3.3.2. Memory

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3.3.2. Memory

Memory for events, strategies, training, and skills is a crucial predictor for future behaviour. For instance, if employees effectively use their learned knowledge and safety skills during a risky situation (e.g., to assist other workers or to comply with safety rules), it will enhance their own safety as well as the safety of their co-workers. Furthermore, one employee may remember safety measures that may not be automatically accessible to other workers; this individual will be able to assist others and enhance their safety in times of crisis.

In cognitive psychology*, memory* is defined as the retention of information, skills, and knowledge learned in the past and the ability to recall it when required in the future (Throness, 2014). Psychologists differentiate several types of memory including: memory related to future actions (i.e., *prospective memory*), memory related to thinking and doing at a particular moment, which has limited in capacity (i.e., *working memory*), memory that entails unlimited storage (i.e., *long-term memory),* memory related to events, situations, and personal experiences that took place in the past (i.e. *episodic memory*), and memory for physical motor skills (i.e., *procedural memory*; Throness, 2014). These distinct types of memory function simultaneously in individuals and influence their behaviour and decisions, including their assessment of risks and willingness to engagement in safety behaviour.

Applied researchers study the capacity limits of working memory and ways to prevent memory errors and false memory (e.g., a fictional "memory" of an event that did not actually occur) while enhancing remembering and recall. *Remembering* refers to a bottom-up approach that signifies a recognition of events as soon as one perceives a particular object, event, or cue, whereas, *recall* refers to the volitional retrieval of information from memory as related to a past event (Throness, 2014). *Working memory capacity* refers to the amount of information one can store for a short time period and is different for each individual. If an individual fails to remember or recall information accurately, he/she is committing a *memory error*. *False memories* occur when one remembers an event but is unable to accurately describe it or 'remember' an event that has not occurred at all. False memories of previous events, memory errors, and limited working memory capacity may influence one's safety behaviour in the workplace.

The question that guided our scoping review was: "How does one's memory affect employees' safety engagement in the workplace?

Method

Search Strategy. A scoping search of the literature was undertaken using the following key words:

1. Memory (autobiographical memory, early memory, eidetic memory, episodic memory, explicit memory, false memory, implicit memory, long-term memory, memory consolidation, memory decay, memory trace, prospective memory, reminiscence, repressed memory, retrospective memory, short term memory, spatial memory, verbal memory, visual memory, spontaneous recovery (learning), forgetting, free recall, learning, memory training, metacognition, procedural learning, retention, source monitoring).
2. Safety engagement (see General Methods section).

The searches were undertaken from April to June, 2015.

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. Memory Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Related to aviation, chemical safety, or driving safety • Memory AND Safety • Memory supplements and safety • Learning/recall AND safety • Neuropsychological functions AND safety • Related to use of schemas related to safety • Safety sign training • Safety management practices related to memory • Working memory and multitasking • Cognitive-behavioural management of memory • Change blindness • Awareness AND Safety	• Involves under or over age populations (e.g., children, elderly, etc.) • Related to other domains of risk taking (e.g, alcohol, drugs, extreme sports, financial, etc.) • Related to food or patient safety • Work shift • Related to health but not safety (e.g., Alzheimer's, neurological disorders, traumatic brain injury, cognitive dysfunction, surgery, vaccinations, eating disorders, etc.) • No psychological findings • Related to physiological therapies, treatments, medications, or assessments • Memory is not main focus of article (e.g., decision making, learning, behaviour and cognition not, sleep deprivation, stress) • Homeless persons, suicides • Intrusive memories, not safety • Digital memory • Job satisfaction • Genetic influences • Earthquake safety/ Memory of earthquakes

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. Memory Number of Articles by databases searched

Database	Articles found from search	Articles Selected for Review	Final article selection
Academic Search Complete	236	3663	19
CINAHL	319		
EMBASE	4073		
MEDLINE	203		
ProQuest Dissertations & Theses	28		
PsycINFO	227		
Scopus	3983		
Sociological Abstracts	37		
Web of Science	461		

Table 3. Memory Number of articles by type, country, and, population

Type of Publication:	Country of Publication:	Population Studied:
- 2 summary discussions - 17 original research articles (all experimental designs)	- 5 Australia - 4 Canada - 4 USA - 2 UK - 1 France - 1 Japan - 1 Netherlands - 1 Spain	- 9 Undergraduate students - 4 Aviation industry (i.e., pilots and air traffic controllers) - 2 general employees (i.e., did not distinguish between job type or industry) - 1 Construction - 1 Military - 1 Motorists - 1 Industry (unspecified)

Although no research has been conducted on mining employees specifically, knowledge obtained in other industries/workplaces may be generalized to this population.

