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When workplace safety depends on behavior change: Topics for behavioral safety research ☆

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ABSTRACT

Introduction: Comprehensive interventions that address public-health concerns invariably include behavior-change strategies. In occupational safety and health, *behavioral safety* is an approach designed to improve safety performance directly through peer observations of safe behaviors, goal setting, performance feedback, and celebrations or incentives for reaching safety goals. Although the basic components of behavioral safety processes have been studied and widely documented, the current safety literature reveals several gaps in knowledge. These gaps are associated mostly with wide practice variations among the common process elements and uncertainty about the influence of organizational and other external factors. *Impact to Industry:* A major objective of this paper was to highlight not only key topic areas that warrant further research, but also to propose a list of research questions that are tied to uncertainties about various intervention practices. If only a portion of these topic areas and research questions are addressed through systematic reviews, field interventions, surveys, and laboratory-based studies, then the knowledge gained will significantly improve the delivery and effectiveness of behavioral safety interventions and thus their impact on worker health and safety.

1. Introduction

According to recent Bureau of Labor Statistics estimates, there were 5,703 fatal and 3.9 million nonfatal workplace injuries in the United States in 2006 (BLS, 2007a,b). When the costs of workplace injuries, illness, and fatalities to the economy are also considered, the public health significance of developing effective occupational safety and health interventions is clear. As with other public-health concerns (Lutzker & Whitaker, 2005), a comprehensive intervention program will include one or more behavior-change strategies. In the occupational-safety arena, *behavioral safety* is an approach designed to change safety-related behaviors directly through the application of behavioral principles and multiple strategies, such as peer observations of safe behaviors, goal setting, performance feedback, and celebrations or incentives for reaching safety goals.

The term *behavioral safety* is used herein as a catch-all term for a variety of behavior-based occupational safety interventions (Agnew & Snyder, 2002; Geller, 2001; Krause, 1997; McSween, 2003). Although the general features of various behavioral safety processes are similar, the specific process elements and practices associated with implementation vary considerably. Furthermore, many processes are proprietary or not well documented in the safety literature; therefore, it is difficult for safety professionals to identify best intervention practices. This paper identifies the common features of behavioral safety, and highlights some important sources of variation among the different intervention approaches. A major objective of this paper is to propose and organize topics of research that will help fill key knowledge and practice gaps. Our main goal is to provide a resource that can help safety researchers conceptualize and develop studies that will provide data-based evidence for or, when appropriate, against the adoption of specific practices associated with behavioral safety.

This paper is not intended to be an exhaustive review of the behavioral safety literature. Topical reviews can be found elsewhere (Grindle, Dickinson, & Boettcher, 2000; Krause, Seymour, & Sloat, 1999). Nor is this paper intended to provide a comparison or evaluation of behavioral safety interventions relative to other safety controls. We acknowledge that there is no better solution for reducing worker injuries than eliminating safety hazards and risks through direct engineering or administrative controls. Thus any recommendation for behavioral interventions herein assumes that a behavioral safety process was deemed necessary and appropriate in accordance with the widely accepted hierarchy of safety controls (NSC, 2008): elimination, substitution, engineering controls, administrative controls, and personal protective equipment.

☆ The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

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Behavioral safety can actually be conceptualized as fitting into any level of the hierarchy whenever implementation or evaluation of a control depends on behavior change. For example, in some variations of behavioral-safety processes observers are trained to identify and record potentially hazardous conditions and equipment to be fixed, with the goal of eliminating the threat. Behavioral-safety texts also advocate active positive involvement of supervisors, safety experts (such as safety engineers), and managers as administrative controls in the process. In addition, awareness campaigns and comprehensive safety training are prominent features of a state-of-the-art behavioral-safety process. Finally, the use of Personal Protective Equipment can be recorded through peer observation, which offers opportunities for feedback and even recognition for high levels of use.

Most accounts of the origins of behavioral safety credit Herbert W. Heinrich's identification of human behavior in the 1930s as an important factor in occupational safety (Heinrich, 1931; Heinrich, Petersen, & Roos, 1980). Heinrich argued that the overwhelming majority of workplace injuries were the result of unsafe actions by workers. To prevent or reduce unsafe behaviors and thus the risk of injuries, Heinrich advocated engineering controls, as well as non engineering interventions such as safety training, hiring on the basis of safety-related selection criteria, progressive disciplinary programs, and, as a last resort termination of repeated safety violators (Heinrich et al., 1980). Unfortunately, reports of behavior-based safety implementations that over-emphasized behavioral controls at the expense of improving unsafe conditions led to the common criticism that behavior-based safety "blames the worker"(Cooper, 2003). While being sensitive to this criticism, contemporary behavioral safety providers eschew negative or coercive methods, and they regard behavioral approaches as just one of many components in a comprehensive safety program. Furthermore, behavioral safety processes are not intended to replace other control technologies or approaches (Cooper, 2003).

Because current behavioral safety providers and researchers emphasize *positive reinforcement* as a method for addressing variability in safety performance, contemporary behavioral safety processes were influenced arguably more by the psychologist B. F. Skinner than by Heinrich. In fact, the application of Skinner's *principles of reinforcement* to occupational safety and health is one of psychology's important contributions to society (Zimbardo, 2004). Systematic research on the behavioral approach to organizational issues, including safety began in 1977 with the *Journal of Organizational Behavior Management*, which was dedicated to the scientific analysis of work-related performance, mainly from a Skinnerian perspective. Two separate papers by Komaki, Barwick, and Scott (1978) and Smith, Anger, and Uslan (1978) published in 1978 are probably the first two empirical investigations of safety behavior that combined training, performance feedback, and reinforcement to increase the frequency of safe behaviors in manufacturing settings. Since these early studies, the field of behavioral safety has evolved into numerous variations (Agnew & Snyder, 2002; Geller, 2001; Krause, 1997; McSween, 2003).

Many scientific studies and anecdotal reports support the claims of behavioral safety proponents that lasting injury reductions can be achieved through some form of behavioral safety process (Agnew & Snyder, 2002; Grindle et al., 2000; Krause et al., 1999). However, because specific intervention practices vary considerably, and because few studies have systematically evaluated and compared the various approaches, it is difficult for safety professionals to identify best practices. Nevertheless, contemporary behavioral safety approaches have increased in popularity, and they appear to be an important component of comprehensive injury prevention programs, especially when at-risk behaviors persist even after other controls have been implemented.

