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Carpentry Apprentices, Work and Noise

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Human-centred design in civil road construction: Methods to inform procurement and improve performance

Sara Pazell1,2, Robin Burgess-Limerick1, Tim Horberry3 & Paul Davidson4

Abstract:
Productivity, fatality, injury and health risks are associated with the operation and maintenance of mobile plant in road construction. Unwanted events include: slips, trips and falls from ground or at height; exposure to hazardous manual tasks, pinch points, heat, noxious chemicals and whole body vibration; low levels of distributed situation awareness; fatigue; vehicle roll overs; and collisions. It may be possible to remove or reduce the risk of these events through improved design of the equipment.

The Earth Moving Equipment Safety Round Table (EMERST) - Design Evaluation for Earth Moving Equipment Procurement (EDEEP) method was adapted for road construction equipment. Six field visits were undertaken to review an asphalt job truck. A task-based risk assessment process identified 15 design issues contributing to hazards associated with the equipment. Many of these issues had not previously been captured during routine reporting processes. Design parameters were established to inform procurement regarding preferred specifications for future job truck purchases.

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KEYWORDS
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Introduction
Industry Profile and Injury Trends
The Australian construction industry is the fourth largest contributor to Gross Domestic Product (Australian Bureau of Statistics, 2010), employing 9% of the workforce (Safe Work Australia, 2013). It provides for traditional head-of-household income: full-time (86%) and male workers (89%) (Australian Workforce and Productivity Agency, 2013). In the last 11 years, the number of construction workers has increased by 33% (Safe Work Australia, 2015). In 2012-13, the construction industry had the fourth highest incidence rate of serious claims per 1000 employees and fifth highest rate of fatality per 100,000 workers in 2013-2014 (Safe Work Australia, 2015). Work in this industry in 2012-2013 has given rise to 10% of worker’s compensation claims for injuries and diseases involving one or more weeks off work (Safe Work Australia, 2015).

Safe Work Australia (2015) reported that the main cause of the injury claims included body stressing (37%); falls, trips and slips of a person from height or at same level (28%); and being hit by moving objects (14%). Fatalities were constituted by 28% of claims for falls from height and 16% of claims from vehicle incidents.

Across Australia, the occupation groups with the highest serious claim rate include labourers, intermediate transport, and trades workers (Safe Work Australia, 2011); construction includes all three groups.
The construction industry exposes workers to hazardous work conditions with awkward postures, force, exertion, repetition, contact stress, pinch points, vibration, collision risks, chemical exposures, occupational noise exposure, exposure of outdoor work elements, and trip and fall hazards (Boatman et al, 2015; Kramer et al, 2009; Glimskar and Lundberg, 2013; Pazell, 2014a,b and Safe Work Australia, 2015). Physical demands are high yet control over product design and material selection has been limited (Kramer et al, 2009). The Australian Work Health and Safety Strategy 2012-2022 (Australian Strategy) has identified the construction industry as a priority for intervention. This is underpinned by the guiding principles that all workers have the right to a healthy, safe environment and that well-designed, healthy, and safe work will permit more productive lives (Safe Work Australia, 2012).

**Design as an Intervention**

Prevention through Design (PtD) refers to the elimination of hazards through the application of a traditional hierarchy of controls as well as the introduction of novel controls applied throughout the lifecycle of equipment and human-interface design. PtD recognises the increase to business value associated with its practices (NIOSH, 2014). “Healthy and safe by design” is one of seven key action areas of the Australian Work Health and Safety Strategy 2012 – 2022 (Safe Work Australia, 2012). Design includes equipment, task, workstation; environment; work processes; organisation of work and management practice (Creaser, 2008; Driscoll et al, 2008; and NIOSH 2014). The Total Worker Health® initiatives provide that design, and the design process, may integrate protection from work-related safety and health hazards with promotion of injury and illness prevention and advance well-being for workers (NIOSH, 2015). Fundamental influences on employee well-being are rooted in the design of work because design provides for a differentiated, targeted approach to address the most vulnerable issues affecting the workplace: management systems, safety hazards, or productivity hazards (Karanika-Murray and Weyman, 2013).

Equipment and mobile plant used in heavy industry pose a major occupational hazard, particularly given their use in close proximity to pedestrian workers and other plant. The design is likely to have been focussed on durability and task outcome rather than the optimum interface with operators and maintainers (Horberry, 2011; and Horberry et al, 2011). Participative approaches to design improves work safety and health (Burgess-Limerick, 2010; Burgess-Limerick et al, 2011; Cantley et al, 2014; Grandjean, 1986; Horberry et al, 2011; Horberry et al, 2014; and Karwowski, 2012), reflects positive workplace culture (Lallemand, 2012) and exhibits change-readiness in leadership (Kramer et al, 2009 and Village and Ostry, 2010). Such an approach also enables duty holders to discharge their duty to consult with workers under the Australian work health and safety legislation.

**Human-Factors Design Strategies: Design OMAT, EDEEP, and Hazard Patterns**

There are a number of human-centred design tools developed for use in the mining sector which may be applicable to road construction equipment. Design for Operability and Maintainability Analysis Technique (OMAT) is a human-centred design approach that is a hierarchical, task-based procedure and focuses on risks for operators and maintainers in relation to the interface between people and equipment (Burgess-Limerick et al, 2012).

Design OMAT is an integral component the Earth Moving Equipment Safety Round Table (EMERST) Design Evaluation for Equipment Procurement (EDEEP) process. The EMERST is a collaboration of multinational mining companies which formed in 2006. Its purpose is to engage with equipment manufacturers to facilitate design improvements for mining equipment (Burgess-Limerick et al, 2012). The design philosophies include eight key functions associated with human-equipment and system interface: 1) Access and working at heights; 2) Tyres and rims; 3) Exposure to harmful energies; 4) Fire; 5) Machine operation and controls; 6) Health impacting factors; 7) Manual tasks; 8) Confined spaces and restricted work areas.