Description of Identified Factors. Based on a descriptive analysis of the selected articles, four memory factors emerged: memory enhancement procedures, effect of multitasking on memory, emotional context and memory, and memory and trauma. The primary results and potential applications of each identified factor are discussed. All definitions of concepts as used in the current literature are provided in Appendix D.

Memory Enhancement Procedures. Nine articles were related to memory enhancement procedures. Safety specialists and trainers may use the knowledge gleaned from psychological research to improve the transmission of safety information and to enhance the degree to which it is learned and recalled. Employees may also take part in initiatives to personally improve their own memory, especially

when memory deficits are likely such as when multi-tasking or recalling traumatic events.

Deterioration of memory over time. Memory includes remembering and accurately recalling knowledge and skills absorbed in the past; however, the learned skills and knowledge are vulnerable to deterioration as time passes (Anderson et al., 2012; Throness, 2014) and there is a reduction in the comprehension of certain proficiencies with time. For example, in an experimental task, industrial employers were trained cardiopulmonary resuscitation (CPR) on a manikin and their post-training performance was routinely tested (Anderson et al., 2012). The researchers found a significant decline in performance (e.g., incorrect procedure, missing steps in between the procedure, etc.) after training such that as days from last training session increased, employers displayed a greater number of errors. Thus, preventing memory loss is important for increasing compliance with safety strategies and procedures (Anderson et al, 2012; Throness, 2014).

Memory enhancement strategies for safety trainers. Memory loss is prevented by rehearsal and incorporating new information into previously known knowledge. Thus, safety specialists and trainers at mining sites must try to repeatedly integrate new information and safety rules with the information and strategies already known by the employees (Anderson et al., 2012; Throness, 2014). Similarly, employees are more likely to remember safety measures if the messages or skills are tailored to an employee's personal interests and if the new information is relevant to an individual in the near future. It has also been shown that people tend to remember the material for longer periods if the future relevance of the information is clearly given beforehand (Van Donger et al., 2012).

Another strategy to enhance the memory of workers is through improved organization and presentation of safety measures (Seelig et al., 2014; Throness, 2014). For example, poorly organized rules are not well comprehended by workers (Throness, 2014). Specifically, visual information enhances encoding but overuse of visual aids may hinder retrieval in the distant future. Using words at a higher grade level and poor display of information may further hinder learning (Seelig et al., 2014; Throness, 2014). Thus, it is beneficial to keep new safety information simple in terms of presentation. It is also known that information presented first (i.e., primacy effect) and last (i.e., recency effect) within a sequence of new information is better retained in memory than material presented in the middle; thus, the most important safety messages should be presented at the beginning or in the end of meetings or training sessions to be best remembered by employees (Galy et al., 2010).

Memory enhancement strategies for employees. Employees' compliance to safety rules could be enhanced using specific strategies to improve cognitive processing and memorization of information. For example, if employees can change the way they embed new safety information in their memory (i.e., encoding), then it is possible that in the risk-prone situations they might be better able to retrieve and use the informantion more efficiently. *Mnemonics* refer to particular methods or techniques designed to enhance a recall of information from the memory. Incorporation of mnemonics, such as phrases, string of digits, cues, etc., or strategies to identify indications that might be precursors to an accident tends to enhance memory and leads to greater recall (Albert et al., 2014). Enhancing prospective memory of a worker is also crucial for decreasing memory errors. This could be achieved by inducing prospective memory aids such as directing future tasks using related cues (e.g., Post-It notes, automatic alarms, etc.;

Loft et al., 2011; Loft, 2014). It has been shown that using various cues related to a future job leads to enhanced encoding in human brain, which decreases memory errors substantially. This will also reduce mistakes during an on-going task, simply because the worker would not have to tax his or her memory with too much information.