2. Recommended Research Areas

Despite some existing evidence of successful applications of behavioral safety processes, there remain many knowledge gaps, unanswered questions, and thus many opportunities for research. We categorized the research needs into three main categories: (a) surveillance, reviews, and case studies, (b) best-practices research, and (c) intervention effectiveness studies.

2.1. Surveillance, Reviews, and Case Studies

Although the use of behavioral safety is believed to be widespread across industry (Sulzer-Azaroff & Austin, 2000), we know of no study that has quantified its prevalence through surveillance research. Moreover, information about industry's experience with these approaches is limited at best. A better understanding of these experiences will help identify not only best or promising practices, but also the obstacles and barriers to successful implementations and the knowledge or practice gaps that provide opportunities for research. Accordingly, comprehensive surveys need to be developed and administered periodically across all industry sectors to identify recent experiences with behavioral safety implementations, which appears at this time to be a research endeavor of great importance. Minimally, these surveys should: (a) assess the prevalence of behavioral safety approaches; (b) identify the common practices associated with behavioral safety; (c) assess individual perceptions and attitudes toward the intervention process; (d) identify specific behavioral safety practices that are correlated with superior safety performance; and (e) identify organizational and cultural factors that are associated with intervention effectiveness, such as those related to safety policies, management structure and practices, employee and management participation, employee and management performance appraisals, and labor-management cooperation.

Systematic reviews of the surveillance data and meta analyses of the published safety research also are needed to evaluate and compare the effectiveness of various intervention approaches and process elements. These analyses can help reveal knowledge gaps and highlight topics for further research. Systematic reviews or meta-analyses (Krause et al., 1999) of published intervention effectiveness studies are needed to determine the generality of intervention outcomes across various work settings. Moreover, it is important that reviews be conducted by impartial researchers and that any possible bias or conflicts of interests be revealed, especially when proprietary intervention packages are studied. Whenever possible, behavioral safety providers and safety consultants might also partner with researchers in government or academia to assist the development and conduct of well-designed and controlled intervention studies. Such collaborations also can alleviate possible suspicions of bias toward specific intervention process.

Detailed case studies also are important to illustrate common or unique experiences associated with implementations of behavioral safety interventions across various industry sectors and organizations. Case studies are especially informative when they illustrate process or organizational variables that are critical for success, and when they illustrate cost savings, improvement in work life, and company profitability (Rose & Harshbarger, 1991). Case studies also can be used for identifying best or promising industry-specific safety practices, illustrating common or unique barriers and obstacles to implementation and maintenance, and benchmarking.

2.2. Best-Practices Research

Studies that will lead to the development or identification of best behavioral safety practices comprise our second category of research. We have proposed specific research questions across several topic areas that correspond to the most common features of the behavioral safety process.

Fig. 1 depicts a generic behavioral safety process map that shows the involvement of key participants at different stages of the process in their respective "swim lanes." Some elements of the process are more common than others, but Elements 13-15 are especially

