Attention Interrupted
Cognitive Distraction & Workplace Safety

By Joseph Cohen, Cindy LaRue and H. Harvey Cohen

IN BRIEF
- **Diversions of attention tend to decrease productivity, increase errors, and have associated human and monetary costs in the workplace.**
- **By thinking of cognitive distractions as task interruptions, OSH professionals can focus on aspects of the environment that can be observed, measured and controlled like other hazards facing workers.**
- **Effective solutions to prevent cognitive distraction must follow a task-oriented approach whereby interruptions in the environment are systematically evaluated and mitigated through various means, including education, policies and technology, rather than trying to prevent a cognitive process that occurs in the mind of an individual worker.**

Pay attention is a phrase we have all heard at some point. Yet, despite our best intentions, most of us have likely experienced a distraction that caused a mistake or interrupted the task at hand.

Different forces are continually vying for people's attention. Trying to focus on one or even a few relevant fluxes of information can be challenging and lead to errors. To add complexity, basic repetition and monotony can also lead to a loss of focus and resulting errors. Thus, combating the potential catastrophic effects of distractions and interruptions is a challenge in many workplaces.

What is at stake? Cognitive distractions tend to decrease productivity and increase the number of errors workers make (Ratwani, Trafton & Myers, 2006). Interruptions can be particularly detrimental to safety because they stretch operators' attention spans. Many jobs are potentially affected, but the detrimental effects most often occur during time-critical and supervisory-level work activities, such as command-and-control operations, and emergency response (Sasangohar, Scott & Donmez, 2013) in which the limits of human performance may be tested.

Attention

Classic research in applied cognitive sciences indicates that attention is a complex cognitive process, not a singular event. Attention is multifaceted since people can direct attention in different ways, often simultaneously (Sanders & McCormick, 1993). In certain situations, one must monitor several information sources and attend to differences using selective attention. Other times, one must focus to block out stimuli including nearby sights and sounds. Monitoring displays for long periods for rare changes in system status relies heavily on sustained attention or vigilance. While performing two or more tasks simultaneously, and attending to both, an individual relies on divided attention.

During ordinary activities or while multitasking, the brain switches rapidly among competing stimuli. The brain must run through a series of actions rather than processing tasks in a parallel fashion. For each task, the brain must select the information it attends to first, process that information, then encode it into memory. For action to occur, a person must retrieve the information, make the appropriate decision and execute a plan. So, the brain does not

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juggle tasks so much as it directs attention, filters information and focuses on what is deemed important. What is deemed important depends on an individual's memories and experiences.

For example, while driving, a person must perform tasks simultaneously and rapidly shift attention to multiple sources. To manage the constant flow of information through the senses and prevent overload, the driver's brain filters information, catching relevant information and allowing the irrelevant to pass through; this process is called inhibitory control (Nielson, Langenecker & Garavan, 2002). This hard-wired higher-order thinking helps a person focus and accomplish amazing feats. However, a sense of control and overconfidence about how one allocates attention can lead to underestimating the detrimental effects of distractions and interruptions on performance.

Distractions

Although most definitions of *distraction* include *diversion of attention,* the root of the word is *traction*, which Merriam-Webster defines as "the force that causes a moving thing to stick against the surface it is moving along." In some contexts, traction is what is needed underfoot to prevent slips and falls. Cognitive traction involves the rapid transmission of electric pulses across connections between tiny neurons inside the brain.

Like surface traction on a floor, cognitive traction and safety go hand in hand. People who experience cognitive traction execute properly and seldom slip. Distraction is the opposite of traction; think of it as the force that causes a moving thing to stay apart from the surface it is moving along. Revisiting the analogy of walking across a wet floor, cognitive distraction would slow people down, sometimes to the point of overload.

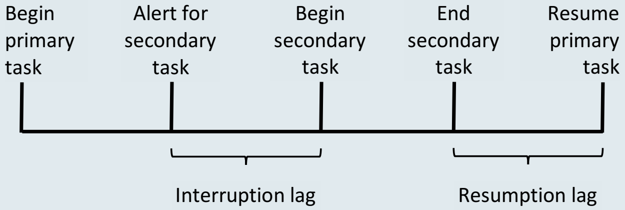
Distractors can be divided into irrelevant and relevant. Irrelevant distractions are not related to the task at hand; they include a conversation among people walking near a workstation or an object seen along the roadside when driving. Other distractions are made by stimuli that are relevant and require the worker to allocate some attention to either make a response or decide whether to respond (e.g., pilot responding to an air traffic controller, nurse responding to a patient alarm) (Forster & Lavie, 2008).

