3.3. Cognitive Processes in Safety Regulation
3.3.1. Attention

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3.3.1. Attention

Attention is a mental state of "conscious awareness, accompanied by sensory clearness … such as focusing on specific stimuli or specific aspects of the environment, having concerns for details such as intensity, movement, repetition, contrast, and novelty of stimuli" (Corsini, R, 2002, *The Dictionary of Psychology*, p. 75). An attentive person is a safe person, who focuses on the environment and pays attention to its details. Lapses in attention are one of the major psychological factors that may lead to accidents and injuries. Applied cognitive psychologists, human factors engineers, occupational health and safety specialists, and organizational psychologists are intensively working to discover factors of inattention and creating equipment, technical systems, and organizational programs that help employees to maintain their attention toward the goals of their occupational activity. Employees may be distracted from their activities by various factors and conditions; when one attends to the source of a distraction, it may cause accidents with severe consequences. To eliminate distractions to a minimal level and train people to deal with them in an effective manner is an important tactic for promoting safety.

The research question that guided our scoping review was: What are the main forms of attention and inattention that occur in the workplace and how do they relate to the safety of employees?

Method

Search Strategy. A scoping search of the literature was undertaken in April 2015 using the following key words: Attention (attentional capture, divided attention, selective attention, vigilance, etc.); dual task performance (concurrent task, dual task procedure); human channel capacity (cognitive load and mental load); human error; safety engagement (see General Methods section).

Screening Strategy. The screening process was similar to other topics such that articles were excluded for publication date (e.g., published before 2010), irrelevant records (e.g. non English), irrelevant medium (e.g., book reviews, letters to editor, etc.), irrelevant safety domain (e.g., sexual risk taking, gambling, etc.), or other irrelevant content based on the inclusion/exclusion criteria listed in Table 1. The inclusion and exclusion criteria were kept broad in that we did not specify the types of research methods to be included or excluded in order to capture as many research articles on the topic as possible. In our search, we collected articles that were pertinent in this topic area.

Table 1. Attention Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Safety OR Accidents OR Injuries ANDed with the following:	Not related to safety
Attention (also distraction or interrupted)	Related to HEALTH not safety
Dual Task Performance (doing more than one thing at once	Patient safety
Split attention	Drugs
Human error	Alcohol
Human channel capacity	Children
Divided attention, selective attention, sustained attention, etc.	Elderly
Mining or workplace safety	Financial risk taking
	ADHD
	Food safety
	Gambling
	Sexual risk taking

Results

Description of included articles. A brief summary of each article including its location, population studied, main issue addressed, comparison group, and primary outcomes is provided in Appendix G. The following is an overview of the included articles.

Table 2. Attention; Number of Articles by databases searched

Database	Articles found from search	Articles Selected for Review	Final article selection
Academic Search Complete	361	9,609	37
CINAHL	850		
EMBASE	1311		
MEDLINE	801		
ProQuest Dissertations & Theses	915		
PsycINFO	924		
Scopus	3800		
Sociological Abstracts	25		
Web of Science	2050		

Table 3. Cognitive processes: Attention. Number of articles by type, country, and population

Type of Publication:	Country of Publication:	Population Studied:
9 reviews and theoretical analyses	15 USA 6 Australia	19 Drivers from a general population 4 General population/students
28 original research	5 France	2 General employees
13 experimental	4 UK	3 Health care workers
5 questionnaire surveys	2 Canada	2 Pilots
3 cases analysis	2 China	2 nuclear plant operators
2 field studies	1 Iran	And by 1 article railroad workers,
2 multi-method	1 Hong Kong	pedestrians. and truck drivers
3 database analysis	1 The Netherlands.	

Description of Identified Factors. Based on an analysis of the selected articles, five factors emerged: general aspects of cognition and attention in the workplace; situation awareness; inattention/inattentional blindness and deafness; general aspects of workplace distractions; and, distractions while driving.

General aspects of attention and cognition in the workplace. Seven articles (Allahyari et al., 2014; Cheng et al., 2011; denDaas et al., 2013; Pape, 2011; Xu, et al., 2014a; Xu, et al., 2014b; Yanko et al., 2013) discussed general mechanisms and factors related to cognition and attention in the workplace.