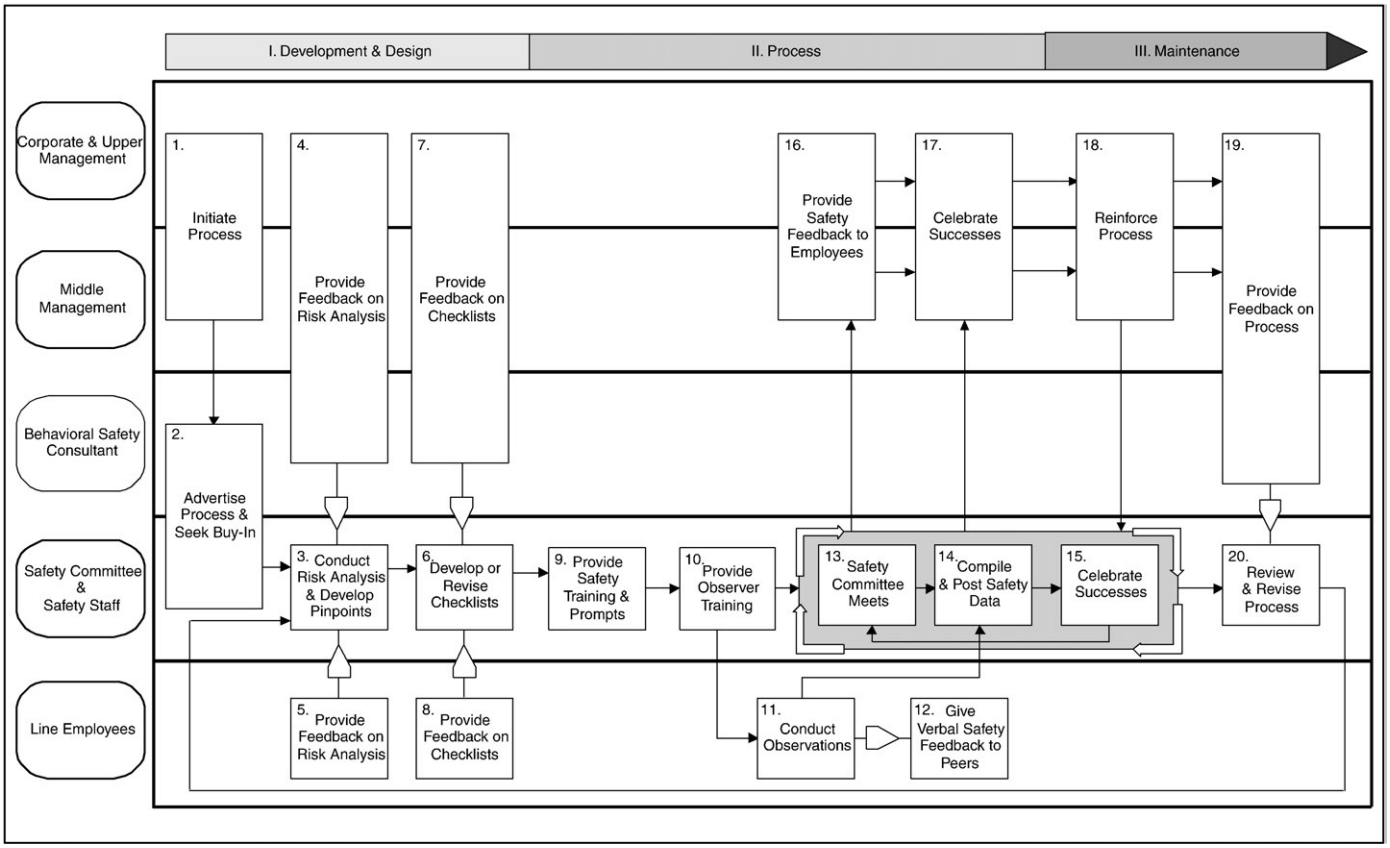

Fig. 1. A generic behavioral safety process map showing the involvement of key participants at different stages of the process in their respective "swim lanes." Activities that span more than one swim lane indicate multiple or shared involvement in that activity. Arrows indicate the flow of information, and lines with open pentagons indicate feedback. Elements 13-15 represent core activities that drive the process.

highlighted as they represent what most behavioral safety experts agree are crucial to a successful behavioral safety process. The critical reader might notice that the contribution of line employees and consultants to the development of the process appears in Fig. 1 to be minimal; however, because line workers usually are well represented on safety committees, their additional contributions are captured in that swim lane. Safety consultants also are involved in many of the process activities, but due to space considerations, their main contributions are depicted during the initial development and design stage only. During this stage, the importance of establishing a safety committee is perhaps the single most important practice linked to improved safety performance (Parker et al., 2007).

We organized our proposal for best-practices research around topic areas that encompass the various elements shown in the process map. These topic areas are: (a) risk analysis and pinpointing, (b) goal setting, (c) training and prompting, (d) observation and measurement, (e) feedback, and (f) rewards and incentives. A list of specific sample research questions appears in Table 1.

2.2.1. Risk Analysis and Pinpointing

The first step in any behavioral safety process is the identification of critical safety-related behaviors (Killimett, 1991); however, there are no universally accepted guidelines for pinpointing or targeting appropriate behaviors for change. The approaches advocated by different behavioral safety providers vary widely, and little empirical evidence exists to support the use of one approach over another.

A distinguishing feature of most behavioral safety processes is the identification and quantitative measurement of safe, unsafe, or "at-risk" behaviors. Most often, relevant safety-related behaviors are targeted for change (Komaki et al., 1978), rather than probable adverse health or safety consequences of those behaviors (e.g., injury, illness, or lost-time instances), which are often too remote or uncertain to provide a useful, immediate measure of intervention effectiveness. The distinction between pinpointing *safe* versus *unsafe* behaviors for change is often overlooked, but it has important implications for selecting an appropriate behavior-change strategy. For instance, reinforcement is an appropriate strategy when the goal is to increase the frequency or probability of a behavior, whereas punishment (e.g., progressive discipline) is the strategy for decreasing the frequency or probability of a behavior (Catania, 2000). Although punishment may be appropriate under rare circumstances, such as when a blatant disregard or violation of a clear safety rule or policy occurs, the vast majority of behavioral safety providers advocate positive reinforcement to promote safe behaviors. [More about reinforcement and punishment later].

One of the most important research questions in this area is whether the effectiveness of a behavioral safety process depends on the specificity with which the target behaviors are defined. One approach is to identify several different general categories or *classes* of behaviors associated with an increased risk of causing injuries or illnesses (Komaki et al., 1978). An apparent advantage of specifying classes of safety behaviors, rather than every instance or occurrence of a specific behavior, is the potential for influencing a large set of safety-related behaviors efficiently. A potential disadvantage of specifying several classes of safety behaviors is that influence over any one specific instance of behavior might be limited and attention might be directed toward behaviors that do not currently pose a risk. It is perhaps more effective and efficient to differentiate safety-related behaviors according to whether they have led to injuries in the past versus only those classes of behavior that have recently caused injuries (Komaki et al., 1978; Sulzer-Azaroff & Santamaria, 1980). Resources and attention then can be directed toward specific behaviors according to greatest priority. According to some experts (Sulzer-Azaroff & Santamaria, 1980), this approach is more pragmatic, especially in large industrial settings; however, an alternative

Table 1
Suggested topic areas and specific sample questions for *best-practices research* related to behavioral safety processes

Topic Areas	Research Questions	Exemplar Studies
1. Risk Analysis and Pinpointing	a. What behaviors should be targeted for behavior-change interventions? How does targeting behaviors directly compare with targeting behavioral outcomes (e.g., housekeeping)?	(Lingard & Rowlinson, 1997)
	b. How precisely or globally shall behaviors be defined? Are general classes of behavior appropriate targets for intervention?	(Killimett, 1991; Komaki et al., 1978; Sulzer-Azaroff & Santamaria, 1980)
	c. Should the performance of supervisors, managers, and executives be targeted for behavior change?	(Zohar, 2002)
	d. What tools are available to aid in the identification of target behaviors? Can these tools be evaluated? Can better tools be developed?	(Wiegmann & Shappell, 2001)
2. Goal Setting	a. Is goal setting critical for successful interventions?	(Ray et al., 1997; Reber & Wallin, 1984; Reber et al., 1990; Reber et al., 1984)
	b. What tools are available to aid goal setting? Can these tools and their features be evaluated? Can better tools be developed?	(Cooper et al., 1994; Fellner & Sulzer-Azaroff, 1984)
	c. What organization factors influence adherence to safety goals?	(DePasquale & Geller, 1999)
	d. Is worker participation important for goal setting? Does it matter if goals originate with management?	(DePasquale & Geller, 1999; Ludwig & Geller, 1997)
3. Training and Prompting	a. What learning objectives will support a successful behavioral intervention? Should they be specific or general?	
	b. How do mandatory and voluntary training programs compare? Are participatory approaches better?	(DePasquale & Geller, 1999)
	c. How frequently should training or retraining occur? Under what conditions is retraining necessary?	
	d. How can prompts be used effectively to help promote safety performance?	(Austin et al., 2006; Berry et al., 1992)
4. Observation and Measurement	a. Are behavioral checklists and observations the best way to measure safety performance? Are there alternative methods?	(Cooper et al., 1993)
	b. What number of behaviors (pinpoints or targets) is optimal for inclusion on a behavioral checklist? Does the number of checklist items affect accuracy of measurement?	(Geller, 1997; Krause, 1984, 1997)
	c. Does frequency of observations affect measurement accuracy or reliability? What is the minimum effective observation frequency?	(Cooper, 2006)
	d. Are observers more likely to engage in safe behaviors (observer effect)? What conditions or variables influence the observer effect?	(Alvero & Austin, 2004; Alvero et al., 2008; Sasson & Austin, 2004)
5. Feedback	a. Is performance feedback always necessary for behavioral change? Under what conditions is feedback critical?	(Alvero et al., 2001; Balcazar et al., 1985)
	b. How does the timing of performance feedback impact intervention effectiveness (e.g., frequency, immediacy, or duration)?	(Alavosius & Sulzer-Azaroff, 1990; Pampino, MacDonald, Mullin, & Wilder, 2003)
	c. Is the mode or type of feedback important (e.g., verbal or written, tangible vs. non tangible, specific vs. general, or public vs. private)?	(Alvero et al., 2001; Balcazar et al., 1985)
	d. Who should provide feedback (e.g. peers, supervisors, and/or managers)?	(Alvero et al., 2001; Balcazar et al., 1985)
	e. Should feedback be individualized to each worker? Under what conditions is group-based feedback effective?	(Komaki et al., 1980)
6. Rewards and Incentives	a. Are non tangible rewards (e.g., praise or recognition) less, equally, or more effective than tangible consequences (e.g., monetary rewards or gifts)? Who should provide rewards and participate in celebrations?	(Geller, 2001)
	b. What is the efficacy of various incentive programs? Under what conditions do incentives become disincentives for incident reporting?	(McAfee & Winn, 1989)
	c. Under what conditions might token economies be effective?	(Fox et al., 1987)