Another well-known strategy to enhance recall from memory is *rehearsal*. Repetition and rehearsal of newly learned safety measures increases adherence to safety precautions. In a laboratory experiment, Molesworth et al. (2011) investigated pilots using a simulated flight strategy to examine memory under high hazard environments. The authors divided aviation pilots into two groups. The first group of pilots conducted a simulated flight followed by a self-explanation questionnaire (i.e., they elaborated the actions they took while performing the flight); the second group completed a relapse prevention questionnaire (i.e., they identified situations related to safety relapses and measures required to avoid the same); and, a control group was not given any special instructions. Pilots in the first condition (self-explanation) displayed greater compliance with safety rules during their test flight compared to second (relapse prevention) and control conditions. Furthermore, the first group showed 100% adherence to safety rules after repeated rehearsals. Thus, repetition of a safety strategy leads to greater encoding of information which makes it more likely to be available during a risky situation (Molesworth et al., 2011). Likewise, understanding new information (e.g., a safety method) in a meaningful way (self-explanation) appears to lead to better retrieval of this information in the near future (Molesworth et al., 2011; Molesworth et al., 2011b). Mere learning of factual details without fully understanding the strategy is not the best approach to encode safety material. In addition, rehearsals should be as specific to the behaviour required as possible to ensure transfer of the encoded behaviour from rehearsal to practice, known as encoding specificity (Molesworth et al., 2011; Molesworth et al., 2011b; Seeling et al., 2014).

Prospective Memory. In addition to remembering content learned in the past, workers must also remember to apply this knowledge in the future (i.e., to perform an intended action at an appropriate point in the future; Loft, 2011). Prospective memory demands cognitive resources during work, and thus, prospective memory errors are common; these errors are associated with risky behaviour and may result in significant costs to ongoing tasks (Loft et al., 2011; Loft, 2014). Prospective memory errors may be reduced by using prospective memory aids that direct future tasks using related cues (e.g., Post-It notes, automatic alarms, safety signs, etc.; Loft et al., 2011; Loft, 2014). Inclusion of spatial context also reduces the load on memory which leads to reduction in prospective memory errors; for example, in an aviation simulation experiment, pilots who were given spatial context information (i.e., told that prospective memory cues only apply to aircraft approaching from a certain region) made fewer errors than pilots provided with prospective memory cues alone (Loft et al., 2011). Thus, safety signage and visual aids on mine sites should be purposefully oriented in space to reduce prospective memory errors and improve reaction times. This will also reduce mistakes during an on-going task as the worker will not have to tax his or her memory with too much information. In addition, higher workload leads to lower attentiveness towards prospective memory targets; hence, care should be taken to ensure employees' workload is not high enough to critically affect prospective memory.

Multitasking. Four articles were related to the influence of multitasking on memory as related to

safety. The research has consistently found that interruptions while performing a task can have negative consequences due to limited attentional and working memory resources. For instance, maintaining conversation while performing a task taxes one's ability to hold task-relevant information in working memory and reduce awareness of one' surroundings due to lower involvement of attentional resources, and ultimately lead to poor performance in the main task (Gregory et al., 2014; Heenam et al., 2014; Strange & Takarangi, 2012). More generally, doing more than one job at a time is not beneficial as it strains attentional resources and WMC; however, multitasking may be unavoidable for some workers. Jobs that involve frequent switching between tasks should recruit individuals with higher WMC. Specifically, WMC is a greater predictor of successful multitasking than intelligence or analytic reasoning (Colom et al., 2010).

Emotional Context and Memory. Four articles were related to emotionality and memory. All articles found that emotional content is remembered better than neutral content (Bisby & Burgess, 2014; Furnham & Goh, 2014; Kuriyama et al., 2010; Throness, 2014). Therefore, safety information that is incorporated into a broader emotional context is better remembered and better recalled than safety information alone; this effect is especially strong for information associated with positive affect. This is likely because light-hearted messages do not posit cognitive overload and thereby information is better retained in memory (Furnham & Goh, 2014). Although there is evidence that neutral messages are retained for a longer period of time than negative messages (Bisby & Burgess, 2014), strategies explained in relation to critical unfortunate events exhibit greater recognition than strategies explained without any emotional content (Bisby & Burgess, 2014). Thus, utilizing emotions and sentiments instead of bluntly delivering the material to employees will enhance recognition and recall in future.