Distracted Driving

An estimated 660,000 Americans use electronic devices while driving despite being aware of the risks. Many report being able to use their phones while driving but wish others would not do the same. A survey by American Automobile Association (AAA) Foundation for Traffic Safety found more than 40% of people from ages 19 to 39 claim to text and drive simultaneously; of that number, 10% say they do it regularly (Strayer, Cooper, Turrill, et al., 2013).

While many will agree that mobile phones provide convenience, their use quadruples the risk of

FIGURE 1
Interruption & Resumption Process



Note. *Adapted from "Preparing to Resume an Interrupted Task: Effects of Prospective Goal Encoding and Retrospective Rehearsal," by J.G. Trafton, E.M. Altmann, D.P. Brock, et al., 2003,* International Journal of Human-Computer Studies, *5, pp. 583-603.*

a crash. In 2012, National Highway Traffic Safety Administration (NHTSA) attributed 3,328 road crash fatalities to distracted driving, and distracted driving was the cause of 10% of all crashes on the nation's roadways, resulting in 387,000 injuries (Strayer, et al., 2013). The frequency of these events has led to distracted driving laws as well as a national voluntary consensus standard, ANSI/ASSE Z15.1-2012, Safe Practices for Motor Vehicle Operations, that addresses distracted driving.

Recent studies by AAA have shown that newer in-dash technologies with voice recognition systems may be greater distractors than mobile phones. Such technology places more demand on attention than previously thought. Research indicates that people using voice commands while driving are less likely to scan the road ahead and check rear-view mirrors. The same drivers are more likely to look straight ahead, but often fail to see safety-critical situations unfold directly in front of them, such as the presence of pedestrians and red lights (Nichols, 2013).

A critical scenario occurs when a person looks but does not truly see or appreciate what is unfolding directly ahead. Researchers call this inattentional blindness or perceptual blindness. It occurs when an individual fails to observe a fully visible event due to the engagement of attention on another aspect of the visual scene (Mack & Rock, 1998).

Consequences of visual distractions are typically immediately obvious, but the costs of cognitive distractions may not be so apparent. Changes in the scenery may go unseen unless what a person experiences is processed in working memory. The effects of inattentional blindness may explain why a driver engaged in conversation may not notice an easily visible event and why National Safety Council (NSC, 2012) maintains that hands-free devices may offer no real safety benefit.

Distracted Walking & Working

The recent increase in use of personal mobile electronic devices, primarily cell phones, while walking and at work has rapidly become a significant safety issue. Using these devices to listen to music, text, converse, play games, take photos, access the Internet and use mobile apps, has created new distractions for pedestrians (LaRue, Bakken, Cohen, et al., in press). Add these distractions to other pedestrian challenges such as stairs, street crossings, elevated walking surfaces, sidewalk uplifts and other tripping hazards, and the potential for injury and death only increases. NSC even began to include the category of distracted walking in the 2015 edition of its *Injury Facts* publication.

While the frequency of vehicular crashes and subsequent research on the effects of cell phone use while driving have led to educational campaigns and enactment of laws to prevent their use by drivers, similar research regarding their impact on pedestrian safety is fairly new. Pedestrians on cell phones have exhibited similar distracted behaviors as distracted drivers and are involved in an increasing number of fall and collision incidents due to inattention to other pedestrians, vehicles and features in their walking environment.

Neider, McCarley, Crowell, et al. (2010), found evidence that conversing on a cell phone leads to a diminished ability to process visual stimuli and encode the visual information into working memory, the short-term memory where information is stored and managed to execute complex tasks involved with learning and information-processing tasks. Therefore, distracted pedestrians are either switching back and forth between concentrating on the conversation/phone activity and visually scanning the environment, or attempting to do both activities at the same time but to the detriment of visual data gathering and processing.

Research has found that individuals on cell phones tend to exhibit what appear to be safe behaviors, such as walking at a slower pace, looking left and right prior to crossing a street, and taking longer to decide to cross the street. However, the results indicate that these behaviors do not necessarily help the pedestrian walk more safely. These behaviors perhaps serve as an attempt by distracted pedestrians to compensate for what they may recognize as impaired attention (Kuzel, Heller, Gray, et al., 2008).

A pedestrian's distracted behavior is different when s/he is just listening to music as compared to conducting activities on a cell phone. It could be that when engaged in a conversation, a person must pay attention to the other person and formulate responses while passively listening to music may allow the pedestrian to tune out the music at times and direct attention elsewhere (Neider, Gaspar, McCarley, et al., 2011).