approach is to target only a few specifically defined behaviors at a time until they occur reliably (Geller, 2001).

Another area for research concerns the evaluation and development of new risk-assessment tools, which safety professionals, employers, or safety committees can use to systematically identify appropriate behavioral targets for change. Various tools, such as root cause analyses of injuries (ABSConsulting, 2005) and PIC/NIC analysis of consequences (Agnew & Snyder, 2002; Daniels & Daniels, 2006), have been developed to aid the identification of at-risk behaviors. PIC/NIC analyses focus on the consequences of behavior from the employee's perspective, and whether those consequences are positive or negative in nature, immediate or delayed, certain or uncertain. The effectiveness of root cause and PIC/NIC analyses in guiding the pinpointing process has not been empirically evaluated within a behavioral safety process, but the Performance Diagnostic Checklist (Austin, 2000) is a tool that has been validated in organizational interventions involving non-safety related behaviors. One interesting question to be addressed in future research pertains to the convergent validity of these tools—that is, do these tools identify the same problems and solutions or do they provide unique recommendations? Another question pertains to the extent to which safety-engineering skills are needed to conduct analyses of hazards and risks. Some behavioral safety texts suggest non-safety staff might be sufficient for conducting some types of assessments, such as peer observations (McSween, 2003).

Most risk assessments are designed to identify the at-risk behaviors of front-line workers because of their involvement with and close proximity to hazardous conditions; however, behavior-based safety providers agree that the effectiveness of a safety process is strongly dependent on maintaining support and participation of individuals at other organizational levels, including company management (Cooper, 2006). Despite this acknowledgement, behavioral interventions rarely target the safety-related behaviors of supervisors and managers explicitly. Exceptions include two studies (Sulzer-Azaroff & Santamaria, 1980; Zohar, 2002) that involved company managers and sometimes the company vice president providing regular feedback to *supervisors* on their specific roles in a behavioral safety process. These studies highlight the importance and potential usefulness of applying or evaluating behavioral safety processes at multiple levels of an organization. Studying the interdependencies among the safety performances of workers, supervisors, and management will likely lead to more effective and sustainable interventions.

Behavioral safety researchers and providers might also use existing risk-analysis tools such as the Human Factors Analysis and Classification System (HFACS) (Reinach & Viale, 2006; Wiegmann & Shappell, 2001). The HFACS, which originated in the aviation industry, is a systematic approach toward identifying various factors that can lead to a safety-related incident, including decision and judgment errors that occur at all organizational levels. A major advantage of such tools is their systematic approach and comprehensive consideration of all possible contributing factors in the chain of events leading to an injury.

2.2.2. Goal Setting

Goal setting in a safety process has received some attention in the safety training literature (NIOSH, 1999), and goal setting is commonly

used in behavioral safety to augment the effects of safety training alone (Reber & Wallin, 1984). There are several issues pertaining to goal setting that warrant further research. For example, several studies have compared the effectiveness of goal setting that is assigned (e.g., goals assigned by a supervisor without employee input) and goals that are participative (e.g., goals generated by employees or safety committees), however, the evidence for differential effects of assigned versus participatory goal setting is mixed (Fellner & Sulzer-Azaroff, 1984; Ludwig & Geller, 1997). Furthermore, when participatory approaches are used, it is not known whether participation rate (i.e., the proportion of all workers involved in the goal setting process) is an important factor in establishing effective safety goals (Cooper, Phillips, Sutherland, & Makin, 1994).

There also is no clear understanding of how goal setting interacts with other components of the safety process. For example, in studies of performance feedback combined with or without goal setting, the addition of goal setting did not appear to lead to further reductions of at-risk behaviors and unsafe conditions (Fellner & Sulzer-Azaroff, 1984). Other reports suggest that combining feedback and goal-setting is more likely to yield improvements beyond goal setting alone (Reber & Wallin, 1984; Reber, Wallin, & Chhokar, 1990; Reber, Wallin, & Chhokar, 1984), and that safety performance will track gradually increasing performance criteria (Sulzer-Azaroff, Loafman, Merante, & Hlavacek, 1990). Further research is needed to analyze the independent contribution of goal setting to the safety process, and to analyze its effects on individual worker behavior. Other avenues for goal-setting research include the development of tools that aid in the generation of safety goals, how employees can be motivated to contribute to goal setting, and how organizational factors influence adherence to goals.