In addition, an emotional stimulus enhances item representation but impairs between-item associations. For instance, Bisby and Burgess (2014) asked participants to view neutral (low arousal) and negative (high arousal) items embedded in various backgrounds. Later, participants were asked to recognize previously displayed items followed by a test to assess memory for associated background context. The results demonstrated a decrease in associative memory for negative affect such that there was a decline in recall of associated items in the high arousal condition. These findings suggest that negative affect decreases associative memory but increases the recognition of negative items. Thus, presenting safety strategies or measures with emotional aspects (e.g., images of people with emotions on their faces) will lead to greater encoding of novel information compared to neutral images.

Memory and Trauma. Three articles were related to memory and trauma. Research indicates that individuals' memory for traumatic situations is more likely to be distorted than memory for neutral or positive situations (Strange & Takarangi, 2012). Specifically, there is a greater level of false recognition for traumatic and stressful events than neutral events (Morgan et al. 2013; Strange & Takarangi, 2012; Uttl & Kisinger, 2010). For example, participants who viewed multiple video clips and received a surprise memory task 24 hours later, falsely recognized events from the clips such that incorrect recognition was greater for traumatic and critical scenes than neutral scenes (Strange & Takarangi, 2012). These memory distortions are especially prevalent for peripheral scenarios (i.e., non-central to the event; Strange et al., 2012).

The resulting memory errors (i.e., omission or alteration of information in memory) creates false memories (i.e., memories for events that were not actually observed). For example, Morgan et al. (2013) studied memory during stressful events by presenting military personnel who participated in a mock POW camp role-playing exercise with photos of individuals who interrogated them during the exercise. When misinformation was introduced, more than half of the military personnel falsely recognized an individual who was not actually present during the mock POW camp. Thus, stressful or traumatic events, such as past workplace incidents, are especially vulnerable to misinformation which may lead to the development of false memories. While discussing previous risky situations or events with employees, information (e.g., questions, statements about event, etc.) should be chosen wisely to reduce the creation of memory errors.

An employee may misremember facts about an incident (Morgan et al., 2013; Strange & Takarangi, 2012), which will cause them to confidently report inaccurate information and distort their perception of the event in the future. Thus, it is important for managers to realize that workers may benignly report incorrect details about prior accidents. Once a false memory exists, it is difficult for individuals to incorporate new (e.g., correct) information in their memories later on (Uttl & Kisinger, 2010), which has negative consequences for workers' safety behaviour in the future as well as the safety behaviour of coworkers whom they may communicate this misinformation to. Thus, it is beneficial for investigators to question witnesses as soon as possible before false memories set in and, after investigations, to go over the *actual* cause of an accident or traumatic event periodically to prevent the propagation of false memories and misinformation.

Uttl and Kisinger (2010) also found that individuals tend to mention the presence of obvious features when reporting a traumatic event but fail to mention the absence of obvious features even though there is evidence that they remember this absence. This has implications for eyewitness reporting of serious workplace incidents. To ensure all information is relayed during the investigation of a traumatic event, witnesses should be specifically asked about both the presence and absence of features.

Discussion

The cognitive processes surrounding human memory have received considerable attention in psychological research. However, relatively few researchers have applied this knowledge to the safety field. Although workers' memory may be impaired by the passage of time, multi-tasking, or traumatic events, there are many available strategies to enhance memory supported by the literature.

Gaps in the Literature. The majority of psychological research on memory included in this review utilized laboratory experiments on university students. Applied research used pilots and military personnel. Hence, future research is needed on memorizing safety information and using it in the workplace and applying these regularities to different industries including mining. Specifically, the effects of cognitive enhancing programs may be studied on workers in the mining industry in order to determine how permanent and effective these changes are at high-risk sites.

Memorizing and using safety information include not only memory, but attention, symbolic thinking, emotions and other processes. Using different combinations of these processes may enhance safety learning and retrieval. While prior studies tested one or two cognitive strategies on a population of

individuals, multiple learning strategies may be implemented by using different arrangements of these processes. Most of the studies used a cross-sectional design, whereas, using a longitudinal design may provide better insight on the mechanism of memory and effects of suggested memory enhancement procedures.

