), while RMSEA was found more sensitive to model specification, degrees of freedom, and sample size (Chen et al., 2008). For both the two indices, values of less than .05 indicate a good fit, whereas values ranging from .05 to .08 are usually considered acceptable.

Finally, the internal reliability of the scales was tested with the Cronbach alpha coefficient, while a self-report measure of frequency of engagement in the target behaviour (usage of PPE) was used to estimate the statistical correlations of the SBCQ scales with the target behaviour, in order to obtain some preliminary information about the criterion-related validity of the calibrated version of the SBCQ.

4.6.3 SBCQ overall measurement model validation with CFA analysis

The following validation step involved a confirmatory validation test of the measurement model identified in the earlier steps in two independent samples of railway maintenance workers. This last step involved a third sample of safety-critical rail workers for whom the target behaviour was specified as “safely storing tools, equipment and materials” (safety behaviour 3).

As above, we used CFA to test the goodness of the measurement model, using CFI, RMSEA, SRMR, and $\chi 2/df$ ratio as statistical indicators of the quality of the TDF questionnaire in the new samples. Again, we adopted the same threshold values used at the previous research stage. The internal reliability of the scales was tested with the Cronbach alpha coefficient. As before, criterion validity was assessed using correlational analysis of the relationship between SBCQ scales and a self-report measure of target behaviour frequency (safe storage). In addition, a 2 × 13 between subjects MANOVA was undertaken to further assess criterion validity (based on safety behaviour levels – low performers versus high performers). The multivariate analysis of variance (MANOVA) is a procedure for comparing multivariate sample means. As a multivariate procedure, it is used when there are two or more dependent variables (Warne, 2014). In this way, the MANOVA essentially tests whether or not the independent grouping variable simultaneously explains a statistically significant amount of variance in the dependent variable (Tabachnick, & Fidell, 2012).

4.6.4 Multi-group analysis of invariance of the SBCQ across the distinct research samples

The final validation contribution provided by the present study is the analysis of the psychometric measurement invariance of the SBCQ across the distinct research samples included in the previous factor analysis stages. This final stage allowed us to verify the final measurement tool in terms of the stability of the theoretical structure of the questionnaire *(configural invariance)*, its measurement assumptions *(metric invariance)* and comparability of item responses *(scalar invariance)* from distinct research samples and conditions (target safety behaviours).

More specifically, the measurement invariance analysis aims to test whether a given construct is stable across multiple groups, samples, or measurement occasions (Little, 2013). To do so, the scale undergoes a series of increasingly restrictive tests (Vandenberg & Lance, 2000), namely configural invariance (i.e., equal forms), metric invariance (i.e., equal factor loadings), and scalar invariance (i.e., equal factor loadings and equal intercepts). The first step, and the least stringent one, tests whether the construct exhibits the same pattern of free and fixed parameters across groups. Invariance at this level means that the basic organization of the construct (i.e., 13 latent factors with two observed indicators each) is the same across subsamples. The second step is designed to test whether each item contributes to the construct in a statistically equivalent way by constraining like-item factor loadings to equality across groups. Metric invariance means that like-indicators increments are equivalent to increases in the latent factor (i.e., equality of scaling units; Brown, 2015). The last step, and the most restrictive, is designed to test whether mean differences in the latent constructs capture all mean differences in the shared variance of the items by maintaining the constraints on like-item factor loadings and adding equality constraints on like-item intercepts. Scalar invariance means that for any given factor value, the predicted value for like-indicators is statistically equivalent across groups (i.e., there is no evidence of differential item functioning) and have established a common zero point.

5. Results

5*1. Explorative factor analyses on the SBCQ domains*

Data collected from the first employee sample (N = 287) using the initial prototype SBCQ questionnaire with "removing or managing slip/trip hazards at work" as the target safety behaviour were subject to a series of exploratory factor analyses. PAF extraction and oblimin rotation were utilised with each SBCQ domain analysed separately. In line with the indications provided by Jung and Lee (2011), item factor loadings on the latent factors were considered meaningful if above a threshold of .40. However, where items cross-loaded onto more than a single latent factor, we adopted an additional factor loading cut-off value of 0.60 (Comery and Lee, 1992). In these cases, we decided to retain the cross-loading items only when the factor loading of the item on the principal factor was at least double the factor loading on the secondary latent factor.

Results of these EFA analyses are reported in Table 4. In the first column, the percentage of explained variance is report for each domain scale dimension of the questionnaire. In the second column, we report the item factor loading indices for each scale, referring to the principal latent factor emerged in the EFA conducted on that domain. The third column provides information on the presence of cross-loading of the items, and the relative index. Finally, the fourth column reports information about the decision on the items (retained/discarded) based on considerations associated with low levels of factor loading and/or cross-loading effects.