2.2.3. Training and Prompting

Training has received much attention in the safety literature, and several comprehensive reviews already exist (Cohen & Colligan, 1998; Johnston, Cattledge, & Collins, 1994). Traditional one-time organizational training interventions might fail or be only minimally effective if they do not program for sustained reinforcement contingencies to motivate behavior (Malott, 1992). The same criticism may be directed toward traditional safety training programs (Bell & Grushesky, 2006; McDonald, 1989). Nevertheless, if workers lack critical safety skills, training is a necessary prerequisite to any intervention. Research opportunities in behavioral safety training pertain to both safety skills training and safety observer training. For example, studies need to evaluate whether training objectives should be general (e.g., improve lifting safety) or relatively specific (e.g., teach specific movement/lifting strategies). In addition, it is not clear whether safety training must always address both critical behaviors and unsafe conditions. Other topics for training research can include whether peers, supervisors, safety staff, or safety consultants are the most effective trainers, whether training aids such as modeling and role-playing or the use of computer-based training modules can enhance training effectiveness, and how to determine whether re-training is necessary. Furthermore, in any study of training effectiveness, it is important to measure knowledge gains following training and satisfaction measures, and also strive, when possible, to collect observational data before and after training to gauge how training impacts safety behavior and injury rates. Other research guidelines specific to training effectiveness research can be found elsewhere (NIOSH, 1999).

Another topic of relevance concerns the use of behavioral prompts (e.g., sign, poster, verbal reminder). A prompt is an event that increases the probability of a target behavior that follows it. Much of the research on prompts in safety has been in the arena of traffic safety. These studies suggest that verbal prompts delivered by an individual are more effective than written prompts (Berry, Geller, Calef, & Calef, 1992; Williams, Thyer, Bailey, & Harrison, 1989), and that prompts delivered immediately before the target behavior is to be emitted are more effective than prompts that are delayed (Austin, Sigurdsson, & Rubin, 2006). The extent to which these relationships generalize to behavioral safety in occupational settings has not been systematically studied, but this certainly appears to represent a key research question in the area of behavioral safety given the widespread use of prompts in safety interventions. Another question concerns the novelty of prompts in the environment, and whether safety prompts will lose their effectiveness over time and thus need to be replaced (Geller, 1997). Several additional research topics regarding the use of prompts appear elsewhere (Geller, 1997).

2.2.4. Observation and Measurement

Since an early review of the advantages and limitations of various behavioral-measurement strategies (Komaki, Collins, & Thoene, 1980), few studies have been conducted to systematically evaluate or compare the different measurement approaches used in safety research. Thus several questions remain about what measurement tools and strategies work best. A characteristic feature of behavioral safety is its reliance on direct peer observations of safety-related behaviors. Although the direct observations of at-risk behaviors are typical, it is not uncommon to also target the outcome or consequences of safety-related behaviors, such as a clean floor, guard installed on a machine, or a secured ladder.

Because not every occurrence of a target behavior can be observed feasibly, most behavioral safety processes rely on observational sampling procedures with a goal of capturing a representative sample of behavior. The accuracy of the sampling procedure might be dependent on factors such as the frequency of observations and the number of observers employed, but these factors have not been studied systematically. Observation frequency, for example, can vary hourly, daily, weekly, monthly, and even yearly depending on the behavioral safety provider. In addition, it seems intuitive that the more eyes, the better, and anecdotal reports suggests that training all or most workers in the observation process also facilitates the long-term acceptance of the behavioral safety process (Krause, 1997), but this also has not been tested empirically.

Another question that warrants further research is whether the accuracy of observations and workers' perceptions of the observation process are affected by different observers—peers, members of the safety committee, supervisors, or managers. One reported advantage of training peer observers is the claim that the act of observing the safety performance of others promotes the observer's own safety behavior (McSween, 2003). The so-called “observer effect” has been studied empirically (Alvero & Austin, 2004; Alvero, Rost, & Austin, 2008; Sasson & Austin, 2004), but it is unclear what conditions promote or influence this effect.

Observational recording methods are usually aided by behavioral checklists to record occurrences or non occurrences of the target behaviors or behavioral outcomes (Komaki, Barwick, & Scott, 1978). Variations in practice occur mainly in the specificity and comprehensiveness of the checklist. Depending on the behavioral safety provider, checklists can include 40-50 general behaviors under several categories of performance (e.g., housekeeping, personal protection, procedures, and environment; Krause, 1997; McSween, 2003), whereas others can include only 3-5 specifically-defined target behaviors (Agnew & Snyder, 2002). Checklist detail and comprehensiveness seem to differ mainly on the basis of the provider's own preference or experience, but checklist design also reflects important differences in behavioral strategy, and different strategies might have differential effects on short- and long-term safety performance. For example, some behavioral safety providers target only a few high-priority safety-related behaviors at any one time. When performance of a target behavior reaches a goal (i.e., 100%), the behavior is “retired” and replaced with a new target behavior. The process continues indefinitely, and long-term maintenance of safety performance is promoted by regularly revisiting (i.e., observing and measuring) previously retired behaviors. A decision to target few behaviors, many

behaviors, or sometimes both may depend on several other factors (Geller, 2001), but the systematic study of these different strategies should be a priority research topic.

Various measurement statistics are used to summarize the behavioral observations. Some behavioral safety providers record the actual number of occurrences; some calculate a percentage of safe behaviors among all recorded observations. The occurrence of behaviors also can be recorded as an all-or-nothing measure or as a proportional measure (e.g., percentage of unsecured ladders or fully boarded scaffold platforms). One study found that proportional measures have advantages over all-or-nothing approaches because, among other reasons, they are more sensitive to minor changes in safety performance (Cooper, Phillips, Robertson, & Duff, 1993). Another report showed that an aggregate measure of safety behavior was effective in monitoring performance across several specific housekeeping behaviors (Saari, 1987). Despite some research in this area, the safety literature lacks sufficient information to guide the selection of an appropriate measurement statistic.

2.2.5. Performance Feedback

Feedback is a ubiquitous feature of most, if not all, behavioral safety processes (Agnew & Snyder, 2002; Geller, 2001; Krause, 1997; McSween, 2003), and the vast majority of studies on feedback report its effectiveness in promoting behavior change (Cohen & Colligan, 1998). In a typical behavioral safety process, opportunities for effective performance feedback occur at Elements 12, 14, and 16 in Fig. 1. Although the safety literature includes numerous studies and reviews of performance feedback both within and outside the safety arena, there are several specific knowledge gaps that are important for further research.