The design philosophies outline potential unwanted events (PUE’s) associated with foreseeable variability in human behaviour and equipment use. These have been grouped to include 20 exposures including: falls; blocked emergency egress; contact incident; caught between moving objects; wheel assembly, rim, or tyre failure or explosion; fire; manual tasks; collision; loss of machine stability; inadvertent or erroneous operation of a control; incorrect interpretation of a display or label; failure to respond to an alarm; extreme temperatures; respirable dust; diesel particulate material or other particulates; noise; whole-body or peripheral vibration; failure of control system; and irrespirable atmosphere in a confined space.

The study of the interrelationship of person, equipment, environment and task in terms of ‘hazard patterns’ is recognised as a human-factors practice (Burgess-Limerick and Steiner, 2007; Cooke, 2014; and Drury and Brill, 1983). The possibility of extending this layering technique to include design and health considerations linked to a hazard and task pattern was explored in this study.
Objectives of the Study
The aim of this study was to investigate the potential for improvements to vehicle design that may mitigate safety risks and positively affect worker health through the use of a human-centred design approach. An asphalt job truck review was chosen for the investigation.

Methods
An asphalt job truck was chosen for review within a road construction business unit of a multi-national construction firm (Refer to Figure 1). This machine was chosen owing to its routine and regular operation and interface with work crew and mechanics. Supporting material detailing the applications of human-centred design review of mining equipment was provided. A request was made to the regional contracting operations manager to allocate staff time and resource for this review: the manager provided approval and introduced the idea to other relevant managers, including the local assets and maintenance managers, the local safety advisor, and the regional contracts manager. Research gatekeeper approval was obtained as was individual informed consent from work crew and mechanics or representatives involved in the review. Ethics approval was obtained from The University of Queensland.

Field Visits and Observations
Six field visits were made (including one visit at the depot) with 49 general activities attributed to this project. Field visits allowed semi-structured and unstructured interviews with work crew, mechanics, team leaders, foremen, and project managers. Naturalistic and simulated task observations were undertaken during day and night shift operation. Five field visits were attended by the local safety advisor and two visits included meetings with field and workshop mechanics at another region. Field visits were coordinated according to crew availability, ease of access, and operational demands that would permit consultation with the investigator. Conversations were conducted as operation demands allowed, except for one structured meeting held with a job truck operator at the depot, and one held with a small group of volunteer maintenance workers (n = 3), including the maintenance manager, in the other region. The activities undertaken included: participatory task analyses (including taking images, video playback, measurements for reaches, exertion requirements, and body mechanics); generation of a job analysis report; hazard identification; task simulation at the depot; field visits as described above; application of a truck design checklist and reporting; dissemination of literature to inform the managers of the process and evidence for practice; coordination and facilitation of a participative design review; participative application of the risk rating tool (e.g. EDEEP); consultation with other business units including transport teams; and internal communication of findings with verbal and written reports. Additional consultation with industry experts and national procurement teams occurred and face to face presentation of findings were made to a regional management team and a national product group within the company using power point media. General findings were shared...
with the regulator in a transport advocacy group and conversations were held, also, with a representative of the
Truck Industry Council as to design improvement methods that may be considered among manufacturers. A
representative of the board of the Australian Trucking Association was also informed of the results.

Design-OMAT & EDEEP Application

The Design-OMAT six-step process was undertaken: critical task identification, hierarchical task analysis, hazard
identification and risk determination, control strategy development, feedback and action planning, and risk
register documentation (Horberry et al, 2011). To mobilise and implement this practice, additional organisational
activity was required. Table 1 (adapted from Horberry et al, 2011) provides a description of the Design-OMAT
steps and the supplemental, supportive activity undertaken to support the process within an existing management
framework. After completing the task analysis, with information provided by the structured interview process
and use of the vehicle checklist described below, the EDEEP risk matrix was reviewed and completed during
two meetings held with the safety advisor and workshop mechanic. The risk matrixes required identification
of hierarchical tasks, potential unwanted events (informed by historical occurrence, near misses, near rights –
where workers have had to intervene to assure optimum performance even if the action is contrary to written
procedure, and an imagined reality of what may be), the link made to relevant, established design philosophy, and
perceived likelihood and consequence of the event. A total inherent risk score is generated by the tool when tasks
are considered and risk-rated with regard to framework of the 20 potential unwanted events. The tool requires
identification, also, of current control measures, evaluation of these controls, and recommendations for effective
control implementation. Periodic checks were made with crew and operations managers to affirm the validity of
information recorded and rated.

TABLE 1: WORK FLOW PROCESS

<table>
<thead>
<tr>
<th>Organisational Support Activity</th>
<th>Design OMAT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Management consultation to support design trial and for equipment selection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Prioritisation of critical tasks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Conducting task analysis: identification of the step-by-step physical, cognitive, or communicative sub-components of the task required within the job role: multiple on-site visits coordinated with work crew</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Truck measurements and analysis with worker consultation: multiple visits at depot and/or on site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Iterative documentation of findings with workers and stakeholders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Hazard identification, escalation, and risk determination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Participative review of findings and application of EDEEP tool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Control strategy (solution) development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Consultation with workers through seeking feedback (occurs throughout the process)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Maintenance of a risk register imbedded in project management planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Presentation to management and procurement for process and design review</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Supplemental Checklist

For the purposes of description and measurement, a checklist of the history of vehicle operation and general features
was developed. These included items such as primary vehicle functions; injury or incident history; a discomfort
survey; mechanical care requirements; administrative controls advised; and planned procurement schedules.
Features were included such as seating systems; general visibility associated with driving or critical tasks; stairwell
measures for ingress/egress; grab rail dimensions; hand and foot control types and methods (lay-out, number required
to operate, type, shape coding, level length coding, colour coding, functionality or direction, and other comments
by workers); alarms, indicators and general noise or haptic alerts; access points to the truck body; pinch points
associated with cabinetry or other associated equipment; fixed and portable equipment transported; whole-body
vibration exposure measures; steering systems; and proximity sensors. The tools and raw material transported and
associated environmental conditions were also considered. This checklist, along with the application of the EDEEP
risk management tool, provided for a semi-structured interview process. The EDEEP findings were elaborated using
hazard and design layering (Refer to examples provided in Table 2 and 3).
**TABLE 2: HAZARD TO DESIGN LAYERING: INGRESS AND EGRESS**