At the end of this stage of initial EFA analyses one item was deleted from each of the following domain scales, due to low factor loading: beliefs about capability, optimism, skills, social/professional role and identity, reinforcement, goals, social influence, and emotions. In all these cases, the discarded item presented a factor loading index lower than the threshold value recommended in literature of .40 for the retention of the items of a new developed questionnaire (Awang, 2015). Items whose factor loading falls below this threshold value are not considered stable (Child, 2006). In addition, an item was discarded from the domain beliefs about consequences, given double loading issues. Finally, in order to keep a valid, short and balanced form of the questionnaire (i.e., the same number of items for each questionnaire domain), only the three items with the highest factor loading were retained for the domains of knowledge; memory, attention and decision processes; organizational safety climate; group safety climate. This is in accordance with the goal of developing the SBCQ questionnaire as a short, yet complete, assessment tool that can be easily handled by the final users (i.e., safety managers and practitioners), alongside other assessment and evaluation kits that might be already in use in a safety-specific industry.

Insert Table 4. about here

5.2. Calibration of the SBCQ with CFA

In the next stage of analysis, a full 13 factor model – including eleven factors from the TDF and the two additional contextual determinants of organizational and group level safety climate - was specified and evaluated with the calibration sample (N = 180) using CFA, employing maximum likelihood estimation, in AMOS 25. The target safety behaviour included in the SBCQ for this sample of workers was “correctly using all PPE provided for the task”. The data did not initially fit the model well: $\chi2$/df ratio = 1.93 ($\chi2$ (624) = 1207.05, $p < .001$), CFI = .84, SRMR = .12, RMSEA = .09. Upon inspection, modification indices (MIs), standardised residuals (SRs), and item content identified causes of model misspecification, and therefore post hoc model fitting was conducted. For example, the largest MI was obtained for the social/professional role and identity item ‘Identity1’ (MI = 28.52), which also produced three standardised residuals above 2.58. Based on these results and after assessment of item content, the item was removed. These changes subsequently improved the fit of the model: $\chi2$/df ratio = 1.95 ($\chi2$ (587) = 1144.6, $p < .001$), CFI = .85, SRMR = .212, RMSEA = .08. Therefore, from this point forward, all specification and estimation with the calibration sample represent exploratory factor analysis on the whole measurement model (Byrne, 2001). Altogether, eight amendments were made using these methods until we were able to achieve a model presenting good statistical fit indices: $\chi 2$ ratio = 1.43 ($\chi 2$ (356) = 508.6, $p < .001$), CFI = .95, SRMR = .07, RMSEA = .05. More information on the refinement steps conducted with the information provided by the modification indices are reported in Table 5.

Insert Table 5 about here

The measurement model obtained at this point was composed of 31 items representing the 13 dimensions of the SBCQ derived from the TDF and safety literature. This model comprised 8 dimensions each with two items, and 5 dimensions with three items. In light of this imbalance and because one of our research goals was to devise a measure to be used in occupational settings where time may be limited, we ran an additional measurement model whose single dimensions were all defined by two items. To do this, for the 5 domains with three items, we selected the two items with the highest factor loading. The resulting model with 26 items presented very good statistical fit indices: $\chi 2$ ratio = 1.36 ($\chi 2$ (221) = 300.9, $p < .001$), CFI = .97, SRMR = .06, RMSEA = .05. In the light of the calibration CFA findings, we selected a measurement model with 26 items and 13 latent factors as the foundation for the final confirmatory validation stage.

5.3. Descriptive Statistics and Criterion-Related Validity (Calibration Sample)

Table 6 reports descriptive, correlational and reliability statistics for the 13 domain scales of the 26-item version of the questionnaire following model calibration. As reported in the table, our model components reported reciprocal correlations with Pearson's *r* indices between .76 (p <

.01; between ‘knowledge’ and ‘skills’) and .10 (ns; between ‘optimism’ and ‘memory, attention, & decision processes’). Each scale presented good or acceptable internal reliability values, which were assessed with the Cronbach Alpha index, with a maximum of .93 (beliefs about capabilities scale) and a minimum of .60 (reinforcement, and social influences scales). Finally, all the dimensions of the questionnaire presented significant correlations ($p < .01$) with a single self-report item assessing the frequency of the target behaviour (using PPE), which was included as a criterion variable. The correlation values varied between a maximum of .69 (with the dimension ‘goals’) and a minimum of .21 (with the dimension of ‘group safety climate’) measured with the Pearson’s r index.

Insert Table 6. about here

5.4. CFA on the Validation Sample

The 13-factor independent cluster model was tested using a strictly confirmatory approach with the validation sample. We performed a confirmative CFA analysis on the 26 items selected at the end of the previous model calibration research stage. These analyses aimed to confirm the measurement model identified in the previous stage, in order to provide a validation of the SBCQ in a final independent sample. Participants included in this sample (N = 153), completed the SBCQ with “safely storing tools, equipment and materials” as the target safety behaviour. The analyses revealed good statistical fit indices, $\chi 2$ ratio = 1.34 ($\chi 2$ (221) = 297, $p < .001$), CFI = .96, SRMR = .06, RMSEA = .05, confirming the high quality of the final SBCQ measurement solution identified during the calibration step, which is reported in appendix 1.