Cognitive researchers (den Daas et al., 2013) experimentally investigated the mental states in which people's attention is regulated most effectively. They discovered that in the *impulsive* state of mind, which is generated by the impulsive system of behavior regulation, people are ultimately driven by the immediate incentive or aversive values of incoming information (e.g., see danger and immediately react by withdrawal). In this state, people's attention is focused on more salient, attractive, or aversive information/cues at the expense of other contextual cues and information. In the *reflective* state of mind, which is produced by the reflective regulatory system, people thoroughly process knowledge about value and probability of potential consequences of all upcoming information and make decisions based on these elaborations. In this state, one's attention is distributed and contextualized.

These findings have direct safety implications as workers in an impulsive state, or those with high impulsivity as a personality trait (see the chapter on "Accident proneness") are less inclined toward hazard information elaboration and considerations of future consequences. Because of this, these individuals make riskier choices that have high potential for accidents and injuries. Contrarily, workers in the reflective state are those who are *mindful* and *safety conscious* (see the chapter on "Accident proneness"). They have a more complete picture of the environment (higher *situation awareness;* see next section) and make more weighted and volitional decisions that lead to safer performance.

Chinese safety researchers (Xu et al., 2014b) discovered that both internal processes (i.e., controlled/reflective and automatic/impulsive) influence one's personal regulation of his or her safety behavior. Their prevalence is mediated by one's inhibitory control (control over impulsive actions); for example, operators with high impulse control work mostly through the reflective mode of regulation while operators with low impulse control rely more strongly on the automatic and less on reflective system of regulation. Differentiating these two mechanisms of the safety behavior regulation has important implication for employees' selection and training. The same team of researchers (Xu et al., 2014a) inquired further into the automatic regulation of attention through the process of *attentional bias toward safety* (ABS) and its relation to workplace safety. ABS is "a basic, early-stage cognitive process involving the automatic and selective allocation of attentional resources toward safety cues, which reflect the implicit motivational state of employees regarding a safety goal" (Xu et al., 2014, p. 144). This process connects one's attitudes toward safety, his or her attention toward safety cues, with the resulting safety behaviors. ABS is an implicit process that works automatically without much deliberation, and thus, is time effective. These researchers discovered that employees with better safety performance have higher ABS in comparison to less safe workers. This process of attitudinal bias is positively related to perceived safety climate and worker's safety motivation.

Pape (2011) summarized research on cognitive factors leading to mistakes and errors in a hospital operation room setting. By considering professional and errorless performance as a systemic phenomenon, she suggested that all components of such functioning (e.g., cognitive, attentional, organizational, and personal) should be viewed as an interconnected system related to productive and safe performance. Among cognitive factors, Pape (2011) highlighted lapses due to cognitive overload, limited attention span (i.e., people cannot typically stay alert for more than 10 to 20 minutes when watching for rare events), distractions, interruptions, multitasking that lead to medication errors, and mistakes based on

rule-based and knowledge-based knowledge failure. Several recommendations were suggested, including: noise reduction, signage increase, promotion of teamwork, effective communication, and reduction of distractions and interruptions.

Yanko and Spalek (2013) examined the role of a route familiarity in relation to mind-wandering while driving. They stated that a route familiarity might provide drivers with additional attentional resources available to attend to potentially hazardous stimuli in the environment. However, in their experiments, route familiarity led to driving impairments such as multitasking while driving. The authors suggested that this impairment occurred because drivers have more mind wandering states on familiar routes which distract them from focusing on driving. Similarly, safety researchers Cheng, Ng, & Lee (2011) compared the main features of attention as demonstrated by accident-involved and accident-free motorcycle riders. They discovered that the divided and selective attention of accident-involved riders was inferior to that of accident-free riders. As a result, it took longer for accident-involved drivers to identify hazardous situations, and they exhibited more driving violations compare to their accident-free counterparts. This study provides evidence of the important role attention plays in safety performance. Industrial researchers (Allahyari et al., 2014) used a survey questionnaire to examine the relationship between industrial company employees' cognitive failures during their work and safety consequences. Statistical analysis of their results revealed that a high rate of occupational cognitive failure is positively related to near misses, minor incidents, and major injuries. The results of these studies indicate that employees' cognitive processes, including attention, play important roles in processing safety-relevant information and thus demonstrate direct or indirect contributions to safety performance.

