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Abstract

In forestry work, conditions exist and develop that are complex, unpredictable, and highly consequential and therefore cannot be handled entirely by following static work procedures. Cognitive adjustments are necessary. The objective of this research was to determine whether performance (cognitive) variability is actually necessary to safely fell trees in the coastal region of British Columbia, Canada. In this paper two perspectives were contrasted: the traditional view of safety and the resilience perspective. A collection of empirical evidence established that while safe work procedures provide a good foundation, it is individual performance variability shaped by experience and "know-how" that guides the application of technical skills in such a complex, dynamic, high-risk environment.

Introduction

In the profession of manual tree felling, work often takes place in remote areas with steep, rocky, and uneven terrain and in all weather conditions. The environment is often extreme and every situation is novel. Every tree is different—its species, health, location, and condition. Given these factors and the potential for unknown interactions, unexpected and often escalating situations can result. In tree felling, fallers independently assess the tree and make a decision on an appropriate course of action. Using a chainsaw, an axe, and safety gear, the tree is strategically felled in relation to the other trees with the aim to facilitate the future collection of the logs.

Unlike most other professions, fallers deal with complex, dynamic, high-hazard conditions as a regular part of their work. While exposure to adverse environments and this level of risk is not typical for most workers, it is considered normal in the forestry industry. One faller explained typical conditions in his interview:

> You're blocked off by a rock bluff with nowhere to go and you're seeing the butt-end of the tree […] under a lot of tension and you just can't tell how "loaded" it is until you start cutting it and even then, you're not expecting it and the cut drops and goes sailing by…it just narrowly missed me because I had just taken a half step to the left—and all the while I'm thinking, this could go bad.

In an industry where there are no redundancies for error, this research sought to understand how manual tree fallers are able to safely and successfully manage the work in this unforgiving environment. Two contrasting perspectives were compared to determine how tree fallers deal with complex and varied conditions: the traditional safety perspective and the resilience perspective. Each provides very distinct and different explanations. In the forestry industry many hold a traditional view on safety; that systems are simple and humans are independent actors subtracting safety from the system. In this paradigm, humans are considered as a source of risk. If something goes wrong it could well be the fault of the human. As a result, advancing safety involves protecting the system from people who may degrade it. The practice is to introduce constraints which limit decisions and actions in order to prevent unsafe actions and restrict individual performance variability. The most common constraint in this industry is the application of safe work procedures (SWPs) (Dien, 1998; Lautman & Gallimore, 1987).

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However, strictly following the procedures (rules) is often not how real work is performed. In reality, work is accomplished by intelligently and freely applying the rules based on context. This is in keeping with the second perspective and theories of resilience engineering. Researchers in this domain claim that people—with multiple goals, limited resources, and in the context of uncertain circumstances—have to have the ability to anticipate, respond, and flexibly adjust to safely manage their work in dynamic conditions. In this view, systems are considered complex and not inherently safe (Dekker, 2006; Hollnagel, 2006) and humans are deemed to be the valuable and positive components of the system. Research by Hollnagel (2006) and others (Dekker, 2003; Woods, 2006) asserts that performance variability is necessary and useful. Claiming that progress in safety comes from enhancing people's adaptive capacity in the face of systemic vulnerabilities (Woods, 2006) has gained appreciable momentum.

Due to the sheer complexity of the situations that workers are exposed to, human cognition cannot possibly account for all possible scenarios of what might happen. Staying safe is primarily dependent on what cues are available, if they are recognized, and how they are interpreted and acted upon. Research acknowledges that people can cope with a high degree of complexity. "People are able to make tough decisions under difficult conditions such as limited time, uncertainty, high stakes, vague goals, and unstable conditions" (Orasanu & Connolly, 1993, p. 457). Successfully operating in complex environments often requires taking action because taking action means getting feedback and understanding an unknown environment. A reluctance to act could be associated with less understanding and more errors. Action is fueled by contextual cues that people match with pre-existing schemas to transform the complex into the simple. However, when action is based on preconceptions and it becomes apparent that expectations were wrong, there may be few opportunities to correct—especially in an industry where the consequences are often severe.

Weick and Sutcliffe (2007) observed operations within high reliability organizations (HROs) to understand how individuals managed the unexpected. It was found that the workers expanded their knowledge to include imagining what is possible. To improve foresight, HRO principles steer people towards imaginative practices. This bolsters anticipation and raises doubts about all expectations. This type of strategy is encouraged because it is only a very brief interval between surprise and success that offers opportunities to discover what one does not know. People apply resilience strategies (the ability to anticipate as well as the process of continuous monitoring and learning) to refine expectations. Performance variability usually increases the effectiveness of the response but on occasion this variability can lead to failure.