5.5. Descriptive Statistics and Criterion-Related Validity (Validation Sample)

Table 7 reports descriptive, correlational and reliability statistics for the validation sample. As reported in the table, our model components reported reciprocal correlations with Pearson's r indices ranging from a maximum of .70 ($p < .01$; between 'knowledge' and 'skills') to a minimum of .00 (not significant; between 'safety climate' and 'memory, attention & decision processes').

Insert Table 7. about here

Each domain presented good or acceptable internal reliability values, which were assessed with the Cronbach Alpha index, with a maximum of .90 ('organizational safety climate' and 'knowledge' scales) and a minimum of .60 ('social influences' scale).

With regards to the criterion validity of the final model, all the dimensions of the questionnaire presented significant correlations ($p < .01$) with a single self-report item assessing the frequency of the target behaviour (safe storage), which was included as a criterion variable. The correlation values ranged between a maximum of .56 (with the dimension 'social/professional role & identity') and a minimum of .21 (with the dimension 'beliefs about consequences') measured with the Pearson's r index. To further test criterion validity worker responses for the single item safety behaviour measure ($N = 61$) were split into two comparison groups. Respondents who stated they performed the behaviour 'very often' or 'always' were classified as 'high performers' and those who stated they engaged in safe storage behaviour only 'sometimes', 'rarely', or 'never' were considered 'low performers. The difference in SBCQ subscale scores between high performers and low performers was assessed using a 13×2 between subjects MANOVA (Table 8.). Across determinants, there was a significant difference in scores on the SCBQ between low (N = 25) and high performers (N = 36), $F(13, 47) = 2.73$, $p = .006$, and the difference was large, partial $\eta 2 = .43$.

The univariate ANOVAs showed a significant or near significant ($p = .052$) difference between high and low performers for all determinants, except ‘beliefs about consequences’, ‘social influences’, ‘organisational level safety climate’, and ‘group level safety climate’, but means for all thirteen determinants were lower for the low safety behaviour performers, indicating they reported more barriers, as they were further away from the optimal score on each subscale.

Insert Table 8. about here

5.6. Multi-group analysis: testing the measurement invariance of the SBCQ questionnaire

To the end of examining whether the SBCQ questionnaire was invariant across distinct target safety behaviors and research sub-samples, we combined the three data samples into one dataset and carried out a measurement invariance analysis with MPlus 8.5 (Muthén & Muthén, 1998-2017). Following Little (2013), we used change in CFI (ΔCFI < .010) as the invariance criterion. Results are presented in Table 9.

First, the Equal Forms model (i.e., the baseline model with no equality constraints) fitted the data satisfactorily, providing support for the assumption of configural invariance of the SBCQ questionnaire across the distinct target behaviors and research samples. In other words, the property of configural invariance of the SBCQ questionnaire means that the theoretical domains of SBCQ (latent factors) are equally measured across the three research samples, and across the distinct target behaviors, suggesting that the latent structure of the questionnaire is consistent across the different research conditions included in our validation process, according with the original theoretical assumptions of the present research.

Second, adding equality constraints on like-item factor loadings (i.e., Equal Loadings model) did not result in a significant decrement in model fit (ΔCFI = .003), providing evidence for the SBCQ questionnaire metric invariance. This finding shows that the statistical relationship between the two single items of each scale and its underlying theoretical domain (or latent factor) are constant in the different research samples included in our study, independently of their characterizing target behavior. In other words, the metric invariance of the SBCQ questionnaire supports the consistency of its measurement assumptions across the different research conditions considered in our validation study (e.g., the items of the “social influences” scale domain will constantly measure this underlying theoretical domain – and not others - across the distinct research samples).

Third, we checked the scalar invariance of the SBCQ with the test of equal intercepts. Adding equality constraints on like-item intercepts (i.e., Equal Intercepts model) did result in a significant decrement in model fit (ΔCFI = .021), hence, the criterion for scalar invariance was not met. However, building on this model, we relaxed selected equality constraints for two single items from the “knowledge” and “skills” scale domains (see Table 9) before running a revised model, which did not show a significant decrement in fit compared to the Equal Forms model (ΔCFI = .010). This provided evidence for partial scalar invariance, suggesting that, apart for two items, the functionality of the other 24 items of the SBCQ questionnaire items across the distinct research samples was quantitatively comparable.

Insert Table 9 about here
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6. Discussion

Using the Theoretical Domains Framework (TDF) of behaviour change, 13 scales measuring the psychosocial domains of safety behavior change among safety-critical rail workers were developed, tested, validated, revised and re-tested. The final 13 factor model contained 26 items and resulted in a good fit, demonstrating improvement in the overall fit statistics, and internal consistency reliability compared to the earlier version of the SBCQ. In total, of the original 52 items of the SBCQ, 26 were discarded during the EFA and calibration steps. In the final model all determinant areas consisted of two items improving the practical usability of the tool. The final research step utilised a multi-group invariance analysis which demonstrated the measurement stability of the SBCQ questionnaire across the three samples for the three distinct safety behaviours. The latent factor structure of the questionnaire was found to be stable across the different work samples (configural invariance) as well as the relationships (in terms of factor loading) between the items and their relative questionnaire domain (metric invariance). These two invariance findings support our research assumption that the TDF framework and our novel SBCQ questionnaire can be used as a conceptual framework and measurement tool, respectively, to identify the barriers for safety behaviour change for different safety behaviours and distinct samples of workers.