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
<td>Asphalt Job Truck</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
<td>Rear of Dual Cab: Steps</td>
</tr>
<tr>
<td><strong>Task</strong></td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
<td>Ingress / Egress</td>
</tr>
<tr>
<td><strong>Mechanism</strong></td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
<td>Slip/Trip/Fall</td>
</tr>
<tr>
<td><strong>Behavioural Risk</strong></td>
<td></td>
<td></td>
<td></td>
<td>Forward facing egress; jump versus step out</td>
<td>Forward facing egress; jump versus step out</td>
<td>Forward facing egress; jump versus step out</td>
<td>Forward facing egress; jump versus step out</td>
</tr>
<tr>
<td>(Tactics inconsistent with written procedure)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Design Philosophy</strong></td>
<td></td>
<td></td>
<td></td>
<td>Night Visibility; Cascade Steps; Neutral Alignment (truck body and steps); Initial Step &lt; 500mm; &lt;= 5mm differential among risings; Reaches and heights vast anthropometric range; non-slip grip; Ease in rail reach 90 – 110% of stature of broad population range; clearance of rear steps and engine components; fold-down tiered stairwell where possible</td>
<td>Night Visibility; Cascade Steps; Neutral Alignment (truck body and steps); Initial Step &lt; 500mm; &lt;= 5mm differential among risings; Reaches and heights vast anthropometric range; non-slip grip; Ease in rail reach 90 – 110% of stature of broad population range; clearance of rear steps and engine components; fold-down tiered stairwell where possible</td>
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</tr>
<tr>
<td><strong>Health Opportunity</strong></td>
<td></td>
<td></td>
<td></td>
<td>Involve Workers in Re-Design; Physical conditioning with safe step up/down; more gender inclusive design strategy</td>
<td>Involve Workers in Re-Design; Physical conditioning with safe step up/down; more gender inclusive design strategy</td>
<td>Involve Workers in Re-Design; Physical conditioning with safe step up/down; more gender inclusive design strategy</td>
<td>Involve Workers in Re-Design; Physical conditioning with safe step up/down; more gender inclusive design strategy</td>
</tr>
<tr>
<td><strong>Image(s)</strong></td>
<td></td>
<td></td>
<td></td>
<td>FRP grating high slip-resistance material</td>
<td>FRP grating high slip-resistance material</td>
<td>FRP grating high slip-resistance material</td>
<td>FRP grating high slip-resistance material</td>
</tr>
<tr>
<td>Item</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
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<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Equipment</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
<td>Diesel Bath Bucket</td>
</tr>
<tr>
<td>Location</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td>Transported from truck body to screed arm lug attachments</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Used to carry and contain diesel to clean tools. Physical demands: Lift, lower, 2-person carry, adhere and attach</td>
<td>Lift, lower, 2-person carry, adhere and attach</td>
<td>Lift, lower, 2-person carry, adhere and attach</td>
<td>Lift, lower, 2-person carry, adhere and attach</td>
<td>Lift, lower, 2-person carry, adhere and attach</td>
<td>Lift, lower, 2-person carry, adhere and attach</td>
<td></td>
</tr>
<tr>
<td>Mechanism</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td>Sprain/Strain; Compression Injury (pinch-point)</td>
<td></td>
</tr>
<tr>
<td>Behavioural Risk</td>
<td>(Tactics inconsistent with written procedure)</td>
<td>Drop one end; over-exertion; place on screed walkway versus side arm</td>
<td>Drop one end; over-exertion; place on screed walkway versus side arm</td>
<td>Drop one end and fail to communicate in 2-person lift; over-exertion; place on screed walkway versus side arm</td>
<td>Drop one end and fail to communicate in 2-person lift; over-exertion; place on screed walkway versus side arm</td>
<td>Drop one end and fail to communicate in 2-person lift; over-exertion; place on screed walkway versus side arm</td>
<td></td>
</tr>
<tr>
<td>Design Philosophy</td>
<td>Reduce 55kg to &lt;20kg; transit option via paver not job truck; improved grip handles; sump plug drainage; review environmental concerns and use of non-diesel release product</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Opportunity</td>
<td>Involve Workers in Re-Design; Physical conditioning in safe manoeuvres; less time required; more gender inclusive design strategy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Image(s)</td>
<td><img src="https://example.com/image1.jpg" alt="Image 1" /> <img src="https://example.com/image2.jpg" alt="Image 2" /> <img src="https://example.com/image3.jpg" alt="Image 3" /> <img src="https://example.com/image4.jpg" alt="Image 4" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
An Appreciative Approach

Appreciative Inquiry was engaged by the investigator during worker and manager consultation to elicit contributions to the design strategy (e.g. Cooperrider and McQuaid, 2012). This method provided for unstructured interviews to complement the semi-structured interviews when referring to checklists. To prompt change ideas, the investigator used provocative language and employed guiding principles of anticipation and positivity. A line of questions involved acknowledgment and appreciation of what was working well (rather than only perceived hazards), collaborative idea-sharing, best-practice examples from other industries, and the consideration of a possible shared destiny rather than any established, predictable, prescribed deliverables or assumed outcome (e.g. Bushe and R-Kassam, 2005; and Johnson and Leavitt, 2001). For example:

- We have the chance to investigate this truck. This is an experiment. What would you like the business to know?
- What is the best aspect of operating (or repairing) this truck and what can you dream would make it even more enjoyable?
- If your transport division changed the material of their fleet step well from those with metal, bull guards, and plastic to a FRP/GRP fibreglass grid high-degree slip resistance material. Would that improve your step well?
- The organisation’s job safety analysis advises 3 points of contact and cab facing ingress/egress. However, at least 30% of the time I have observed front-facing egress among the crew. Can you tell me about why they may feel more comfortable facing front?
- If funding support were unrestricted, what could improve efficiency of your work with this machine today?

This appreciative approach was engaged during interactions with managers, team leaders, capital expenditure coordinators, a supply chain representative, other business units, and finance teams. Questions were posed to prime these representatives to consider that a new predictive design approach may be possible, finance and process approvals need not be cumbersome, and that it could be freeing to discard old procedures and systems.