The mode through which feedback is delivered may be one important factor influencing its effectiveness. Some variations of feedback mode include verbal, written, graphic, and computer generated (Alvero, Bucklin, & Austin, 2001; Balcazar, Hopkins, & Suarez, 1985). Verbal and/or graphic feedback is advocated by most behavioral safety experts. Often a specific type of feedback is selected on the basis of organizational and practical limitations. Verbal feedback, for instance, can be delivered quickly and without disruption to ongoing operations by just about anyone in an organization (McSween, 2003), and graphic feedback, showing measures of safety performance over time and relative to performance goals, can be publicly displayed. Graphic feedback also has the advantage of being readily and continuously available to the entire work unit (Agnew & Snyder, 2002; McSween, 2003).

Different modes of feedback delivery have not been systematically evaluated in behavioral safety, and one especially interesting research question pertains to the relative contributions of two common types of safety feedback: immediate verbal feedback following an observation and delayed graphic feedback depicting summaries of past observations. Some behavioral safety experts advocate providing immediate verbal feedback following a safety observation (McSween, 2003), whereas others propose that occasional verbal feedback is sufficient (Agnew & Snyder, 2002). Most experts also advocate publicly displaying graphic feedback, even though it may be delayed by a few days. More empirical investigations are needed to determine the independent contributions of verbal and graphic feedback.

Feedback frequency, or density, is also related to feedback immediacy. For example, one study found that a denser schedule of feedback (i.e., feedback delivered for every observation) led to more rapid acquisition of target behaviors then a leaner schedule (Alavosius & Sulzer-Azaroff, 1990). It seems intuitive that the more frequent the feedback, the more effective it will be in changing behavior, but one study with nurses found that feedback delivered only once every 12-14 days was effective in promoting glove-wearing (Devries, Burnette, & Redmon, 1991). The extent to which feedback frequency or density is an important variable across many different work settings remains unexplored. In settings where feedback is found to be critical, research should attempt to identify the optimal temporal parameters associated with its delivery.

The source of feedback—whether it is conveyed by a peer, supervisor, manager, or company executive—is another factor that requires further investigation. Although some studies have found that a supervisory relationship between the worker and provider of feedback is not necessary for behavior change (Devries et al., 1991), we know of no study that has systematically manipulated different sources of feedback within an organization.

The generality or specificity of feedback also might be an important factor that warrants further research. Some behavioral safety experts advocate delivering feedback on single, well-specified behaviors (Agnew & Snyder, 2002; Sasson & Austin, 2004), whereas others advocate delivering general feedback for broad categories of behavior (Komaki et al., 1978; Komaki, Heinzmann, & Lawson, 1980; McSween, 2003; Reber & Wallin, 1984). A possible shortcoming of delivering feedback globally for a range of behaviors is that the workers may not know how well they are performing any one specific behavior. Another related issue concerns the uncertainly that can arise when feedback is posted publicly as an overall performance score. For example, a posted score of 50% safe can suggest either that all employees are moderately safe or that only one half of workers consistently performed the safe behavior (Alavosius & Sulzer-Azaroff, 1986; McCann & Sulzer-Azaroff, 1996). Although global feedback can be effective under some situations (Williams & Geller, 2000), additional research is needed to understand the appropriate conditions under which global and specific feedback can be maximally effective.

2.2.6. Rewards and Celebrations

Because modern behavioral safety processes focus on increasing the occurrence or probability of safe behaviors, a critical component of the process involves the explicit programming of rewards, celebrations, and other incentives. Technically, reinforcement is a basic learning process that occurs when a behavioral consequence increases the frequency, intensity, or duration of a targeted behavior. But, because it is often not known whether a positive consequence is effective in practice, Geller (2001) has argued that the term *reward* is better in this context because it refers to a positive consequence that has the *intention* of producing the desired change in behavior. According to Geller, even if a reward does not have the intended effect, it is likely to have indirect benefits to workers' perceptions of the safety process.

Because rewards can differ in form and method of delivery, there are numerous opportunities for research to determine how and when rewards should be programmed into a behavioral safety process. It is important to note that, when rewards or incentives are tied to improvements in injuries or other OSHA-recordable incidents rather than safety-related behaviors and near-misses, a disincentive for injury reporting can occur (Pransky, Snyder, Dembe, & Himmelstein, 1999). Research into the causes of underreporting appears warranted, as variables such as injury-based incentives and general safety culture may be determinants of underreporting. It should also be noted that most behavioral safety experts stress the importance of maintaining anonymity in the measurement process and safety-performance data records so as to not undermine worker trust in the safety process (Agnew & Snyder, 2002; McSween, 2003). Thus when rewards and incentive programs are designed carefully, the entire safety process should be sensitive in detecting even rare occurrences of at-risk behaviors.

One variable that requires further study relates to whether the reward is tangible (e.g., financial bonus and gifts) or intangible (e.g., praise, recognition, celebrations). Tangible rewards can be powerful motivators of safety performance (Austin, Kessler, Riccobono, & Bailey, 1996). For example, one study found that establishing a *token economy* in which credits exchangeable for gifts were provided for meeting performance goals was effective in improving safety performance and

reducing injuries in a traditionally hazardous mining setting (Fox, Hopkins, & Anger, 1987). Other approaches have demonstrated success with simpler programs that involve less tangible rewards, such as pizza parties, steak dinners, and other celebrations (Boyce & Geller, 1999). More research is needed to compare the effectiveness of various types of rewards, and to develop selection guidelines that also consider feasibility factors such as time allocations, costs, and other logistic requirements.

Another topic for research concerns whether the value of a reward, and thus its potential to positively influence behavior, is linked to its source (i.e., the person who delivers the reward). Although rewards are provided most often by supervisors and managers for reaching safety-performance goals, it is not clear from the existing safety literature who in the organization should participate in the reward or celebration process. Some studies show that when an organizational intervention is institutionalized, with active participation of line workers and supervisors, as well as managers that provide feedback and personally deliver rewards and participate in celebrations, the long-term maintenance of the process may be enhanced (Sigurdsson & Austin, 2006). Additional information on the reinforcement process and other related conceptual issues can be found elsewhere (Malott, 1992; Michael, 1993).