All domain factors of the 26-item model tested at the calibration step and the final validation step significantly correlated with the criterion variable of self-reported frequency of safety behaviour. The differential pattern of correlations between the frequency of the two specific safety behaviours and the facilitators and barriers measured by the SBCQ implies that the tool can identify the domains that are most relevant for a particular behaviour. For example, ‘goals’, ‘knowledge’, and ‘skills’ were the strongest correlates with the frequency of wearing

PPE, and ‘social/professional role and identity’, ‘beliefs about capabilities’ and ‘knowledge’ correlated most highly with safe storage behaviour. When further testing for criterion validity in the validation sample, nine of the subscales significantly differentiated between high and low safe storage behaviour performers, with ‘identity’ (mean difference = 1.03), ‘goals’ (mean difference = .85) ‘emotion’ (mean difference = .85) and ‘capability’ (mean difference = .84) showing the greatest differentiation, indicating that it might be appropriate to target low safe storage behaviour performers with interventions to address these areas.

This is the first study to develop a theoretically underpinned measure (the SBCQ) capable of identifying the barriers (or enablers) of specific safety behavior change, and, in addition, a tool that appears to be adaptable, to allow for application across a range of safety behaviors. Such a tool should serve as a welcome addition to the limited set of largely theoretical strategies available to safety management researchers and practitioners tasked with selecting or developing appropriate safety behaviour change interventions. To date, existing approaches to changing safety behaviour, such as Behaviour-Based Safety (BBS) initiatives, lack theoretical foundation and are too narrowly focused and as such there is a limited body of knowledge about what works, in what situations, for what problems, both within and across sectors (Chadwick, 2018). The development and psychometric testing of the SBCQ in the present study offers both safety researchers and managers the opportunity to grow this knowledge in order to improve worker safety.

The present study builds on existing research conducted in health care settings supporting the viability of using the Theoretical Domains Framework for the construction of theory-based questionnaires. Researchers have highlighted the benefits of questionnaires over more traditional qualitative TDF methods, including time and resource savings and increased sample size, and therefore is also more likely to be adopted by those tasked with facilitating safety behaviour change in their organisation. However, following previous work, it is envisaged that SBCQ may be used to identify barriers across large samples, across a range of safety-critical domains, and for a plethora of safety behaviours, and this information might be complemented by a smaller sample of focus groups to cross validate, and further understand barriers identified. The SBCQ could potentially act as a tool for developing theoretically underpinned large-scale interventions or, at a local level, as we are currently doing with our collaborating organization, working with staff to co-develop realistic and feasible strategies to address key barriers. We have found that, as Taylor, Parveen, et al. (2013) previously suggested, this latter approach is especially relevant if there are differences in key barriers to behavior change within organizations, or between organizations, as this allows for targeted and tailored interventions for specific contexts.

Despite demonstrating some promising reliable and valid properties for the SBCQ, this study has a number of key limitations. First, was the inability of the SBCQ to differentiate between high and low safety behaviour performers for some subscales. For ‘belief about consequences’ the scores for both groups were relatively high which is unsurprising given previous findings which have shown that behaviours which are the focus of concerted initiatives to reach out to populations with regards to behavioural outcomes such as the benefits of physical exercise behaviour (see Taylor, Lawton, & Conner, 2013) and have found similar results regarding this TDF domain. The specific behaviour in our study was safe storage of tools and equipment which was identified as a priority behaviour in the preliminary analysis of the organisation’s accident and incident report data. Storage issues are one of the most common cause of injuries in the rail industry, so it is unsurprising that it has been the focus of many campaigns focussed on these negative consequences. The high scores on this subscale and also ‘social influences’ may also suggest that possessing such information about consequences or specific workgroup norms concerning the target behaviour, may not be enough to induce safe storage behaviour in low performers, especially if they perceive other predominant barriers. These results may also imply that providing interventions to tackle these areas might not be as effective as those aimed at other determinant areas for safety critical rail workers. For ‘organisational level safety climate’, and ‘group level safety climate’ the most likely explanation for the inability of the SBSQ to differentiate between low and high safety behaviour performers is because of the range of responses across both groups represented by relatively high standard deviations. Safety climate is often defined as shared perceptions of the value placed on safety in the workplace. At the organisational level the focus is on ‘top management’ and at the group level ‘immediate supervisor’. Although the rail worker samples used in the present study included employees with similar safety-critical job roles, it is notable that employees work in sub teams under different organisational conditions and with a number of different immediate supervisors. In the present study we were unable to determine the nested nature of this organisational structure, however future studies utilising the SBSQ should consider following recent recommendations concerning the evaluation of shared perceptions in the treatment of safety climate data (Luria, 2019).

