FOREST GROWERS RESEARCH

HARVESTING TECHNICAL NOTE

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Capturing & Harnessing Embodied Cognition

Summary

Skilled workers operating in uncertain environments develop a ‘sixth sense’ over time that affords them automatic responses, allowing attention resources to focus on processing unexpected events. This ability is called ‘embodied cognition’ – a framework that emphasises the significance of the worker’s physical body in cognitive processing. The idea is that the body’s interactions with the environment contribute to cognition, the mental action or process of acquiring knowledge and understanding through the senses. Scion’s Human Factors team takes a pragmatic approach to investigating decision making using this framework to see how it might influence the future of safe practice. Preliminary findings suggest that expert tree fallers have well-established proficiency enabling instantaneous decision making in volatile situations. To leverage this ability, the aim is to first map out the cognitive differences between experts and novices using physical and emotional measurements. Then, those somatic markers will be used to capture strategies processed automatically during expert decision making. Adaptive rules of thumb, ‘simple heuristics’, will be derived and harnessed to design an on-the-job learning approach. Ultimately, the methodology for studying embodied cognition in dynamic contexts could serve to amplify and extend human capability beyond safety critical tasks, changing the way workers interact with the operational forest environment.

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Problem & Opportunity

Despite significant efforts and spending, deaths and injuries continue to plague our workplaces. New Zealand’s workplace fatality rate is twice that of Australia and four times that of the U.K. (1, 2). To address the huge challenge, there is a need to think about workplace safety differently to develop an approach that completely resets the status quo.

Production forestry is NZ’s most lethal workplace (Figure 1) with a fatality rate 28 times the national average – 30 professional manual tree fallers have died since 2010 (3).

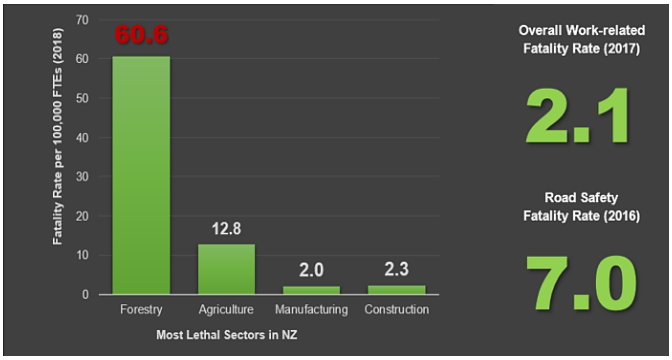

Figure 1. Fatality Rates per 100,000 FTEs/Population Comparison (Ref: 4, 5)

Forestry workers face risk-laden operational demands and unpredictable conditions. The predominant solution is to put manual operators into machines. However, mechanising some tasks can be limited by accessibility, capital cost, and environmental impacts.

In such cases, forestry relies on workers complying with safe operating procedures successfully. But these often only apply in well-defined situations where all outcomes and their probabilities are known (6). In reality, the nature of the work in complex operating environments requires fast decisions to address sudden challenges under variable conditions with incomplete information – a completely different way of thinking to the one on which our safety systems are based (7, 8).

The goal of Scion’s Human Factors research group is to complement, rather than supplant, existing safety approaches in manual tree felling to try to address the unacceptable statistics. Typical of the challenges many workers face, are the demanding environment and manual processes that are too complicated to automate. While high physical workload and difficult terrain contribute to the injury rate, the industry’s safety systems are not as fit for purpose as intended. The unique combination of proven researcher expertise, industry relationships with ready access to participants, and the tree felling task itself, make this an ideal first use case to build more theory that may ultimately transform practice.

The Human Factors team is focusing on the area that will make the biggest impact in terms of reducing harm in forestry – Tree Falling – an area known extensively through previous research. An average of three workers per year, in a workforce of about 250, are killed felling trees. About one-third of the national forest estate comprises woodlots harvested by small contractors and in many cases the most feasible option for tree felling is via chainsaw. The reality is that

in future more harvesting of small forests will happen. Therefore, the industry needs to transform forestry's tree felling safety profile and operational practice.

Research exploring the way people work and think in dangerous occupations has demonstrated that tree fallers use available information to anticipate and avoid hazards (7, 9, 10). This process influenced safe working practice – poor judgements increased injury potential, as did less experience (9, 10, 11). Another significant finding was a marked difference in tree felling technique between experts and novices (10). Experts needed half the decision time to assess and plan, compared with novices, while maintaining a work pace twice as productive.

To leverage this ability, current research will use somatic markers to capture the cue patterns and strategies that are processed automatically during expert decision making. Adaptive and robust rules of thumb, also known as 'simple heuristics', will be derived from the discovered strategies, and then harnessed to support on-the-job learning in alignment with industry practice.

Aligned with the industry's strategy to make jobs safer, it is the vision of this work that a valuable use case not only reduces error and enhances life-and-death decision making in manual tree falling but will act as a credible blueprint to keep workers safe and to improve both productivity and novice performance in other tasks across the operation.