Sensory deprivation, also called environmental isolation, occurs when use of cell phones and other electronics results in limited hearing and peripheral vision. When pedestrians are wearing headphones or are engaged in conversation on a cell phone, the inability to hear sounds emanating from the local surroundings may present unique problems in walking environments where auditory cues can be more important than visual ones, such as around trains (Lichenstein, Smith, Ambrose, et al., 2012). Visual deprivation occurs when pedestrians elect to look at the cell phone screen, thus reducing the available skills necessary to see features in the walking environment.

Interruptions

Task interruptions occur when distractions require the worker to break the continuity of the task at hand. When an interruption occurs, the worker must address the distraction, then s/he must cognitively and physically recover and return to the original task. The recovery-and-return process presents another potential for error.

Cognitive task analysis is a methodology for collecting data about the mental activities performed in complex systems (Stanton, Salmon, Walker, et al., 2005). Cognitive task analysis can help OSH professionals understand how interruptions affect human performance in any specific work context and its potential effects on the performance of the system in which it occurs. Based on cognitive task analysis, Trafton, Altmann, Brock, et al. (2003), define the interruption and resumption process in human cognition (Figure 1).

For an interruption to begin, a person must be performing on a primary task (e.g., entering data into a chart on the computer). While entering data from a handwritten list, the phone rings and captures the worker's attention, thereby introducing a secondary task. As the worker's attention switches away from entering data to the ringing phone, the interruption lag begins.

To focus on the conversation, the person's memory of the primary task begins to fade. Once the person completes the call, s/he resumes entering data. At this point, the worker is in the midst of a resumption lag, and his/her brain must reconstruct what was occurring in the primary task. Fortunately, the worker can get back up to speed quickly because s/he was marking off data and can quickly identify where s/he left off in the primary task.

What happens when there is no safety net? In May 2015, distraction led to a train derailment in Philadelphia, PA, that resulted in eight deaths and more than 200 injuries. National Transportation Safety Board (NTSB) said the train engineer noticed a disabled train on an adjacent track and continued to monitor the radio communications between the disabled train's engineer and the dispatcher for a few minutes. He then returned to his tasks after the distraction of the conversation, but lost track of his train's location. He accelerated full-throttle to 106 mph as his train entered a curve with a posted 50 mph speed limit, mistakenly believing he was on the 110 mph straightaway after the turn.

The engineer was listening to the radio traffic until about 1 minute before his train hit 106 mph, exhibiting an action that would have "made sense for someone who thought he had already passed the curve," said NTSB investigator Steve Jenner (CBS New York, 2016). Jenner also said that with attention diverted to the other train and radio communication, "the Amtrak engineer may have lost situational awareness." NTSB Chair Christopher Hart stated, "It is a world in which the engineer relies in part on the memorized details of the route and a world in which a loss of awareness can take a terrible toll" (CBS New York, 2016).

Consequences of Interruptions

As these two examples show, the consequences of interruptions at work vary greatly from minor inconvenience and delay to creating hazardous situations with catastrophic consequences. Even a momentary interruption can disrupt one's train of thought. Interruptions lasting 2.8 seconds on average were found to double the rate of errors in a sequencing activity (Altmann, Trafton & Hambrick, 2013). Interruptions also contribute to a phenomenon called change blindness in which changes in a visual scene are viewed but not processed (Cavanaugh & Wurtz, 2004; Resnik, 2000).

These findings have significance for safety. In studying the effects of interrupting sequential tasks, in which a worker must accomplish one step before moving onto the next, interruptions hindered participants from accurately following procedures, and they tended to repeat completed steps or skip steps altogether. Psychologist Erik Altmann provides perspective on the potential consequences of such mistakes: "If I add sugar twice to something I'm baking, it doesn't really matter. But if I give a diabetic an extra shot of insulin, that matters" (Dye, 2013).

Examples of interruptions and distractions in industrial settings include:

- removing safety goggles to look for a dropped item, then resuming the task without putting the goggles back on;
- turning toward a distracting noise and moving a finger into a piece of machinery;
- reaching for and drinking from a cup of solvent (or other hazardous substance) instead of one's coffee after being distracted by a friendly coworker;
- removing a safety guard on a saw to dislodge a jammed piece, being interrupted by a supervisor, then returning to cutting without replacing the guard;
- looking for a mop after spilling a liquid, reading an incoming text message and forgetting to clean the floor.