SBSQ criterion validity assessment indicated all domain scores significantly correlated with a single item measure of safety behaviour frequency in both the calibration (wearing PPE) and validation (safe storage) samples, and the majority of domains differentiated between high and low safety behaviour performers. However, future studies should extend the findings of the present research by including objective measures of specific safety behaviours as criteria indicators, such as behavioural observations by work supervisors, given this mode of assessment is accepted as more valid and reliable than that of self-report (Curcuruto et al., 2018).

Finally, although multi-group invariance analysis provided support for the configural and metric stability of the SBCQ across the worker samples included in the present validation study, the final analysis step (scalar invariance) showed that two items from the “knowledge” and “skills” theoretical frameworks did not present statistical evidence of scalar invariance. This measurement bias is likely explained by the existence of external factors not controlled for in the present study (i.e., safety training experience of the workforces with regards to the specific target safety behaviour) that influenced the way in which participants responded to these specific items across the administrations of the SBCQ questionnaire in the three samples.

Given that ours is the first study to apply the TDF framework in the field of occupational safety overall, we are buoyed by these findings, however, we also recognise that, as is the case with all new questionnaires, further studies utilising the SBCQ are required in order to further test the validity, reliability, and generalisability of the measure.

7. Conclusion

This study is the first to describe the development and validation of a theory-based measure of the determinants of specific safety behaviours; the Safety Behaviour Change Questionnaire (SBCQ). Following a 7-stage development and validation process, with three independent worker samples, with a focus on three separate specific safety behaviours it is believed that a measure of the determinants of safety behaviour has been developed. The SBCQ can be used by researchers and practitioners working in areas of safety improvement and for a range of safety behaviours. Further research should be undertaken to fully understand the uses and limitations of the measure, but initial results suggest that it demonstrates reliable and valid properties.

These findings provide sufficient support to suggest that this measure can be used to identify barriers to behaviour change among safety-critical workers. The logical next step should be to assess the efficacy of the tool in informing the development of theoretically informed tailored interventions. Future longitudinal research should aim to understand whether targeting key domains with matched interventions guided by existing taxonomies of behaviour change techniques related to TDF domains (see Michie et al., 2008) can change levels of these determinants, change specific safety behaviours, and in turn reduce associated injury rates.

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Table 1. *Definitions of original 14 TDF domains (Atkins et al., 2017, p. 4-5)*

TDF Domain	Definition
1. Knowledge	“An awareness of the existence of something”
2. Skills	“An ability or proficiency acquired through practice”
3. Identity	“A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting”
4. Capability beliefs	“Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use”
5. Optimism	“The confidence that things will happen for the best or that desired goals will be attained”
6. Consequence beliefs	“Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation”
7. Reinforcement	“Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus”
8. Intentions	“A conscious decision to perform a behaviour or a resolve to act in a certain way”
9. Goals	“Mental representations of outcomes or end states that an individual wants to achieve”
10. Memory, Attention, & Decision Processes	“The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives”
11.Environmental context and resources	“Any circumstance of a person’s situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour”

12. Social Influences	“Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours”
13. Emotion	“A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event”
14. Behavioural regulation	“Anything aimed at managing or changing objectively observed or measured actions”

Step One	Literature review and selection of relevant TDF domains for safety behaviour.
Step Two	Identification of target behaviours.
Step Three	Initial Development of the SBCQ questionnaire items.
	Data collection
Step Four	Test of the dimensionality of the SBCQ domains (for safety behaviour 1) with explorative factor analysis (EFA).
Step Five	Calibration of the overall SBCQ measurement framework (for safety behaviour 2) using a confirmatory factory analysis approach.

Step Six	Validation of the SBCQ framework (for safety behaviour 3) in a third and final sample of safety critical workers.
Step Seven	Multi-group analysis of the psychometric invariance of the SBCQ across the three research samples and target safety behaviours.

Figure 1. *Schematic of the seven-step SBCQ development and validation workflow.*

Table 2. *Selection of relevant scales from literature for the composition of the prototype of SBCQ*

TDF Domain	Example of Item	Source (Adapted from content based on:)
Knowledge	I am aware of and understand the purpose of [insert safety behaviour] at work.	Amemori et al. (2011); Huijg, Gebhardt, Dusseldorp, et al. (2014).
Skills	I am confident in my ability to [insert safety behaviour] at all times.	Amemori et al. (2011); Lawton et al. (2016); Michie et al. (2005).
Identity	People in my role should be able to [insert safety behaviour].	Huijg, Gebhardt, Dusseldorp, et al. (2014).
Capability beliefs	I am confident that I am able to [insert safety behaviour], even when time is limited.	Huijg, Gebhardt, Dusseldorp, et al. (2014); Huijg, Gebhardt, Crone, et al. (2014).
Optimism	The benefits of [insert safety behaviour] outweigh the time and effort it takes to do so.	Di Fabio et al. (2018); Pedrosa et al, (2015)
Consequence beliefs	The consequences of not [insert safety behaviour] can be severe.	Gainforth et al. (2016) Huijg, Gebhardt, Crone, et al. (2014); Michie et al. (2005); Squires et al. (2014).
Reinforcement	Not [insert safety behaviour] is not tolerated.	Henning et al. (2009).
Goals	[Insert safety behaviour] should be a top priority for promoting safety.	Gainforth et al. (2016); Squires et al. (2014; Sullivan et al. (2017).