Results & Discussion
Design-OMAT and EDEEP Findings

Findings from the Design-OMAT job truck review revealed 3 serious or major risks (fatality or severe to moderate disability) and 4 moderate risks (potential injury relating to musculoskeletal disorder) as shown in Table 4. Overall, 15 hazards were identified and strategies for design improvement were provided. The organisation prepared for some changes to be made by workshop mechanics but, ultimately, favoured the development of procurement specifications that would shift the responsibility of design improvement to the truck body build supplier.

<table>
<thead>
<tr>
<th>No</th>
<th>Consequence</th>
<th>Likelihood</th>
<th>Description</th>
<th>Design Considerations: Preliminary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Major</td>
<td>Unlikely</td>
<td>Crane lift failure risk for loss of machine stability or hitting object or person</td>
<td>Capacity routinely engineering rated; training to workers; escalate for review with management as to cost-benefit; assess rural versus metro use</td>
</tr>
<tr>
<td>2.</td>
<td>Serious</td>
<td>Possible</td>
<td>Retrieval of diesel bath bucket: Manual task exposure with risk for sprain/strain</td>
<td>Referral for further ergonomic risk assessment; re-design diesel bath bucket, paver lug attachment, storage and transportation strategy</td>
</tr>
<tr>
<td>3.</td>
<td>Serious</td>
<td>Possible</td>
<td>Retrieval of vibrate-plate and jackhammer: manual task exposure - sprain/strain risk</td>
<td>Independent quick-activation control for hydraulics of lift platform or cradle release with hydraulic or air ram to lower items to ground</td>
</tr>
<tr>
<td>4.</td>
<td>Medium</td>
<td>Possible</td>
<td>Access to battery behind electrical housing: manual task exposure – sprain/strain risk</td>
<td>Specify clear access to battery housing for ease in replacement in depot and in the field.</td>
</tr>
<tr>
<td>5.</td>
<td>Medium</td>
<td>Possible</td>
<td>Rear cab egress: fall from height</td>
<td>Redesign stepwell for uniform step height, swing away access (for mechanics) and improved visibility and access; add night-time lighting; add coated safety high-vis yellow tread.</td>
</tr>
<tr>
<td>6.</td>
<td>Medium</td>
<td>Possible</td>
<td>Front cab ingress/egress: fall from height and sprain/strain</td>
<td>Replace plastic top tread with metal step and add coated safety high-vis yellow tread to steps; design for even risings ≤ 5mm variation; add focal lighting and strip lighting; design for visibility day and night.</td>
</tr>
<tr>
<td>7.</td>
<td>Medium</td>
<td>Possible</td>
<td>Hard edge and heavy weight cabinet lids: pinch point risk</td>
<td>Use foam insert and install gas struts to prevent hand injuries from pinch point risks.</td>
</tr>
</tbody>
</table>
The assessments included day and night time observations to capture naturalistic study when and where the equipment may be operated or accessed. This contributed to the breadth and scope of hazard identification.

Short-, mid-, and long-term recommendations for redesign or improvement to the procurement specifications were prepared. Several short-term design improvements were authorised in-house and included redesign of the diesel bath bucket to reduce its carrying weight and provide ease for attachment on the paver side arm (Refer to Table 2: Hazard and Design Layering: Diesel Bath Bucket).

In one vehicle, mechanics installed lighting to the vehicle door strips to improve night visibility. Gas struts were added to tool box lids with foam inserts to help address pinch-point hazards. Another short-term intervention identified by mechanics and crew was their perceived need for training by the truck body-build supplier for the crane operations. Metropolitan crew could not identify a need for the truck crane while regional teams stated that they used the equipment at least once a quarter. This suggested that task-specific work requirements may differ in different regions and equipment needs may vary accordingly. Savings could be found if the crane was not required in metropolitan area trucks. Similarly, reports that the overhead hang and shade cloth on the truck body was never used suggest potential savings.

The work crew and mechanics reported issues such as:

“(Our) head hits the rear overhead hang when we climb the stairwell to the body of the truck”.

“The guys do not use the lift platform to retrieve the whacker packer vibe plate (up to 80kg) or the jack hammer (40kg) if the truck is not already operating; it takes too long to wait for the hydraulics to kick-in”.

“Workers typically exit the rear of the dual cab forward-facing as the design of the steps (are not conducive) to cab facing exit (egress) (difficult to see, flush with the body, require legs to cross midline)”.

Impact on Hazard Reporting Process

The findings were significant given that workers had not previously reported hazards related to the job truck. Further, multiple site visits and conversations were required to elicit content reporting. Initially, work teams were reserved and made statements such as, “This is just how the machine is delivered to us. This is construction and heavy industry – nothing is designed for comfort”.

The only previous hazard report on file related to the findings of this experiment was with the difficult access, carrying effort, and tactics required to attach the diesel bath bucket to the paver side arm (Refer to Table 2). However, crew reported that this hazard report had been made over a year prior with an external investigation authorised, however no change in equipment or task method had occurred. When asked why there were no previous reports of the other hazard issues or potential cost savings with equipment that was not required, the workers ascribed this to not believing that there was potential to affect change in large machinery and equipment design and they had never been asked. Workers uniformly reported that they appreciated being asked their opinion about their interface with the equipment, even if some did not believe that the organisation would do anything with the findings.

Hazard reporting methods engaged routinely in the past included the development of a job safety analysis of equipment or work methods completed by a corporate safety advisor. The recommendations predominantly constituted behavioural recommendations and did not address design. For example, slips/trips/fall hazards were addressed with the recommendation of “cab facing egress and maintain 3 points of contact” and “operators should be aware of their surroundings”. This study showed that the design of the rear cab steps was not conducive to use in this way (Refer to Table 1). Hazards were otherwise reported during tool box meetings with team leader facilitation encouraged during conversations and observations with supervisors (key performance indicators required supervisors to hold these regularly with work crew), and permitted spontaneously.