Situation awareness. Seven articles discussed situation awareness as a workplace phenomenon (Golightly et al., 2014; Kilingaru et al.,2015; Munduteguy et al., 2011; Naderpour & Zhang, 2014; Nazar & Troyer, 2013; Salmon & Stanton, 2013; Schwebel et al., 2012). In the last decade, the phenomenon of situation awareness has gained substantial attention from safety specialists in many high-risk industries: aviation, military, railroad operations, firefighting, and policing. *Situation awareness* is the state of being aware of what is happening in one's direct vicinity; it includes understanding how information, events, and one's own actions will impact goals and objectives immediately as well as in the near future. Situation awareness can also be defined as "'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future' (Endsley, 1995b)" (from Naderpour et al., 2014, p 174). Thus, this phenomenon is intimately connected to the processes of attention and conscious awareness as well as to safe and productive performance.

Compared to the traditional approach to understanding attention, the situation awareness construct highlights contextual embeddedness and the situational dependence of human attention. The main appeal of this concept is that high situation awareness is considered to be one of the main determinants of success, safety and ultimately, survival. As the result, situation awareness is intensively researched and rigorously propagated at different professions. Salmon and Stanton (2013) outlined the main issues addressed by the situation awareness research: differences in situation awareness across operators, the influence of systems design on situation awareness, relationships between situation awareness and other safety-related concepts (e.g. driver distraction, fratricide, stress), the influence of organizational structures

on situation awareness, the ethical issues associated with studying situation awareness within a safety critical system, and measurement of situation awareness. Aviation psychologists Kilingaru et al. (2015) examined different methods of assessing situation awareness in pilots. They used eye-tracking systems and behavior-pattern analysis and discovered that situation awareness can be diagnosed and assessed.

Safety researchers (Golightly et al., 2013) examined the situation awareness of railway track workers and its impact on their safe and effective work. Using a scenario and functional analyses of the trackwork, they highlighted several factors related to situation awareness. One factor was using a human lookout (i.e., a designated person who monitors the environment). The researches highlighted the team-based nature of the trackwork and importance of mutual understanding of roles and functions during this work. Other discovered factors were local knowledge of the site, expertise, and importance of effective strategies for distributing awareness across people and artefacts. Traffic safety researchers (Munduteguy et al., 2011) focused on the specific awareness of motorcyclists in relation to vehicle drivers and concluded that the mutual awareness and understanding of traffic situations between drivers and riders plays a crucial role in preventing accidents. Differences in expectations and situation awareness between these parties was a primary source of traffic accidents. American researchers (Nazar & Troyer, 2013; Schwebel et al., 2012) focused on the situation awareness of pedestrians who used mobile phones (e.g., listening music, texting, etc.). They found that mobile-phone related injuries among pedestrians increased relative to total pedestrian injuries and paralleled the increase in injuries for drivers; in 2010, phone related injuries among pedestrians even exceeded those for drivers. Pedestrian injuries related to mobile-phone use were higher for males and for people under 31 years old. Both studies indicated that using a mobile phone, listening music, or texting while walking puts pedestrians at risk of accident, injury, or death and one reason for this is that they look away from the street environment and are not aware of their immediate situation.

Inattention and inattentional blindness and deafness. Five articles analyzed various forms and factors of inattention (Castel et al., 2012; Dehais et al., 2014; Grissinger, 2012; Paparella, 2013; Young et al., 2015). The phenomenon of inattention is opposite to the state of situation awareness and can take different forms, all of which are relevant to safety. One form of inattention is *inattentional blindness.* This occurs when an employee simply does not notice or is not aware of objects, people, or events that are present in his or her surroundings. Health researchers Grissinger (2012) and Paparella (2013) analyzed the inattentional blindness that occurs in healthcare workers while reading labels and dispensing medications. These researchers highlighted four factors that determine attention in a workplace: *conspicuity* of an object or thing that includes sensory (visibility, contrast) and cognitive (perceived relevance of stimuli) conspicuity; *expectations,* we notice what we expect to see and do not notice the unexpected; *cognitive capacity*, one's personal capacity to maintain high vigilance and attend to several objects simultaneously (dependent on mental aptitude, age, day of time, stress, etc.); and, *mental workload and task interference,* factors that divert one's attention and cause inattentional blindness. These authors concluded that inattentional blindness is a natural and involuntary consequence of our defense against information overload. They suggested to increase the conspicuity of critical information,

decrease diversion of attention, and reduce the number of secondary tasks when carrying out complex assignments.