Beyond safety issues, disruptions cost employers money. The most recent estimate is that an average of 2.1 hours of interrupted work per day cost U.S. companies $588 billion per year in lost knowledge, work and downtime (Spira & Feintuch, 2005). Other negative effects reported by employees who are frequently interrupted include stress-induced physical ailments and higher rates of exhaustion (Shellenbarger, 2013).

Despite all the information regarding the negative costs of interruptions, some benefits should be noted. If an individual performing a task is interrupted by another person (coworker or dispatcher) to hear that a task is being performed incorrectly, the person can make corrections. Some interruptions provide a much-needed opportunity to alleviate fatigue or provide a temporary break from a monotonous task (Jett & George, 2003; Mark, Gudith & Klocke, 2008). Interruptions can also lead to informal collaboration and social interactions

that may enhance workplace morale.

Managing Interruptions

Interruptions are inevitable in most work situations, and they are even required in some (e.g., a nurse responding to an alarm from a patient's equipment). Whether interruptions are inherent in the job or not, being aware of the types of common workplace interruptions is the first step in determining how to manage them. Once the sources of interruptions are identified, management can identify ways to eliminate or minimize the interruptions and the consequences of these breaks in work using approaches grounded in safety, ergonomics and human factors principles.

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Sometimes, a simple indicator (e.g., closed office door, do not disturb sign) effectively transmits the intention that a person does not wish to be disturbed. Carton and Aiello (2009) assert that workers who can control interruptions experience less stress. Workers can also use items such as checklists that provide steps for a process to track where a task was interrupted and where to resume.

Training employees about the potential consequences of typical workplace interruptions (e.g., skipping steps in a process, disrupting the rhythm of a punch press operator, forgetting to put PPE back on, giving the wrong medication to a patient) is a way to manage interruptions. Training helps employees understand what can happen in their specific line of work.

As noted, the use of cell phones and other portable electronic devices in the workplace is of growing concern. An organization must set specific guidelines for use of these devices to encourage safe behaviors in the workplace. Finally, determining which alerts and alarms are significant and reducing/eliminating any superfluous and insignificant ones will help reduce unnecessary interruptions; it is important that the alarms causing distraction are relevant and important.

In the healthcare profession, distractions and interruptions can have severe consequences. Medication errors are a concern, and research indicates that distractions involve all disciplines and every step of the medication administration process, including prescribing, transcribing, preparing, dispensing and administering (Feil, 2013). Consider this incident reported to the Pennsylvania Patient Safety Authority's Reporting System. A pharmacist began entering pharmacy orders in an online record for patient A. He was interrupted by a nurse taking care of patient B and accessed patient B's record to review. The pharmacist finished his discussion with the nurse, then continued entering the information for patient A in the record he had opened for patient B. The error was eventually caught, but not before the nurse administered the incorrect medication to patient B (Feil, 2013).

To address errors made due to interruptions, some medical facilities have implemented no-interruption zones to improve communication and coordination between interdependent healthcare professionals. An example of this practice is marking "no-interruption zone" on the floor with red tape around dispensing cabinets and other areas where drugs are prepared. Anthony, Wiencek, Bauer, et al. (2010), evaluated the impact of such a zone for medication preparation in an intensive care unit and found a significant reduction (40.9%) in the number of interruptions after 3 weeks. Other steps that have helped reduce medical errors include the Institute of Medicine's recommendation that nurses wear a visual signal, such as a colored vest, during medication administration to indicate that they are not to be interrupted (Rivera & Karsh, 2010).

Worker interruptions and distractions are also a great concern in the railway and airline industries. In 1981, Federal Aviation Administration (FAA) introduced an early-interruption-focused administrative control policy with the sterile cockpit rule. This rule aims to limit nonessential communication between pilots and crew while an aircraft is below 10,000 ft (e.g., during taking off, landing and taxiing).

Newer rules prohibit pilots from using portable electronic devices in the cockpit for any purpose unrelated to operating the aircraft. This extension of the sterile cockpit rule stems from a 2009 incident in which a commercial airliner overshot its destination by approximately 150 miles without contacting air traffic control. An investigation found that the pilots had been using laptop computers to check a newly introduced flight crew scheduling system when the mistake occurred.

Although passengers and crew ultimately arrived safely without further incident, FAA responded as if it were an emergency and asked North American Aerospace Defense Command to scramble military jets. The incident was resolved when air traffic control established contact with the aircraft after it landed at the wrong airport.