2.3. Intervention Effectiveness Research

The third category of proposed research encompasses various gaps in research and knowledge pertaining to various organizational factors that influence the overall effectiveness of behavioral interventions. We organized the specific research questions by the various organizational and methodological factors that likely influence the implementation, maintenance, and evaluation of behavioral safety interventions: (a) methodological issues, (b) safety culture and climate, (c) integrative interventions, (d), sector-specific applications, and (e) impact assessment. Examples of specific research questions pertaining to intervention effectiveness are listed in Table 2.

2.3.1. Methodological Issues

Reliable demonstrations of intervention effectiveness begin with scientifically sound methodology. Although the basic tenets and underlying principles of behavioral safety approaches are well-supported by science (Sulzer-Azaroff & Austin, 2000), the application of those basic principles must still be tested and verified in the real world. Furthermore, if intervention effectiveness studies are intended to support best-practice guidelines, then they must be held to rigorous scientific standards.

There are several research designs that are well-suited for demonstrations of behavioral safety effectiveness (Komaki & Goltz, 2001). For instance, reversal and multiple baseline designs are characterized by their reliance on establishing pre-intervention performance baselines against which the effects of an intervention process can be assessed. These within-subjects designs can be further improved by incorporating traditional group designs to differentially target multiple work groups or sites within the organization.

Unfortunately, field-intervention studies are challenging to design and conduct. They often are plagued by scheduling or work-organization conflicts, limited company resources, and other restrictions imposed by labor or management. If challenges or limitations are too difficult to overcome, then laboratory simulation studies may provide an alternative means to study a process element. For example, Johnston and Hayes (2005) provide a convincing case for the feasibility of laboratory simulations to study various components of the behavioral safety process. In their study, a computer simulation work task was used to investigate how different incentives affected the rate of at-risk behaviors and the reporting of those behaviors. Other investigators have used laboratory-based preparations to simulate occupational hazards and risks (Rubinsky & Smith, 1973) and variables associated with the observation and feedback processes (Alvero & Austin, 2004). These studies illustrate that laboratory-simulation studies can offer researchers controlled environments in which various features of the behavioral safety process can be dissected and systematically analyzed.

It is worth emphasizing that intervention studies should be designed and conducted by impartial researchers, and that any possible bias or conflicts of interests be revealed, especially when proprietary intervention packages are studied. Whenever possible, behavior-based safety professionals and safety consultants should partner with researchers in government or academia to develop well-designed and properly controlled intervention studies.

2.3.2. Safety Culture and Climate

Safety culture generally refers to the shared set of safety-related attitudes, perception, and behaviors among individuals in an organization (Zohar, 1980). Similarly, the notion of safety climate (Zohar, 1980) largely concerns employee perceptions of the safety culture in an organization (Choudhry, Fang, & Mohamed, 2007). Assessments of safety culture and climate have relied mainly on surveys (Guldenmund, 2007), but some researchers have integrated multiple approaches and assessment methods such as peer observations and climate surveys (Choudhry et al., 2007). Regular and systematic assessment of organizational safety climate and culture may help the safety professional monitor an ongoing behavioral safety process.

The analysis of safety climate has been shown to be generally predictive of safety performance in the workplace (Cooper & Phillips, 2004), but more research is especially needed to identify specific features of safety culture and climate that are associated with the effectiveness of a behavioral safety process. This research should focus not only on aspects of employees' perceptions of the safety culture, but also on those of supervisors, managers, and executives because workers and managers sometimes have different perceptions of safety climate (Prussia, Brown, & Willis, 2003). Management's role in a safety process is important in establishing a supportive safety climate (Zohar, 2003). In behavioral safety, management participation plays a key role in supporting the process by providing feedback during risk assessment and pinpointing phases, contributing to the development of checklists, providing performance feedback and reinforcement directly to workers and safety committees, and initiating celebrations of successes. In addition, labor union support and participation in early stages and in various components of the behavioral safety process have been found to increase cooperation and trust among workers (Ray, Bishop, & Wang, 1997). More research is needed to assess the relative importance of these key managerial and union roles in the behavior-safety process. Other specific research recommendations pertaining to the assessment of safety climate at multiple levels of an organization appear elsewhere (Zohar & Luria, 2005).

Several other research issues related to safety climate and culture are discussed elsewhere. Cooper (2000) and Geller (1997) provide a useful conceptual framework that incorporates three dynamic and interacting components involving the person, behavior, and environment that are compatible with the behavioral safety process. Another research topic of particular relevance to behavioral safety is the impact a process has on improving safety climate. Despite the belief that behavioral safety is not perceived favorably by workers, many studies have reported that implementations of the process affect worker perceptions positively (DePasquale & Geller, 1999; Grindle et al., 2000). More research in needed to confirm these reports, and determine the direction of any causal relationships found between the various elements of a behavioral safety process and concomitant improvements in safety climate. In particular, survey research appears needed on the possible causes of distrust toward behavioral safety, such as determining what particular elements of behavioral safety processes are likely to elicit unfavorable perceptions among workers and workers' unions.

Table 2
Suggested topic areas and specific sample questions for *intervention-effectiveness* research related to behavioral safety practices