Castel et al., (2012) conducted an experiment with office employees that involved recalling routine objects they see every day: fire extinguisher, drinking fountain, clock, etc. Despite seeing fire extinguishers (which are characterized by high sensory conspicuity) every day, only 24% of participants could recall their locations. Such *inattentional blindness* may prevent workers from finding extinguishers when smoke and stress preclude direct visual contact with them. More research on real-life cognition and greater attention to actual mechanisms of human cognition during training is suggested as a remedy. Other researchers (Young et al., 2013) studied attention of drivers while crossing high-load urban railways and discovered that drivers do not focus on the railway crossing per se but are over-reliant on RLX warning signals and the behaviour of surrounding vehicles. This occurs because drivers divert their attention to other objects and use them as indirect indicators to guide their behaviour. Suggested measures to remedy this deficiency include: removing non-essential signage, increasing the visibility of PLX marking and infrastructure, and implementing in-vehicle warnings. Aviation researchers (Dehais et al., 2014) investigated inattention to audio stimuli in pilots using flight simulators. They discovered a phenomenon of *inattentional deafness* wherein 39% of pilots who were pre-occupied with an experimental task while landing did not notice an alarm signal of landing gear failure and continued the landing procedure. The main cause of inattentional deafness was an excessive workload imposed on pilots. Prior experience of pilots did not affect their susceptibility to inattentional deafness. A suggested solution is to increase the cognitive load during training so that pilots are not overwhelmed with the information if similar overload occurs during a flight. Pre-exposure to alarms in different conditions of cognitive load may also reduce one's vulnerability to inattentional deafness.

General aspects of workplace distractions. Four articles examined general aspects of workplace distractions (Beaman, 2005; Chan, 2012; Canella, 2013; Swedler et al., 2015). Various forms of distraction are one of the main causes of inattention. Beaman (2005) reviewed experimental research on auditory distractions from low-intensity noise. Although conducted with the general population, this research has several workplace relevant applications: consider the nature of the population exposed to the noise (e.g., age, noise sensitivity, etc.); consider the auditory environment (e.g., high- or low-reverberation environment); consider the nature of the cognitive task (tasks with a memory load are especially susceptible to the distractions); consider the nature of the noise (irrelevant noise and speech that changes in frequency or pitch is particularly disruptive).

Chan (2012) studied perceptual load and sustained attention while driving. He concluded that introducing a strategic concurrent task can improve performance when demands on sustained attention are low. However, this benefit carries the cost of reduced visual attention to the objects in a periphery. Swedler et al. (2015) examined the relationship between safety climate and distracted driving. They discovered that high safety climate was negatively correlated with distracted driving. An interview suggested that these relations are indirect indications of management providing distraction free environments for drivers. Canella (2013) explored some components (central executive function, risk perception, and risk taking) of attention mechanism in distracted driving. Executive functioning and the

way that information is presented were each significantly related to task performance and eye gaze in a dual-task setting.

Distractions while driving. Fourteen articles (Bakiri et al., 2013; Beanland et al., 2013; Collett et al., 2010; Divekar, 2013; Ehsani et al., 2014; Feldman et al., 2011; Holland & Rathod, 2013; Lemercier et al., 2014; Llerena et al., 2015; McCartt et al., 2006; Stavrinos et al., 2013; Talbot et al., 2013; Young & Lenne, 2010; Zhang, et al., 2014) addressed various forms of distracted driving, both in-vehicle (e.g., smoking, eating, picking up an object, listening to music, talking to passengers, etc.) and outside-vehicle (e.g., outside vehicles, objects or events on a road, etc.). All forms of distractions increase the probability of accidents and being at fault (Bakiri et al., 2013), especially for novice and teen drivers (Llerena et al., 2015; McCartt et al., 2006; Talbot, Fagerlind & Morris, 2013). Specifically, texting and phone conversation distract traffic flow (e.g., fluctuation of speed, changing lanes, etc.; Stavrinos et al., 2013). Even an ignored phone call (Holland & Rathod, 2013) or distractive thoughts (Lemercier et al., 2014) can be a severe distraction during driving. External-to-vehicle distractions (e.g., billboards, passing events, etc.) are as dangerous as in-vehicles distractions as drivers lose their situation awareness and have a slower response to hazards.