Memory, Attention, & Decision Processes	Forgetting to [insert safety behaviour] is a simple mistake to make.	Huijg, Gebhardt, Dusseldorp, et al. (2014); Taylor, Parveen, et al., (2013).
Safety Climate (org. level)	Top management listens carefully to workers' ideas about improving safety in relation to [insert safety behaviour].	Curcuruto et al. (2018); Zohar and Luria (2005).
Safety Climate (group level)	My direct supervisor spends time helping us learn to see problems before they arise in relation to [insert safety behaviour].	Curcuruto et al. (2018); Zohar and Luria (2005).
Social Influences	[Insert safety behaviour] is normal and expected here.	Greaves, M. et al (2013); Huijg, Gebhardt, Crone, et al. (2014); Michie et al. (2005)
Emotions	Work is stressful enough without having to worry about [insert safety behaviour].	Amemori et al. (2011); Sullivan et al. (2017); Taylor, Lawton, & Conner (2013).

Table 3. *Sample Characteristics*

Demographic Variables	**Slips/Fall Hazard Removal Data Sample (*N*=287)**				**PPE Data Sample (*N*=180)**				**Safe Storage of Equipment Data Sample (*N*=153)**			
	Mean	(SD)	*n*	(%)	Mean	(SD)	*n*	(%)	Mean	(SD)	*n*	(%)
Gender												
Male			232	(82.86)			155	(89.60)			136	(90.07)
Female			48	(17.14)			18	(10.40)			15	(9.93)
Age												
<18			3	(1.07)			3	(1.73)			0	(0.0)
18-24			37	(13.21)			16	(9.25)			20	(13.33)
25-34			76	(27.14)			50	(28.90)			38	(25.33)
35-44			62	(22.14)			34	(19.65)			32	(21.33)
45-54			62	(22.14)			47	(27.17)			39	(26.00)
55+			40	(14.24)			23	(13.29)			31	(14.00)
Employment typology												
Employee			237	(86.81)			125	(73.10)			112	(74.66)
Contractor			36	(13.19)			46	(26.90)			38	(25.33)
Tenure / Experience												
Industry	12.49	(10.19)			13.35	(10.81)			13.32	(10.38)		
Company	4.56	(5.24)			37.25	(4.77)			37.25	(4.31)		

Table 4. *EFA results on the Safety Behaviour Change Questionnaire (SBCQ) Scales (N=287): Slips/Trips Hazard Removal as the target behaviour*

TDF factor & explained variance	Item factor loading	Cross-loading	Decision on the item
Knowledge (58%)	.88	No	Retained
	.84	No	Retained
	.70	No	Retained
	.59	No	Discarded for scale reduction purposes
Skills (34%)	.76	No	Retained
	.63	No	Retained
	.53	No	Retained
	.31	No	Discarded for low factor loading
Identity (51%)	.82	No	Retained
	.87	No	Retained
	.74	No	Retained
	.25	No	Discarded for low factor loading
Capability beliefs (39%)	.80	No	Retained
	.71	Yes (.21)	Retained
	.68	No	Retained
	.19	No	Discarded for low factor loading
Optimism (36%)	.72	No	Retained
	.69	Yes (.34)	Retained
	.64	No	Retained
	.39	No	Discarded for low factor loading
Consequence beliefs (45%)	.86	No	Retained
	.67	No	Retained
	.42	Yes (.20)	Retained
	.31	Yes (.51)	Discarded for double loading
Reinforcement (37%)	.73	No	Retained
	.67	No	Retained
	.51	No	Retained
	.32	No	Discarded for low factor loading
Goals (36%)	.72	No	Retained
	.69	No	Retained
	.60	No	Retained
	.28	No	Discarded for low factor loading
Memory, Attention, & Decision Processes (33%)	.70	No	Retained
	.56	No	Retained
	.54	No	Retained
	.46	No	Discarded for scale reduction purposes
Safety climate	.73	No	Retained

(org. level) (49%)	.72	No	Retained
	.70	No	Retained
	.64	No	Discarded for scale reduction purposes
Safety climate (group level) (71%)	.89	No	Retained
	.87	No	Retained
	.80	No	Retained
	.77	No	Discarded for scale reduction purposes
Social influences (34%)	.75	No	Retained
	.70	No	Retained
	.47	No	Retained
	.30	No	Discarded for low factor loading
Emotions (41%)	.92	No	Retained
	.69	No	Retained
	.65	Yes (.22)	Retained
	.39	No	Discarded for low factor loading