Recommendations. Safety specialists and trainers may use the knowledge gleaned from psychological research to improve the transmission of safety information and to enhance the degree to which it is learned and recalled. Employees may also take part in initiatives to personally improve their own memory, especially when memory deficits are likely such as when multi-tasking or recalling traumatic events. Based on the current scoping review, future efforts may include an integration of the following memory enhancement strategies:

- **Incorporate existing knowledge when presenting new material.** Novel information is best retained if it is presented among already known material (Anderson et al., 2012; Throness, 2014). Thus, for trainers it is important to know past experience of the trainees and the degree of their involvement with safety issues to use this information for tailoring new information. Referring to past accidents, known to trainees may also enhance their memorization of new safety information.
- **Keep presentations and messages clear and concise.** Keeping safety information short and concise with lower-grade words improves understanding and enhances retention (Seelig et al., 2014). Employees should be encouraged to understand the causes and factors related to safety concepts rather than memorizing rules (Molesworth et al., 2011), so their rational thinking involved in a memorization process.
- **Appeal to emotion and personal relevance**. Emotional and personally relevant content is better retained than neutral information (Bisby & Burgess, 2014; Furnham & Goh, 2014; Kuriyama et al., 2010; Throness, 2014; VanDonger et al. 2012). Emotional context maintains one's attention which enhances encoding. Thus, safety information should be delivered in a meaningful emotional way instead of purely presenting facts. It is also beneficial to explain the future relevance of safety strategies before going into detail as this will lead to enhanced retention in memory.
- **Organize messages with most important points at the beginning and end.** Poorly organized information are not well comprehended by workers (Throness, 2014); specifically, information delivered at the beginning and end of a presentation or message is better remembered than information delivered in the middle (Galy, Mélan, & Cariou, 2010).
- **Frequently refresh, rehearse, and test learned information and procedures.** Information in memory fades over time which may negatively affect one's work. Immediate testing and frequent rehearsal of safety information and procedures is valuable for improved retention (vanDonger et al., 2012) and consequently better compliance with safety regulations and better performance in crisis situations (Anderson et al., 2012; Throness, 2014). Specifically, repeating safety strategies every three months is extremely vital for specialists who train and supervise other workers at a mining site (Throness, 2014). In addition, employers may be unaware of the actual cause of a past accident due to being a novice employee or mere forgetting; thus, refreshing the causes of past mining incidents will improve retention and prevent the spread of misinformation.

- **Encourage the use of mnemonics**. Workers may experiment with multiple mnemonic techniques to improve their memory of safety information and these may be incorporated into safety presentations (Albert et al., 2014). For example, some individuals retain information through word associations while some prefer to segmenting information in groups.
- **Combine audio and visual information.** Although auditory information is better remembered than visual information (Galy, Mélan, & Cariou, 2010), combining modes of delivering information may increased memory recall in the future (Throness, 2014). However, excessive use of visual aids can be distracting which hinders future recall and should be avoided (Seelig et al., 2014).
- **Display visual cues around the workplace.** Strategically placed visual cues (e.g., signage, lights, etc.) to remind and guide employees will enhance their attention toward safety signs when at risk (Loft et al., 2011). Prospective memory aids such as Post-It notes, automatic alarms, etc. will also prevent memory errors (Loft, 2014).
- **Consider personal working memory capacity when assigning jobs.** Increasing one's workload usually leads to a decline in performance (Colom et al., 2010). Hence, reducing workload or tailoring work according to an individual's cognitive abilities will lead to fewer memory errors and resulting incidents. If a job requires multiple switching between tasks or performing two tasks at once, it would be beneficial to recruit employees with especially high working memory capacity (Colom et al., 2010).
- **Avoid work interruptions and multitasking**. Work interruptions and multi-tasking tax one's cognitive processes which interferes with memory and may lead to memory errors and poor recall of task related information (Gregory et al., 2014; Heenam et al., 2014; Strange & Takarangi, 2012).
- **Recognize the likelihood of false memories for traumatic events.** Employees who have witnessed incidents in the past will continue to be influenced by their memories of these events; but, these memories are especially vulnerable to misinformation (Morgan et al. 2013; Strange & Takarangi, 2012; Uttl & Kisinger, 2010). To ensure all information is relayed during the investigation of a traumatic event, witness should be specifically asked about both the presence and absence of features. It is also important to review the cause and consequence of past events to inhibit formation of false memories.

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