Additional Unanticipated Findings

News of this job truck review activity and findings was shared among work crew. A spray seal team learned of the activity and took the initiative to convince management to make changes to their tool box struts and foam inserts. They also took whole-body vibration measurements using the WBV iOS application to agitate for replacement of their rear seat upholstery.

The truck review checklist was a useful guide to complement the Design-OMAT process. It aided in conversations held among work crew, safety, operations, engineering, and procurement teams. It ensured, also, a comprehensive review of truck features and aided the investigator to develop a shared understanding of the work crew’s language.
The national procurement manager reported that he found the design recommendations to be objective, transferrable and evidence-based. The design process brought together diverse business units which, until that time, had not developed a unified position regarding truck design and body build procurement specifications. There were numerous opportunities for improvement of the equipment, as described in this report, which had not been previously identified through generic and traditional hazard reporting processes.

Challenges Amid Opportunities
EDEEP risk ratings confused some of the team members with regard to the assignment of numeric values and ratings assumptions, but the link to the design philosophy was helpful to inform potential critical control intervention and design strategy. Further, video recording playback was found useful by design review teams, more so than still imagery, of critical work tasks. Overall, this project illustrated the suitability of using the Design-OMAT task-based risk assessment method with the EDEEP risk and design related tool for road construction equipment. Managers reported also, that the hazard and design layering helped illustrate the findings of the project in a comprehensive manner and they appreciated how this added to the weight of design considerations.

The Design-OMAT practice did not occur in isolation from other organisational activity. Significant effort was required to launch and sustain the project and therefore time and resource were consumed. In fact, some managers reported that they thought it a cumbersome process. The 6-step Design-OMAT process, while helpful to outline critical work flow project requirements, did not sufficiently describe the ancillary, inter-related, and supportive functions required to support the project. It did not speak, also, to the need to repeat steps, such as field visits. The use of the Appreciative Inquiry method was critical to the acceptance of the experimental design and encouraged engagement. This method encouraged reporting of a design opportunity.

Conclusions
Human-centred design review of construction equipment within a host organisation may address at least five of the seven national Action Areas of the Australian Work Health and Safety Strategy 2012-2022: healthy and safe by design, supply chains and networks, health and safety capabilities, leadership and culture, and research and evaluation (Safe Work Australia, 2012). To initiate this practice, an organisation may have to take the risk of allocating resources without any expectation of what may be discovered – a phenomenon of predictive design. In this research involving a design review of an asphalt job truck, the findings were extensive, revealing significant design considerations that had not been reported with previous and routine hazard reporting methods. A hierarchical task-based design review process and risk-reporting method, Design-OMAT with the application of the EDEEP tool, provided this rich data.

A semi-structured, task-based method is beneficial in identifying design deficiencies and opportunities for a road construction job truck. The collaboration of road construction operators and maintainers with designers and engineers may be helpful to reduce safety and health risks associated with equipment use. Consultation with workers may provide the most meaningful and relevant findings. The positive feedback from workers suggested that they prized their involvement. The practice of Appreciative Inquiry was useful to engage workers and elicit information: 15 hazards were identified with recommendations for design improvement when only one of these was known to have been previously reported.

There is an emerging trend in Australia for evidence of human-centred design strategies to be demonstrated throughout the supply chain of equipment and service (refer to the Transport Asset Standards Authority of the Department of Transport for New South Wales requirements for Authorised Engineering Organisations: Transport for New South Wales, 2015). The findings in this case review support this initiative: the hazards may have been mitigated if human-centred design had been required of the manufacturer or truck body-build supplier. It may be reasoned that a shared vision in human-centred design with suppliers and manufacturers is required if industry is truly going to develop superior work design for safety, health, and productivity. Further research in human-centred design and sociotechnical systems is recommended as is the sharing of risk management and design innovation across industries.


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Hendra Virus Infection in Animal Workers: An Occupational Health Perspective

Luke Walter

Abstract
The aim of this review was to examine the available literature on equine animal workers’ exposure to Hendra Virus. The review focused on the adequacy of current infection control measures and the work culture surrounding Hendra virus protective measures. Peer-reviewed journal articles paired with Australian government-issued guides and fact sheets were used to highlight Hendra virus as a serious workplace health hazard to equine animal workers. This is due largely to the Hendra virus’s ability to be transmitted to humans while infected horses are asymptomatic combined with the virus’s high mortality rate. Hendra virus poses a low public health risk given its low morbidity rate but is of high significance to animal workers given that five out of a total of seven human cases has been within this subset of workers. Animal workers often fail to recognise the significance of Hendra virus exposure and the dangers involved and accept sub-optimal workplace infection control measures as being adequate. A trend toward better infection control measures within workplaces to protect animal workers from Hendra virus has begun to be observed, however further improvements are still necessary.

CITE THIS ARTICLE AS

KEYWORDS
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Introduction
Animal workers such as veterinarians and veterinary nurses are routinely faced with zoonotic diseases capable of transferring from animals to humans. As one of Australia’s most serious emerging zoonotic diseases, Hendra virus (HeV) poses a great health and safety risk to animal workers and ensuring their protection from HeV exposure is of the utmost priority, particularly within Queensland and Northern New South Wales (Workplace Health and Safety Queensland, 2015). HeV, which is restricted to Australia, was first reported in 1994 when two virtually simultaneous yet unrelated instances were discovered in horses in Mackay in Northern Queensland and the Brisbane suburb of Hendra (Broder, 2012; Ksiazek, Rota & Rollin, 2011). Infections have been reported in horses as far north as Cairns, Queensland, as west of the coast as Chinchilla, Queensland, and as south as Kempsey, New South Wales (Ball et al., 2014; Clayton, Wang & Marsh, 2013). Fifty spillover events of HeV have occurred in horses (the latest occurring in June 2014) with a total of 83 HeV confirmed equine cases resulting in a fatality or euthanasia and an additional four HeV-suspected horses being euthanised (Mendez et al., 2014; State of Queensland, Department of Agriculture, Fisheries and Forestry, 2013). Since 1994, a total of seven human cases have been confirmed (the latest occurring in July 2009) with five of those cases occurring in animal workers (Playford et al., 2010; State of Queensland, Department of Agriculture, Fisheries and Forestry, 2013). Three of the animal worker cases proved fatal (two veterinarians and a veterinary nurse), with a total of four HeV fatalities occurring to date (Playford et al., 2010; State of Queensland, Department of Agriculture, Fisheries and Forestry, 2013). The relatively high number of infected animal workers indicates that these occupations are most at risk of HeV contraction, compelling us as occupational health and safety professionals to investigate the root cause of the issue. Through this review, the relationship between HeV and animal workers, the adequacy of current infection control measures and the work culture surrounding HeV protective practices will be evaluated, culminating in a discussion focused toward the future recommended management of HeV. This review is specifically relevant to animal workers within Queensland.
and Northern New South Wales given their increased risk of HeV due to the current distribution of the disease. Peer-reviewed journal articles paired with Australian government-issued guides and fact sheets will be used to critically explore the main themes, trends and arguments that surround this issue.