Topic Areas	Research Questions	Exemplar Studies
1. Methodological issues	a. What are most effective research designs for demonstrating the effectiveness of behavioral safety interventions? Under what conditions can small-n designs be used effectively in field intervention studies?	(Komaki & Goltz, 2001)
	b. What are the major confounding and extraneous variables that threat internal and external validity of behavioral safety intervention research?	(Komaki & Goltz, 2001; Shannon, Robson, & Guastello, 1999)
	c. Can simulation and laboratory studies be used effectively to experimentally study, isolate, and control process variables associated with intervention success?	(Alvero & Austin, 2004; Johnston & Hayes, 2005)
2. Safety culture and climate	a. What is the relationship between behavioral safety and safety climate or culture? What aspects of safety climate or culture most influence the efficacy of behavioral interventions?	(Choudhry et al., 2007; Cooper, 2000; Geller, 1997)
	b. How are organizational factors measured best? Are perception and attitude surveys useful sources of information?	(Guldenmund, 2007)
	c. To what extent is management and union participation and support critical for intervention success? What specific management roles influence the success of behavioral safety processes?	(Cooper, 2006; Harper, 1996; Zohar, 2003; Zohar & Luria, 2005)
	d. What organizational factors promote the maintenance of behavioral safety processes?	(Bumstead & Boyce, 2004; Sigurdsson & Austin, 2006)
3. Integrative interventions	a. Where does behavioral safety fit among the widely accepted hierarchy of safety controls?	(DeJoy, 2005; Laitinen, 1998)
	b. What strategies or considerations should guide a safety professional's determination of the appropriateness of a behavioral safety intervention relative to other safety controls?	(Geller, 2001, 2005)
	c. Can behavioral safety interventions be implemented effectively in conjunction with other intervention approaches?	(DeJoy, 2005; Laitinen, Saari, Kivisto, & Rasa, 1997)
4. Sector-specific applications	a. Are the basic elements of behavioral safety processes appropriate for all industry sectors? Do behavioral safety processes need to be tailored to address any unique worker characteristics, work settings, or organizational structures of different industrial sectors?	
	b. What barriers, obstacles, or challenges to intervention success exist in various industry sectors?	
	c. Is self-monitoring or self-observation methods reliable and effective in industries where workers often work alone (e.g., long-haul trucking, construction, mining)?	(Hickman & Geller, 2003a,b; Olson & Austin, 2001; Peters, 1991)
5. Impact assessment	a. What is the impact of behavioral safety interventions on rates of injury, illness, and fatalities?	(Krause et al., 1999)
	b. What is the economic impact of behavioral safety intervention successes at the worker, company, and industry levels?	(Rose & Harshbarger, 1991)
	c. Can tools/models be used or developed to predict cost savings associated with improved safety performance?	
	d. What are the relative costs versus benefits of specific elements of the behavioral safety process?	(Kenoyer et al., 2001)

2.3.3. Integrative Interventions

There seems to be an increasing number of proponents of integrative safety processes — those that incorporate psychological, social, behavioral, engineering, and organizational aspects (DeJoy, 2005; Laitinen, 1998). Unfortunately, there is little information or guidance in the safety literature on how various safety controls should be integrated. As a first step, reports of behavioral safety interventions should include a description of other safety control technologies considered and/or implemented to show how behavioral safety interacts with other control technologies. These reports should also describe the various factors that influenced the implementation strategy, such as the availability of engineering solutions, company resources, and any other organizational factors.

2.3.4. Sector-Specific Applications

In 2006, NIOSH and the National Occupational Research Agenda (NORA; NIOSH, 2006) was reorganized around eight major industry sectors to better address industry-specific health and safety problems. According to the NIOSH website, the sector-based approach was developed to better move research to practice in workplaces. To be maximally effective, it follows that the implementation of behavioral safety processes must be tailored to the unique characteristics of various industry sectors. Therefore, studies that lead to the development of industry-specific guidelines for behavioral safety interventions should be a high research priority.

Although the safety literature contains reports of interventions applied to different industry sectors, more research is needed to identify the critical process features and the unique barriers or obstacles that can exist in various industries. This information can then be used to develop and evaluate industry specific behavioral safety packages. In the trucking industry, for example, where drivers often work alone, it is not possible to arrange frequent or regular peer observations to monitor the truckers' safety performances. Instead, a remedy for the trucking industry might be to rely on self-monitoring or self-management (Olson & Austin, 2001). Studies have shown that self-monitoring can yield accurate quantifiable estimates of safety performances of lone or small groups of workers in trucking (Hickman & Geller, 2003b; Olson & Austin, 2001) and in mining (Hickman & Geller, 2003a; Peters, 1991).

Research also is needed to better understand the various safety climates and cultures that persist across industry sectors. For example, in some industry sectors such as forestry and fishing, there is a culture of risk taking that can be a source of pride among its workers. In these settings the social reinforcement that maintains risk-taking behavior must be addressed before behavioral safety interventions can be maximally effective. Identifying specific remedies for improving safety climate and culture remains a high-priority research topic.

2.3.5. Impact Assessment

Evaluations of behavioral safety interventions can be based on a variety of outcome measures. Minimally, researchers must show that a behavioral safety intervention produced the desired behavioral change. Because the targeted at-risk behaviors in most instances are known to be directly related to the occurrence of injuries or other adverse health outcome, obtaining a quantifiable change in those at-risk behaviors may be a sufficient end-outcome to demonstrate intervention effectiveness. The same quantified behavioral outcomes also can be used to assess the long-term maintenance effects of the intervention. A more thorough assessment of intervention effectiveness might also include one or more health outcome measures, such as changes in the rates of injuries, illnesses, or fatalities; however, because many work-related safety and health outcomes develop long after the initial exposures to the hazard occurs, it is not always feasible to use illness or disease as a measure of intervention effectiveness (Hopkins et al., 1986).

Economic impact measures, such as the direct and indirect cost savings resulting from the behavior-safety intervention at the worker, company, and industry levels also can help make the “business case” for supporting an intervention (Rose & Harshbarger, 1991). Research in this area should focus on developing economic tools or models that enable researchers and safety professions the ability to measure and track the economic impact of safety interventions (Kenoyer, Andrews, & Stenner, 2001). In addition, there is a lack of studies examining the costs versus benefits of the various elements of behavioral safety interventions. These costs should be measured not only in terms of the

financial requirements, but also in terms of time and staffing commitments. Associating the relative costs and effectiveness of various elements of the behavioral safety process would give employers and safety professionals much needed information about the feasibility and worth of a specific behavioral intervention.

3. Conclusions

It is widely accepted that in a comprehensive occupational safety program that addresses psychological, social, engineering, and organizational concerns, the inclusion of effective behavior-change processes can further promote worker safety and health. The purpose of this paper was not to compare or evaluate the effectiveness of behavior-change processes relative to other safety controls methods. Instead, areas of research were highlighted to ultimately assist the safety practitioner in making evidence-based selections of the most appropriate and effective behavioral interventions when indeed they are deemed necessary. When available, exemplar references to studies were provided as springboards to future follow up studies. Hopefully, this paper will help researchers conceptualize and organize the various topics of behavioral safety research into a coherent framework that is tied specifically to common intervention processes. If only a portion of these topic areas and research questions are addressed through systematic reviews, surveys, field interventions, and laboratory-based studies, the knowledge gained will significantly improve the delivery and effectiveness of behavioral safety interventions and thus their impact on worker health and safety.

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