Table 5. *Calibration of the SBCQ measurement model with the Modification Index strategy*

Item to eliminate	Modification Index	MI	Par. Change	Modified X2	Modified Df	Modified CFI	Modified RMSEA
Identity 1	Err Id1 – Err Id3	28.5	.54	1144.6	587	.85	.08
Emotion 1	Err Em1- Err SI3	25.8	.51	974.7	551	.88	.07
Social influences 3	Err SI3 - Err Op3	21.4	.68	862.6	516	.89	.07
Skills 3	Err Sk3 – Err Re2	20.9	.48	797.7	482	.90	.07
Memory 3	Err Me3 – Err CB1	18.09	.34	715	449	.92	.06
Consequences 1	Err CB1 – Err Go2	13.9	.16	612.6	417	.94	.06
Safety Climate (Group level) 3	Err GSC3 – Err DM2	13.6	.20	554.3	386	.94	.05
Optimism 2	Err Opt2 – Err SI2	11.3	.27	500.8	356	.95	.05

Table 6. *Descriptive and correlation statistics of the SBCQ scales in the calibration sample (N = 180): Wearing PPE as the target behaviour*

Factor	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Knowledge	4.73	.70	*(.92)*													
2.Skills	4.60	.66	.76**	*(.74)*												
3.Identity	4.61	.77	.68**	.56**	*(.86)*											
4.Capability	4.46	.86	.62**	.61**	.53**	*(.93)*										
5.Optimism	4.40	.85	.42**	.44**	.32**	.55**	*(.75)*									
6.Consequence	4.54	.90	.47**	.34**	.30**	.49**	.34**	*(.71)*								
7.Reinforcement	4.31	.92	.46**	.40**	.32**	.36**	.28**	.32**	*(.60)*							
8.Goals	4.10	.88	.29**	.32**	.26**	.28**	.27**	.16*	.17*	*(.85)*						
9.Memory	3.07	1.28	.19*	.17*	.14	.13	.09	.13	.11	.01	*(.69)*					
10.SC (Org. Level)	3.90	1.06	.32**	.31**	.33**	.29**	.22**	.24**	.45**	.23**	.04	*(.86)*				
11.SC (Group Level)	3.64	1.23	.15*	.15	.16*	.16*	.10	.07	.22**	.21**	.23**	.57**	*(.91)*			
12.Social influences	4.33	.84	.44**	.44**	.32**	.54**	.45**	.53**	.30**	.28**	.15	.33**	.15*	*(.60)*		
13.Emotions	3.88	.99	.38**	.29**	.39**	.34**	.34**	.41**	.25**	.35**	.28**	.30**	.16*	.47**	*(.76)*	
14. Target behaviour	4.64	.69	.63**	.60**	.54**	.52**	.43**	.40**	.48**	.69**	.22**	.41**	.21**	.50**	.34**	*(91)*

Table 7. *Descriptive and correlation statistics of the SBCQ scales in the validation sample (N = 153): Safe storage as the target behaviour*

Factor	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Knowledge	4.33	.98	*(.90)*													
2.Skills	4.02	.93	.70**	*(.72)*												
3.Identity	3.96	1.09	.57**	.59**	*(.86)*											
4.Capability	3.96	.99	.58**	.63**	.54**	*(.83)*										
5.Optimism	4.04	.89	.56**	.48**	.47**	.45**	*(.74)*									
6.Consequence	4.19	.99	.48**	.23**	.25**	.26**	.54**	*(.67)*								
7.Reinforcement	3.69	.92	.28**	.29**	.19*	.33**	.30**	.28**	*(.68)*							
8.Goals	3.82	.86	.39**	.42**	.32**	.29**	.40**	.30**	.32**	*(.72)*						
9.Memory	3.16	1.04	.00	.02	.00	.00	.00	.11	.10	.00	*(.71)*					
10.SC (Org. Level)	3.49	1.06	.26**	.23**	.26**	.29**	.38**	.22**	.42**	.42**	.00	*(.90)*				
11.SC (Group Level)	3.35	1.25	.24**	.31**	.33**	.30**	.34**	0.13	.30**	.35**	.00	.74**	*(.87)*			
12.Social influences	3.98	.86	.48**	.48**	.43**	.38**	.48**	.35**	.43**	.44**	.07	.44**	.41**	*(.60)*		
13.Emotions	3.64	.98	.32**	.26**	.35**	.30**	.40**	.44**	.25**	.35**	.21*	.31**	.25**	.44**	*(.64)*	
14. Target behaviour	3.63	1.47	.49**	.44**	.56**	.51**	.35**	.21*	.34**	.45**	.23*	.22*	.27**	.38**	.31**	

Table 8. *MANOVA univariate and descriptive statistics across low and high safety behaviour performers*