The Science

Decision theory shifts have occurred in parallel with the growth of artificial intelligence. After failing to duplicate human reasoning using analytical algorithms, computers were built that were capable of rapid pattern recognition from structured knowledge bases (12, 13). Again, unable to meaningfully simulate human decision making, they began to seek other feasible explanations for what was tacitly taking place (14).

Skill acquisition has evolved into a nuanced process. The mechanisms of which represent a known theoretical diversion, limited to date by indirect behavioural inferences. Now, advances in cognitive science and decision theory mean the brain can be studied in new ways to improve and augment the mind at work.

Expertise has been studied in numerous contexts (15). Expert workers instantly recognise potentially dangerous patterns in the environment and take action to avoid harm using a seemingly intuitive 'sixth sense' (7, 9, 10, 15, 16). Experts' experience allows them to intuitively compare system states to better predict and avert danger – an ability defined as 'expert intuition' (17, 18, 19). From this point on, expert intuition will be referred to as 'embodied cognition' to more broadly encompass the psychological and physiological processing that occurs as the worker's physical body interacts with the environment and contributes to cognition and decision-making.

To enhance safety, embodied cognition permits efficient experientially based decisions while simultaneously freeing up attention resources for processing sudden hazards characteristic of uncertain operating environments. Preliminary findings suggest expert tree fallers have well-established, extremely well-honed psychophysiological proficiency enabling automatic hazard assessment and felling planning, and that this cognitive process is repeatable (10). This use case allows us to build more theory to apply in practice.

Hypothesis 1. Can we identify processing involving embodied cognition?

Studies using non-invasive brain monitoring have found the brain regions and structures that process information change from the prefrontal cortex to more primitive neural circuitry as we develop expertise (21, 22, 23, 24, 25, 26, 27). As such, the processing strategies that experts use are largely unavailable to conscious introspection (12) because they are automatically processed in the mid-brain rather than areas responsible for reasoned thought. Instead, they dictate responses through indirect channels, like 'gut feeling'. Despite this, most studies rely on descriptions and behavioural observation to infer underlying cognitive processes (28, 29, 30, 31). The Somatic Marker Hypothesis asserts that humans react to patterns before they are aware of them (24, 29). Processed rapidly, somatic marker signals arising from feelings/emotions can influence decisions (24, 29, 30).

This research aims to show that experts' physiological responses to domain specific stimuli differ from novices and control participants, providing converging evidence for discreet decision-making processes (27). To do so, attempts will be made to model the underlying mechanics of the fast, automatic decision-making process without having to rely on reasoned introspection, the glaring fallibility of current methods (32).

Ultimately, this process may offer a method for identifying embodied cognition and a biological measure of expertise.

To identify tree fallers who use this processing, somatic markers (such as eye saccades and fixations, skin galvanic conductivity, heart rate variability, respiration rate and minute motor movements) will be used to establish automatic response to domain-specific stimuli. From a practical perspective, it is known that tree fallers primarily use vision to identify hazards, allowing for stimuli presentation via a visual medium (10). The visual medium permits synchronisation of responses with precise manipulation of the environment physics.

Hypothesis 2. Can we capture the underlying structure of these processes?

Until recently, it was believed that the ability to successfully employ embodied cognition required considerable expertise in a specific field (20). Yet recent research suggests that extensive experience may not be necessary for effective decision making (33, 34, 35). The acquisition of this processing is not based on subject knowledge alone, but the type of thinking deployed in any given situation. Experts consider less information (36, 37), exploit cue hierarchies, and rely on simple strategies known as heuristics to make decisions more quickly and 'frugally' under time pressure (38, 39). Heuristics are efficient cognitive 'shortcuts' and it is proposed that they form the underlying structure of embodied cognition.

The aim is to combine the Practitioner Method (40) – a process designed to derive robust and transparent heuristics - with somatic markers. This is a pioneering means of capturing psychophysical modes of processing below conscious awareness.

To capture the heuristics experts' use, it may be possible to identify the cue patterns and intensity thresholds that are automatically processed in skilled decision-making during tree felling. In situ eye tracking analytics may be able to determine which cues within the environment draw the experts' attention and their order. To ensure that responses are genuinely embodied and deliver an indication of priority cue recognition, participants will be forced to engage their automatic 'gut feelings' through short presentation intervals (41). The presentation of the cues will be followed with a representation of a virtual tree on which participants will demonstrate what they consider to be the correct felling cuts. One risk is that stimuli cues may not elicit strategies, which may be able to be prevented by closely working with industry partners during design.

The hypothesis is that expert participants may have a stronger, faster response to the most decision-relevant contextual cues (e.g., tree branching pattern). From these findings, the importance and priority of the cues can be established, then the heuristic developed.

The second study will explore the thresholds of the most important cues identified. Participants will be presented with a series of trials where cue intensity forms a continuum for response selection. As with study 1, each short interval trial will be directly followed with a virtual tree on which participants will demonstrate their response selection, enabling the intensity threshold for response selection to be established for each cue. Structured reflective interviews will be conducted to establish a qualitative measure of the decision process, to assure alignment with current theoretical practice (10, 42).