Rasmussen (1997) discusses how variability as well as performance adjustments are shaped by the objective as well as constraints of the work system. Workers adapt performance to accommodate organizational pressures, limited resources, and multiple goals in order to be successful. During this adaptive process, workers tend to migrate toward boundaries of efficient and functional performance. Most systems have sufficient dampening to ensure that performance variability does not combine or escalate in a way that could destabilize the situation. However, once in a while performance variability is not compatible with the conditions and destabilization does occur (Hollnagel, 2009). If this happens, and the boundary is crossed, it is likely that an incident will occur. Typically, incidents are the product of normalized performance that has been produced to counter the effects of other system elements. The difficultly is knowing where the boundary of safe performance is and the degree of freedom that is available before an adverse outcome occurs. It is evident that an approach to represent "systems behaviour is necessary which is not focused on error and violations, but on the mechanisms generating behaviour in the actual dynamic work context" (Rasmussen, 1997, p. 190). The goal should not be to dampen the performance variability that is necessary for effective operations, rather to manage it so it remains effective within the boundaries of safe operations.

Method

This study used a qualitative, phenomenological research model (Creswell, 2007) to facilitate the collection of information. This approach was chosen because it was considered to be an appropriate methodology to understand and appreciate performance in context. It enabled the identification of emergent themes and connections between the theoretical work and the rich empirical data. To gather the empirical evidence, interviews were conducted with 22 fallers and faller supervisors, specifically: 2 contract fallers, 4 faller supervisors, 12 company fallers, and 4 non-active fallers. Each had a range of experience (15 to 45 years) from a variety of coastal logging operations. Each participant was guided through the interview using a questionnaire that consisted of 14 open-ended questions. Questions were designed to probe their knowledge, perspectives, and experiences in the context of this high-risk forestry setting. During interviews, a figure (Figure 1) was drawn and presented by the researchers to help the participants understand and articulate what repertoire of skills is necessary to take their technical skills and apply them to context.

Results

In relation to Figure 1, fallers consistently explained that possessing or applying technical skills does not mean that you are competent. "You need a background to apply them in context." With a dynamic setting like the forest, several fallers agreed, "Applying the rule will improve your odds—I

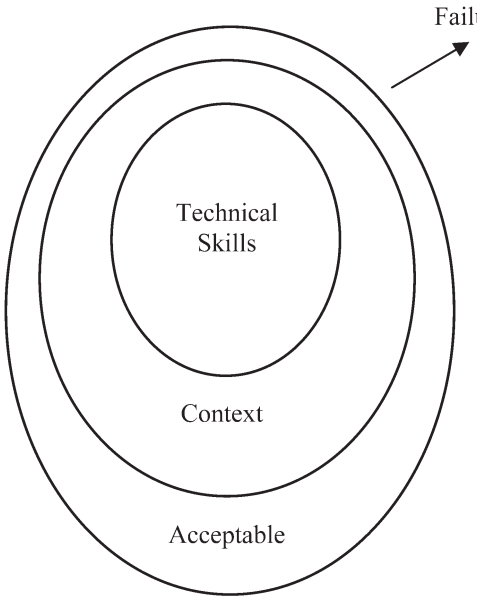

Figure 1. Skills, context, and situational variability ranges to enable safe performance.

will say they do help—but they'll never guarantee." One supervisor stated that you really have to constantly assess where you are working. He stated that judgment is always needed and experience is what fills in the discretionary space between technical skills and acceptable performance. This demonstrates that fallers have to adopt strategies to make the operations successful. It shows evidence of contextual or situational variability, where situations are under-specified, performance has to be adjusted in order to achieve the best possible outcome (Hollnagel, 2009). In part, this is how they are able to cope with applying static procedures to dynamic and varied conditions.

Fallers explained that they assess cues from features of their environment and calculate the expected interaction of forces in motion. However, due to the sheer complexity and the unforeseen nature of the environment, conditions often violate their expectations. If this occurs, consequences are often severe. Hence, in this work environment there is seldom a good match between procedures and actual conditions. While the majority of fallers agreed on the value of knowing and applying the fundamentals, they explained that procedures can never fully prescribe what is out there and how best to deal with it. In the practice of felling trees they agreed with the research, "rules emerge from practice and experience rather than proceeding them, procedures in other words, end up following work instead of specifying action beforehand" (Dekker, 2003, p. 234).

Every day fallers respond to unpredictable local conditions, multiple hazards, and pressures and by doing so develop a "license to think" (Reason, Parker, & Lawton, 1998, p. 299). This know-how provides the basis for operation. It is a trait of an expert; a professional faller who can make intelligent adaptations. Overall, fallers agreed that rules are good. However, the point was also made that, "discretion is based on those rules" saying, "Nothing is concrete" out there. There is a "sliding scale between rules and discretion depending on context." Collectively, there was a consistent message that the basics are essential: "There are rules that get applied in every situation—about a half a dozen…or so" but, after that, the knowledge and experience that are gained from being in the forest and listening to stories of others' experiences are of the greatest value.