Technological solutions are another option in workplaces where interruptions can have dire consequences (e.g., the 2015 train derailment in Philadelphia). In 2008, Congress required railroads to install positive train control (PTC) on approximately 70,000 miles of main lines that provide regularly scheduled intercity passenger or commuter rail services (FRA, 2017). According to FRA, PTC uses communication-/processor-based technology to prevent train-to-train collisions, overspeed derailments, incursions into established work zone limits, and train movement through a main line switch in the improper position.

Had PTC been in use in 2015 along the stretch of track in Philadelphia, the backup safety system would have automatically slowed the train, thereby providing a "technological safety net for inevitable human error" (CBS New York, 2016). In addition to the engineer's error, NTSB cited the rail industry's delay in installing PTC as a causal factor in the derailment. This equipment is now in place there and along much of the northeast corridor.

Interruption controls are increasingly visible in other work settings as well. For example, lifeguards must remain vigilant, scanning pools and other bodies of water for incidents and unsafe behavior. If interrupted, they may miss critical events as their attention divides. In addition to providing sufficient rest periods for lifeguards, steps can be taken to control the risk posed by interruptions. For example, a sign may be posted that prohibits lifeguards from engaging in conversation with swimmers except during emergencies. Similar signs are often seen in city buses instructing passengers not to engage in conversation with drivers while the bus is in motion.

New studies indicate that by creating and mediating interruptions at advantageous break points in manufacturing assembly tasks, management can minimize the costs of interruptions (errors and time) (Kolbeinsson, Lindblom & Thorvald, 2017). In addition, a promising new tool is available for evaluating how prone drivers are to attentional errors: the Attention-Related Driving Errors Scale (ARDES).

The questionnaire, adapted and tested in several countries for cross-cultural stability, uses self-reporting to assess individual differences regarding to what extent drivers have experienced various situations (e.g., When driving to a familiar place, I unintentionally drove past it because I was not paying attention) (Barragán, Roberts & Baldwin, 2016). ARDES can help drivers become aware of their personal tendency toward inattention while behind the wheel and identify those drivers at greater risk of attentional lapses (Barragán, et al., 2016; Ledesma, Montes, Poó, et al., 2015).

Interruption Recovery

In many of today's dynamic, complex and time-critical work environments, tools may be present to facilitate recovery from interruptions. Smallman and St. John (2003) evaluated such a prototype system, Change History EXplicit (CHEX), in the domain of naval air warfare. The main benefit of CHEX is that it automatically detects significant changes and logs those changes into a table that the operator can sort and filter. This is helpful in situations in which workers responsible for monitoring conditions experience frequent interruptions that cause them not to identify changes on the monitor.

An example of the use of CHEX is workers monitoring the course of an aircraft of interest. Significant changes in the aircraft's course may indicate that it has moved from the category of passive monitoring to one requiring immediate action.

Potential uses of the tool include monitoring patients in hospitals and physical plants. CHEX creators claim that it "augments the human attentional system" and facilitates rapid detection and identification of changes to a situation, both of which are central aspects of maintaining and recovering situational awareness among air traffic controllers. Evaluation found that CHEX offered significant improvement in fending off the negative effects of change blindness in comparison to a baseline condition and two other static change awareness schemes (Smallman & St. John, 2003).

Other experimental interruption recovery tools are the Interruption Assistance Interface (IAI) (Scott, Mercier, Cummings, et al., 2006) and the Interruption Recovery Assistant (IRA) (Sasangohar, 2009). IAI consists of a reply window, event timeline and animation controls on a peripheral display in the primary task environment that is updated as events occur. IRA provides a similar interactive timeline of events. In research evaluations, both tools have shown promise in reducing interruption time, improving the quality of decision making and supporting recovery from interruptions.

Conclusion

Diversions of attention seem inevitable at work. While research indicates that some types of interruptions may prove beneficial, OSH professionals are interested in preventing cognitive distractions because of the costs and safety issues associated with them. By understanding potential interruptions and adopting a task-design-oriented approach grounded in ergonomics and human factors principles and methods, OSH professionals can focus on aspects of the work environment that can be observed, measured and controlled like other hazards facing workers.

In addition to task design, organizations can implement countermeasures such as signage, no-interruptions zone, personal electronics policies and available technologies to support attention keeping and interruption recovery. OSH professionals must understand the advantages of helping workers pay attention because trying to prevent a cognitive process that occurs in the minds of individual workers is an exercise in futility. **PS**

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