It is intended to validate a heuristic decision-making model as a way of making sense of the collected data describing cue usage and response selection strategies adopted by the expert group. Heuristics are 'mental shortcuts' typically employed in complex environments with multiple interacting variables. One such potential model (with rudimentary 'if/then' classifications like those employed in tree felling) is coined Fast and Frugal Decision Trees (43). These heuristics are fast, with limited computation, and frugal, only using some of the perceived information, instead relying on rules of searching for information, stopping search, then making a decision (44, 45, 46). They are transparent, easy to teach and learn, and readily used by practitioners (40, 42). The findings may translate into a heuristic allowing precise and unambiguous rules to be derived as decision support. It is intended to apply the derived strategies to accident and injury statistics to provide a quantifiable indication of success against specific performance criterion of accuracy, speed, and frugality – essentially, can the heuristic be used to make the right decision fast with limited information?

A potential risk may be the emergence of individual differences in decision making styles. However, there are advantages to such a finding. For example, if there are two dominant ways of completing the task, then each new learner can have a choice of decision strategy that suits them best.

Impact

Tree felling offers a unique value proposition for identifying, and understanding, thinking processes using embodied cognition. This highly topical use case is well aligned with projected government objectives, posing an opportunity to improve reputation and social license to operate. Despite forming a small sample, tree fallers represent varied communities of practice operating in immensely challenging environments, engaged in dangerous tasks where automatic, intuitive thinking could keep them alive. So, while the immediate impact will be focussed on forestry users, the methods developed may have application to other industries where this type of thinking is advantageous.

To improve industry reputation and social license to operate, safety systems that are fit-for-purpose need to be designed. Expertise can be leveraged with non-invasive brain and response monitoring techniques, to build workforce capabilities in safety-critical jobs, thereby supporting industry resilience.

Through this project, end-users may be provided with proven means to identify embodied cognition and objectively distinguish degree of skill in one critical sector (tree felling). Productivity and quality of the whole harvesting operation is significantly affected by the tree felling phase. Parker (10) has shown that experienced fallers felled on average 50% more trees per hour than novices – success in this project may provide the tools to achieve this level of performance without the requirement of 10 years tree felling experience.

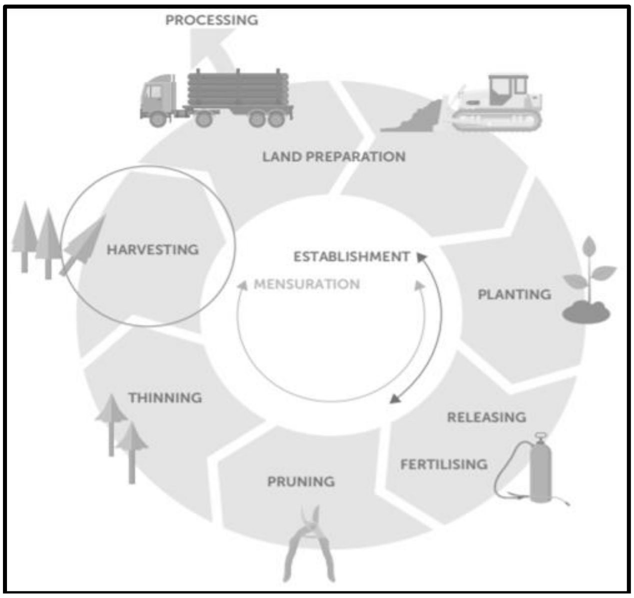

Figure 2. Forestry Value Chain

The strategies and technologies to isolate and articulate embodied cognition form a process for selection and decision support that may translate more widely across the whole forestry value chain (Figure 2). The research methods have potential to be widespread, improving safety and productivity in other areas of the forestry value chain (such as machine operators for increased mechanisation; thinners who can affect the yield of a block years before harvesting; pruners who can influence how well a tree grows).

Conclusions

Our vision to capture and understand the decision making of expert workers in dangerous environments will not only transform forestry's workplace safety profile directly, but it may also change the way people are taught how to safely interact with the world. This research provides a novel approach to the acquisition of expertise, while pragmatically influencing the way the underpinning processes are characterised.

This research will allow for targeted initiatives and spending to genuinely improve the effectiveness of safety on the forest floor. Safety directly costs forestry businesses, as it takes up time and money. It is frustrating when it is not effective, and people get hurt. The Colmar Brunton report found Health and Safety was in the top 5 activities in which forest owners want to invest. A significant proportion of the Forest Growers Levy is spent on safety (around 12%), but accidents are still happening.

This project will help to address the problem of the unacceptably high injury and fatality rates that forestry endures as a sector. It is expected to see fewer injuries stopping people from working, increased innovation, improved quality, enhanced corporate reputation, lower cost of accidents, reduced ACC levies, and improved staff recruitment and retention.

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