**Background**

The virus was initially named equine morbillivirus (EMV) before an extensive serological study of the Queensland equine population conducted by Ward et al. in 1996 determined that horses were not the original source of HeV. The study found that there were no detectable antibodies to the virus from over 2000 equine subjects, essentially eliminating horses as the putative reservoir (Ksiazek, Rota & Rollin, 2011; Ward et al., 1996). This indicated that a different animal species must act as the HeV reservoir. In response to this study, criteria were developed and employed to narrow the search for a potential host species before it was hypothesised that pteropid bats (commonly known as flying foxes) may be responsible (Clayton, Wang & Marsh, 2013). It was indeed confirmed in a study in 2000 by Halpin, Young, Field & Mackenzie that four mainland Australian flying fox species hosted the same HeV isolates as those obtained from the horses and humans infected in 1994 (Clayton, Wang & Marsh, 2013). While the exact mechanism of HeV transmission from pteropid bats to horses is unknown, it is suspected that the ingestion of pastures, feed or water contaminated with urine, faeces, placental tissues, birthing membranes or aborted bat fetuses are the most likely routes (Clayton, Wang & Marsh, 2013; Field et al., 2010). From horses, HeV can be transmitted to humans through contact with infected equine blood, saliva or respiratory secretions (Field et al., 2010). Playfield et al. in 2010 received a detailed exposure history of two animal workers that had been infected with HeV as a part of their case study, and it was estimated that the likely incubation period of HeV within humans is 9-16 days, longer than had previously been stated throughout the literature (Douglas, Baldock & Black, 1997; Mendez, Judd & Speare, 2013). This is corroborated by studies that have examined equine HeV and have noted similar incubation periods (5-16 days) as Playford et al. (Field & Kung, 2011; Ksiazek, Rota & Rollin, 2011). It currently seems unlikely that human to human transmission of HeV can occur (Playford et al., 2010; Wong & Ong, 2011).

The predominant post-HeV exposure treatment to date is the broad antiviral drug Ribavirin, however its effectiveness is often scrutinised and its use in experimental animal models has shown no to little therapeutic benefit (Broder, 2012; Field & Kung, 2011). A HeV vaccine specifically used for horses has been available since November 2012 and is currently the most effective strategy for preventing flying fox to horse and horse to human HeV transmission (Mendez, Büttner & Speare, 2013).

**Health Effects**

HeV is a paramyxovirus of the Henipavirus genus that can produce severe health effects and has a high mortality rate (57%) in humans (Biosecurity Queensland, 2013). Although the mortality rate of HeV is high, its morbidity rate is extremely low given that only 7 cases have been confirmed since 1994 (Biosecurity Queensland, 2013, Ksiazek, Rota & Rollin, 2011). The symptoms associated with HeV can range from mild through to life threatening. Headache, drowsiness and fever are mild symptoms that have been connected to HeV (Wong & Ong, 2011). Beyond these symptoms, HeV can present in two distinct ways, either neurologically or as a pulmonary syndrome (Playford et al., 2010; Wong & Ong, 2011). The neurological symptoms often present as confusion, motor deficits and seizures (Field et al., 2010; Playford et al., 2010). Influenza-like illness, hypoxemia and diffuse alveolar shadowing in chest X-Rays are the most indicative symptoms of the pulmonary syndrome associated with HeV (Field et al., 2010; Wong & Ong, 2011). It should be remarked that the pathology of HeV in humans is still debatable given the relatively low number of cases thus far. Field et al. explored the issue in their 2010 review in which five horses from a HeV outbreak in Brisbane displayed neurological features (which were novel at the time). It was theorised that the viral dose and route of infection could greatly determine the symptoms that are exhibited (Field et al., 2010). It was alternatively theorised that the presence of both neurological and respiratory symptoms may simply indicate the broad spectrum of possible symptoms a HeV infection may manifest into (Field et al., 2010). While Field et al. focused their review on equine HeV, it is possible that the same logic can be employed to explain the variation in symptoms seen in human cases.

**Infection Controls:**

Apart from the vaccination of horses, implementing infection control measures is the most reliable means for ensuring animal workers are protected within their workplace from being exposed and potentially infected with HeV. As outlined in the Office of the Queensland Parliamentary Counsel’s 2011 “Work Health and Safety Act”, it is the general duty of a Person Conducting a Business or Undertaking (PCBU) to, so far as is reasonably
practicable, provide a working environment without risks to health and safety. Therefore, it is not only good practice but also a legal requirement to introduce and maintain infection control measures to protect the health and safety of animal worker employees.

The first step to ensuring HeV exposure is controlled is to develop an equine HeV veterinary practice plan that outlines the standard protocols for dealing with potential HeV cases (Attard et al., 2012; Biosecurity Queensland, 2015). A standard equine plan ensures that animal workers within a practice are informed about the safest route of action should HeV be suspected or diagnosed within a horse and aids in preventing their exposure (Biosecurity Queensland, 2015). The first key component of an equine veterinary practice plan includes a decision as to whether potential equine HeV cases will be accepted at the practice (State of Queensland, Department of Agriculture, Fisheries and Forestry, 2013). The plan should further include details on a triage system that is to be used to help identify HeV risk factors while booking equine consultations (Attard et al., 2012; Biosecurity Queensland, 2015). Information on the appropriate methods for dealing with an equine HeV case and dealing with suspected transmission of HeV from horse to human should be included within the plan (Mendez, Judd & Speare, 2012; State of Queensland, Department of Agriculture, Fisheries and Forestry, 2013). Additionally, entry and exit procedures to be used when dealing with suspected equine HeV cases should be listed (Workplace Health and Safety Queensland, 2015).