Research reveals that drivers can accommodate visual-manual or cognitive-audio distractions, but that drivers cannot handle both types of distractions simultaneously (Zhang et al., 2014). These researchers discovered that these accommodations could occur while following another vehicle, but not while passing. However, the negative consequences of such distractions can be reduced with special training (Divekar, 2013). Furthermore, Collette et al (2010) studied conditions under which it is relatively safe to use various technological devices while driving. These relatively safe conditions include: when using loud-speaker cell phones, having greater driving experience, low traffic density, rural areas, good weather conditions, and being involved with a routine or casual versus business or highly emotional conversations. In addition, drivers who have a low level of trait mindfulness are more easily distracted (Feldman eta al., 2011). Intoxication and fatigue are additional factors of inattention in drivers that are preventable (Beanland et al., 2013).

Discussion

Attention at work is a primary factor in the safe execution of work-related tasks. Cognitive and safety researchers intensively study this process in labs and in work settings to reveal efficient ways to manage distractions and improve attention. Attention is influenced by one's working memory capacity, workload, fatigue, and the absence of various distractors. Inattention is a natural and common process and difficult to avoid. However, inattention can be minimized by individuals' personal regulation of influencing factors, company's specialized training, and both parties promotion of appropriate working conditions such as positive safety climate. One of the most devastating effects of inattention occurs due to distracted driving; thus, the majority of research efforts on attention are directed toward this activity.

Gaps in the literature. Attention research is one of the most advanced studies in safety literature as it spans many different occupations, methods, and high quality reviews. However, the following gaps in existing research were identified: research specific to the role attention plays in mining safety is needed as no studies have been conducted in this industry; additional research should be directed toward creating

and testing special training strategies to deal with unavoidable work-related distractions; a special focus should be directed toward the systemic research of attention in relation to other cognitive processes at work (e.g., memory and decision making) in order to understand cognitive mechanisms of safety performance; additional research on the role of social psychological factors (e.g., safety culture, safety climate, safety motivation, open and constructive communication, etc.) play in employees' attention regulation and situation awareness is needed. Examining these areas will advance attention research to a new level of understanding.

Recommendations. Our scoping review of attention research in relation to safety resulted in the following recommendations:

- Introduce knowledge of impulsive and reflective mechanisms of attention regulation into safety management and training; educate supervisors about these two processes in relations to safety behavior and train supervisors to diagnose them.
- Investigate the role inattention plays in mining incidents and collect locally-specific evidence on importance of this process in mining safety.
- If attention plays a significant role in mining accidents, develop special programs to address this issue. Such programs may include, but not limited to: implement standardized procedures of assessing employees' attention capacities and use this information to direct their training and job placement, especially regarding accident-prone positions and tasks; design training programs with special considerations given to attention and its regulation at a workplace (e.g., teach employees about potential distractors and ways to minimize their influence); special training may be organized to identify crucial equipment (e.g., fire extinguishers) in case of accidents or emergency in order to eliminate inattentional blindness to these objects.
- Introduce into safety lexicon the term 'situation awareness' and provide basic training for managing such a state.
- When work tasks include teamwork, develop special strategies for increasing situation awareness in the team by assigning human lookouts and facilitating mutual understanding of hazards and potential risks.
- Work environments should be conducive toward efficient management of workers' attention. Specifically, signage of hazardous places, equipment, and situations should always be clearly indicated and easily identifiable but all unnecessary signs should be removed; the signs should be strategically placed on order to help employees direct their attention efficiently.
- Test whether inattentional deafness and/or blindness occurs in relation to emergency alarms or other audio signals.
- Test workplaces regarding their noise environment and possibilities of audio distractions that may cause accidents; if there is a potential for audio distractions, develop procedures to minimize them.
- If driving constitutes an important part of work-related duties, provide special training regarding distracted driving and its consequences, including types of distractors, their nature and mechanisms of influence; train drivers to manage distractions effectively.

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