SBCQ Dimension	F	df	p-value	M_{lp}	SD_{lp}	M_{hp}	SD_{hp}
Knowledge	10.53	1	.002	3.88	1.25	4.67	0.62
Skills	7.15	1	.01	3.66	1.18	4.32	0.75
Identity	19.64	1	< .001	3.40	1.09	4.43	0.72
Capability	12.66	1	.001	3.62	1.06	4.46	0.78
Optimism	6.84	1	.01	3.64	0.97	4.26	0.87
Consequences	2.34	1	.13	3.94	1.25	4.35	0.83
Reinforcement	4.10	1	.05	3.28	0.88	3.76	0.93
Goals	16.89	1	< .001	3.32	0.78	4.17	0.80
Social influences	3.52	1	.07	3.86	0.90	4.24	0.67
Emotions	13.19	1	.001	3.22	1.07	4.07	0.75
Decision Making	3.92	1	.052	2.44	0.85	2.94	1.06
Safety climate (Org. Level)	2.15	1	.15	3.20	0.98	3.62	1.20
Safety climate (Group Level)	3.41	1	.07	2.94	1.15	3.53	1.26

Note. M_{lp} = mean for the low performers group; SD_{lp} = standard deviation for the low performers group; M_{hp} = mean for the high performers group; SD_{hp} = standard deviation for the high performers.

Table 9.

Measurement Invariance Analysis

Model	χ^2	df	CFI	RMSEA	SRMR	ΔCFI	Comparison	Invariant?
Equal Forms	1006.15	666	.954	.050	.047	---	---	---
Equal Loadings	1056.93	692	.951	.051	.056	0.003	vs. Equal Forms	Yes
Equal Intercepts	1214.31	718	.933	.058	.066	0.021	vs. Equal Forms	No
Equal Intercepts - Revised	1157.05	726	.944	.052	.101	0.010	vs. Equal Forms	Partially

Note. The following parameters were released in the equal intercepts – revised model: item #1's intercept across Slip and PPE subsamples ("I am aware and understand the purpose of [safety behavior] at work") and item #3's intercept across all groups ("I am confident in my ability to [safety behavior] at all times.") The residual variance of item #20 was fixed to zero to solve model identification issues ("Forgetting to [safety behavior] is an easy mistake to make.")

Appendix 1. *The final SBCQ questionnaire tool*

Please tick one box to indicate the extent to which you agree with the following. (1 – Strongly disagree, 5 - Strongly Agree).	**1**	**2**	**3**	**4**	**5**
Knowledge					
I am aware of and understand the purpose of *(insert safety behaviour)* at work	1	2	3	4	5
I am aware of when and how I should *(insert safety behaviour)* at work	1	2	3	4	5
Skills					
I am confident in my ability to *(insert safety behaviour)* at all times	1	2	3	4	5
(Insert safety behaviour) is simple and easy to always do	1	2	3	4	5
Identity					
People in my role should be able to *(insert safety behaviour)*	1	2	3	4	5
(Insert safety behaviour) to ensure and promote safety, is an important part of my role	1	2	3	4	5
Capability					
If I want to, I would have no difficulty in *(insert safety behaviour)*	1	2	3	4	5
I am confident that I am able to *(insert safety behaviour)*, even when time is limited	1	2	3	4	5
Optimism					
(Insert safety behaviour) is a simple task that promotes compliance with other safety behaviours	1	2	3	4	5
The benefits of *(insert safety behaviour)* outweigh the time and effort it takes to do so	1	2	3	4	5
Consequences					
The consequences of not *(insert safety behaviour)* can be severe	1	2	3	4	5
Safety is likely to be compromised if workers do not *(insert safety behaviour)*	1	2	3	4	5
Reinforcement					
Not *(insert safety behaviour)* is not tolerated	1	2	3	4	5
Not (insert safety behaviour) is taken seriously regardless of whether it results in negative consequences	1	2	3	4	5
Goals					
Targets and goals are likely to be effective in promoting *(insert safety behaviour)*	1	2	3	4	5

(Insert safety behaviour) should be a top priority for promoting safety	1	2	3	4	5
Memory					
If I do not *(insert safety behaviour),* it is likely that I have simply forgotten	1	2	3	4	5
Forgetting to *(insert safety behaviour)* is an easy mistake to make	1	2	3	4	5
Safety Climate (Organizational level)					
Top management uses any available information to improve existing safety rules in relation to *(insert safety behaviour)*	1	2	3	4	5
Top management listens carefully to workers' ideas about improving safety in relation to *(insert safety behaviour)*	1	2	3	4	5
Safety Climate (Group level)					
My direct supervisor frequently talks about safety issues throughout the work week in relation to *(insert safety behaviour)*	1	2	3	4	5
My direct supervisor spends time helping us learn to see problems before they arise in relation to *(insert safety behaviour)*	1	2	3	4	5
Social Influences					
Myself and others are likely to encourage and remind workers to *(insert safety behaviour)*	1	2	3	4	5
(Insert safety behaviour) is normal and expected here	1	2	3	4	5
Emotions					
I would likely worry if I did not *(insert safety behaviour)*	1	2	3	4	5
I enjoy *(insert safety behaviour)* as it helps promote safety in the workplace	1	2	3	4	5