Safe workplace protocols should be developed that are to be followed when coming into contact with horses regardless of their perceived infectious state (Mendez et al., 2014). It should be standard procedure to routinely conduct a HeV risk assessment before coming in contact with a horse, to wash hands before and after contact with horses and between contact with different horses, to cover all cuts and abrasions with water-resistant dressings, to handle, transport, store and dispose all equine related items in a safe and appropriate manner and to wear appropriate PPE at all times (Attard et al., 2012; Biosecurity Queensland, 2015; Mendez et al., 2014). Every animal worker should be trained in the correct use of both the equine HeV veterinary practice plan and the safe workplace protocols that are in place. Recurrent education for all animal workers on the risks of HeV and the importance of following infection control measures should be conducted.

PPE such as gloves, safety eyewear, gowns and P2 half-face disposable particulate respirator should be worn by animal workers as a minimum when in contact with horses (Biosecurity Queensland, 2015; Workplace Health and Safety Queensland, 2015). PPE that offer a protective barrier such as face shields, P2 particulate respirator masks (as a minimum, powered air purifying respirators (PAPR) may be required), protective overalls, nitrile gloves and rubber boots should be used for procedures and situations where an increased exposure to HeV is possible (Attard et al., 2012; Biosecurity Queensland, 2015).

Discussion
Examination of the literature highlights several trends and attitudes that have been developed by animal workers toward HeV. Animal workers that regularly come in contact with horses are faced with a real risk of HeV infection. Playford et al. in their 2010 case study describe an outbreak that occurred in 2008 in a veterinary clinic in Thornlands, Queensland, in which a male equine veterinarian (33-years-old) and a female veterinary nurse (21-years-old) were infected with HeV. It was indicated that transmission of HeV most likely occurred while the animal workers performed a nasal cavity lavage of a horse that was late in its HeV incubation period. An incubation period is the time it takes from the initial infection event until the infected individual beings to demonstrate symptoms of the disease (Ksiazek, Rota & Rollin, 2011). This highlights a serious health hazard, as HeV transmission may occur while horses are asymptomatic and animal workers are not aware of their potential for HeV exposure (Field & Kung, 2011; Playford et al., 2010).

While the risk for HeV infection exists, the implementation and correct use of the previously detailed control measures allows for a significant decrease in the danger associated with equine work. However, some studies suggest that this is not a stance commonly shared by the majority of animal workers, who tend to perceive their risk of HeV infection to be quite high (Dowd et al., 2013; Mendez, Judd & Speare, 2012). Dowd et al. conducted a study in 2013 that engaged 344 veterinarians to complete a questionnaire pertaining to their risk perceptions toward all zoonotic diseases. It was reported that 40–60% of veterinarians perceived their exposure to a zoonotic disease to be either likely or very likely throughout a variety of situations (Dowd et al., 2013). While this study does not specifically question the participants in regards to equine practice of HeV, it does offer useful insight on the subject. The perceived risk for HeV is specifically explored in a 2012 study by Mendez, Judd & Speare in which 21 veterinarians and allied staff from 14 equine and mixed private veterinary practices between Cairns and Brisbane, Queensland, were subjected to in-depth face-to-face interviews. The interviews asked a series of open-ended questions in an attempt to identify workplace health and safety issues for equine practice due to
HeV (Mendez, Judd & Speare, 2012). It was discovered that 22% of veterinarians had chosen to cease equine practice and that 44% knew of at least one colleague who had ceased equine practice in the past 12 months. It was specified that fears for personal safety were often reported as being a major contributing factor for ceasing practice (Mendez, Judd & Speare, 2012). It should be noted that this study occurred prior to the 2012 introduction of the HeV vaccine for horses and a follow-up study would need to be conducted to determine if animal worker perceived risk of HeV has decreased.

The five animal worker cases of HeV all occurred before July 2009, indicating that infection control measures for HeV prior to 2009 were sub-optimal. Additionally, the absence of HeV cases since 2009 likely indicates that an increase in the implementation and use of infection controls within veterinary practices has occurred since this time. In a 2014 study conducted by Mendez et al. the adequacy of control measures prior to 2009 was explored. Most participants agreed that they were initially reluctant to introduce infection control strategies when HeV first emerged, as it required a significant shift in their work culture (Mendez et al., 2014). Participants reported that they failed to recognise the significance of HeV exposure and the danger involved and therefore felt that the sub-optimal control measures that were in place were in fact adequate (Mendez et al., 2014). It was determined that it was not until HeV had fully emerged and animal workers were educated on its potential as a health hazard that a shift began to occur (Mendez et al., 2014). It was further found that by 2010, all participants described using some form of PPE and infection control measures to reduce HeV exposure (Mendez et al., 2014). Mendez et al. did identify that participants still felt that further improvements in the use of infection controls were necessary. This is corroborated by the study conducted by Dowd et al. that not only analysed animal workers perceived risk perceptions toward zoonotic diseases, but additionally their use of necessary PPE. Reported PPE use was compared with current national industry guidelines and it was deemed that the use of PPE was less than “adequate” for majority of participants (Dowd et al, 2013). It was additionally stated that no PPE was used by 60-70% of animal workers when treating equine neurological and respiratory cases (Dowd et al, 2013). Cases of a neurological or respiratory nature could be due to HeV infection and using no PPE would dramatically increase the potential for transmission (Dowd et al, 2013).