Given the many different conditions that the fallers face, procedures are used more as guidelines. The detriment of "forcing operational people to [rigidly] stick to the rules can lead to ineffective, unproductive or even unsafe local actions" (Dekker, 2005, p. 141). Fallers explained: "You keep the principles in mind" while exercising skill and judgment to successfully manage work in a setting where no two situations are similar. The rules are a foundation and the necessary degrees of freedom are related to complexity and other system-level factors. Several mentioned that the skill of manually felling trees requires calculating physics on the fly, knowing the mechanics and how things are going to pivot, shift, interact, and move. They need to be able to recognize where hidden tensions may exist and have the skills to understand and predict the "chain reaction" that can result when a tree, that was once stable, is destabilized. One faller described: "[I need to] recognize that it's going to kill me, what's going to go where, you know your angles and your tension and all that kind of stuff." So while procedures are useful, they are not the panacea. In order to deal with the plethora of unknowns in this environment, fallers require options and flexibility. Dien (1998) points outs that procedures are but one option: individual skills and experience, collective know-how (team coordination, cooperation, and communication), planning, quarter management rules, and everyday practices are also very useful.

"The [rules are] there to help you along but the knowledge you gain is more important." The complexity and unpredictability of the environment is why fallers feel that performance variability is necessary and that they have to develop the skills to handle and predict the unforeseen. The fallers were unanimous in their opinion that the interpretation of procedures is a difficulty that newcomers have to overcome to be successful in this profession. The experienced fallers support Dekker's (2003) perspective that: "Very often working a dynamic environment happens, not in violation of procedures but without procedures all together" (p. 234). "The basics are like feeder rules. And, then as your experience goes on, you're still working by the rules, but you've seen the situation before, so you're going to handle it a bit differently." It is the experience, knowledge, and level of awareness that makes a difference. In context, "you're still using the rules but you've expanded them, or…they've sprouted out a little bit." "You might be tweaking the rule,

but you're doing it through your experience—the safest way you think you can do that."

Conclusions

This research paper explored the concepts of resilience engineering against empirical evidence to evaluate whether performance variability is necessary to safely fell trees in the coastal regional of British Columbia. The empirical evidence provided data about how actual work is practiced and how those practices were consistent with theoretical concepts on resilience. However, the current method of evaluating safe work in this industry is consistent with forestry's traditional safety perspective; one of auditing and quantifying work performance. Audits include the direct observation of workmanship and an examination of cuts made in tree stumps to measure the accuracy of technical cutting skills. Although many may find comfort in objectively measuring performance to ensure safe practices are being followed, the empirical evidence contrasted this methodology by stating that, often, focusing too closely on technical skills in the field actually reduces safety. Concentrating on making perfect cuts limits the faller's opportunity to continually and critically assess the peripheral environment which is so vital to staying safe. The level of performance that is necessary to deliver high levels of technical accuracy limits the variability that is required in such a highly dynamic and complex environment. Given the characteristics of this environment, quantifying performance by focusing on technical skills misses the importance of the contextual features of the surroundings. Fallers remarked that, although an asset, absolute technical accuracy will never guarantee safety in these types of conditions.

The complexity and dynamics of this type of environment were the primary reason why SWPs do not fit every situation, and in themselves cannot create safety. Fallers explained that even after thirty years of falling there are situations that they have never come across before so procedures cannot possibly account for, or be detailed enough to cover, every situation. Although traditional safety practice relies heavily on SWPs for controlling performance, the fallers stated that how the rules are applied, when they should be applied, and whether they should be applied depend very much on the circumstances at the time. They explained that performance variability is necessary to maintaining safety. They need the degrees of freedom and latitude to adapt and respond as conditions dictate rather than be restricted to following rules. They use the rules as principles of safe practice rather than procedures that are strictly adhered to. They explained that due to a multivariable environment, judgment and discretion are necessary. Technical skills and procedures are the foundation of practice but having the ability to vary performance to match conditions is the key to staying safe.

Examining performance in this environment demonstrates how decision making, action, goals, and available resources are intrinsically interwoven with the features of the environment. Decisions stem from the constant assessment of the environment and action is formulated based on the assessment.

Although action taken will always make sense at the time, the cognitive limitation of being able to accurately assess and consider all possible dynamics in such levels of complexity could leave the system open to vulnerability. When a faller's assessment does not match the conditions, their expectations are violated when the unexpected happens and this can be seen as counterproductive to safety. Therefore, while it was agreed that performance variability is necessary and is the reason why things go right most of the time, the same variability is the reason why things sometimes go wrong. The same performance exists behind success or failure and it is only the outcome that determines the difference (Hollnagel, 2009).

Overall, the empirical evidence supported the resilience philosophy; fallers are adaptable and contribute positively to safe and productive systems. They bring a collection of skills and strengths as well as limitations to manage complex and dynamic work. In the context of competing goals, and economic constraints, fallers constantly manage the system-level tradeoffs and priorities to keep the system within safe operating boundaries. Organizations that embrace the resilience theories can develop ways to support people's skill at judging when and how to adapt. They can enhance the attributes of performance variability that are so essential in maintaining and managing limits of control and keeping system performance within safe and acceptable limits. Although resilience strategies require constant monitoring of system performance, appreciating and adopting this philosophy offers the potential to enhance the system of work. Recognizing and supporting adaptive performance in order to safely match the conditions of the work environment has the potential to increase safe production.

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