Conclusion

After reviewing the literature, it has become clear that problems exist regarding the management of HeV exposure by animal workers in Queensland and Northern New South Wales. While HeV may pose a low public health risk, it is of high significance to the health of animal workers. Therefore, it is important to have a plan for the future control of HeV transmission. While a shift in work culture toward the improved use of infection control measures has already begun, it is important to facilitate this shift as much as possible. A potential facilitator to change may be the introduction of standardised legislation that specifies a requirement for adequate infection control measures and outlines safe work practices that should be followed by equine animal workers. A stronger emphasis should be placed on education programs targeted to both current and future animal workers that inform of the control measures and work protocols that need to be introduced to enable safe equine practice. Further research into veterinary infection control needs to occur to increase the effectiveness of controlling HeV. Research should also be directed at investigating animal worker attitudes toward infection control practices, particularly post the introduction of the equine HeV vaccine. Furthermore, research should be devoted to monitoring the work culture of equine animal workers so as to avoid sub-optimal work practices being developed.

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Carpentry Apprentices, Work and Noise

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Abstract:
Noise-induced hearing loss (NIHL) continues to be a major problem for those employed in the construction industry. Hearing loss has been associated with a range of physical and mental health issues, as well as lowered job satisfaction. The purpose of this study, based in Victoria, Australia, was to examine how carpentry apprentices who work in the construction sector understand their risks at work, with a special focus on noise. The employment preparation process for new workers, including how health and safety messages are delivered and understood by these workers was also examined from the instructors’ perspective. Based on data collected from focus groups the research team identified a number of ways to increase apprentice awareness of noise as a hazard and potentially influence noise reduction strategies and use of PPE. These suggestions include informing employers about their responsibilities under the Occupational Health & Safety Act, enforcing induction/training on domestic sites, the provision of safety equipment in the workplace, increased education about ratings of hearing protection and the delivery of safety messages about noise/hearing loss through peers. Audiometric tests at the training college would provide information to apprentices about their level of hearing and could also be ideal opportunities to deliver information about noise at work to apprentices.

CITE THIS ARTICLE AS

KEYWORDS
Apprentices; training; construction; noise induced hearing loss; occupational health and safety; employment

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Introduction
Noise-induced hearing loss (NIHL) continues to be a major problem for those employed in the construction industry and work-related NIHL is among the most common occupational diseases (Timmins & Granger, 2010). The rate of workers’ compensation claims for NIHL in Victoria, Australia increased by 50% between 1995 and 2008 (Radi et al., 2014). The highest claim industries were construction and manufacturing, with the construction industry and trades constituting about 40% of claims. These changes in claim rates may be due to a number of factors including greater exposure; increases to awareness and reporting; and a growth in small business employment.

Besides hearing loss, exposure to loud, persistent noise has been linked to the development of Tinnitus (Axelson & Prasher, 2000) and is also associated with a range of mental health issues and lowered job satisfaction (Timmins & Granger, 2010). Both occupational noise exposure and hearing impairment can increase the probability of other work-related injuries (Moll van Charante & Mulder, 1990). This means that reducing noise exposure and hearing loss can help contribute to the reduction of other work injuries. There are a number approaches to reducing noise exposure but research has indicated a heavy reliance on personal protective equipment (PPE). Unfortunately, a recent Cochrane review found that there is very low quality evidence that the better use of hearing protection devices as part of Hearing Loss Protection Programs reduces the risk of hearing loss (Verbeek et al., 2012).

In this manuscript we examine the experiences and perceptions of a group of carpentry apprentices in Melbourne, Australia who were in the early stages of their career and training. We focus specifically on the issue of noise at work, apprentices’ perceptions of noise as a hazard and their views toward noise control and hearing.
Noise & Hearing Loss in Construction

The construction industry is a major employer in Australia. In 2011-12 over 9% of the Australian workforce worked in construction. Building and construction is also one of the most important small business sectors; ninety-five percent of all businesses in the building and construction industry employ fewer than five people, while less than one per cent employ 20 or more (Master Builders Australia, 2014).

The building and construction industry is Australia’s largest employer of trade apprentices. Apprenticeships remain the main entry point into the industry for people wanting to progress to be qualified trades workers, trade subcontractors, licensed builders or other industry professionals (Master Builders Australia, 2014).

In Australia, qualification as a carpenter within the building/construction industry is achieved through completion of a nationally recognised apprenticeship, which combines onsite work experience with formal education in the form of an accredited Certificate III in Carpentry (Master Builders Australia, 2014). In the state of Victoria, the program is offered by several Technical and Further Education (TAFE) Colleges. Each college has a similar course structure and outline.

An apprenticeship is generally 4 years in length, with schooling taking place part-time, typically within the first 2-3 years, either as “block training”, with eight one-week blocks of classes or a similar part-time arrangement. The units within the course cover practical and theoretical components of tool use, planning in construction, reading plans, safe work practises and Occupational Health & Safety (OHS) requirements in construction. The program may be preceded by the Certificate II in Carpentry commonly known as a “pre-apprenticeship”. This is a short introductory program, (delivered as a six month full time or two years part time program) typically offered to senior secondary school students. The completion of the program decreases the length of time required to complete the Certificate III apprenticeship (Master Builders Australia, 2014).

Apprentice carpenters are employed in the residential, industrial and commercial sectors of the building industry and have the same rights and responsibilities as other workers. Typically, apprentices find employment with one company and are contracted to the same employer for the duration of their apprenticeship, however, it is not uncommon for apprentices to change employers during their apprenticeship.

The construction industry is commonly classified as having highly variable and complex noise exposures, even within the same trade, role or job title (Neitzel et al., 2009; Neitzel et al., 2008). Workers are often exposed to high levels of noise that varies based on the stage of construction, job title and task (Neitzel et al., 2009; Neitzel et al., 2008; Leensen et al., 2011). Noise dosimetry is commonly used to assess 8 hour Time Weighted Average (TWA) exposure levels. The noise exposure standard is 85dB(A) L<sub>TWA</sub> 8h while the recommended noise exposure level is below 80dB(A) (Suter, 2002; Edelson et al., 2009). Many studies have shown workers in the construction industry commonly exceed this level (see for example Kerr et al., 2002). As a result, the high prevalence of NIHL among construction workers is not surprising.

Several studies have noted that within the construction industry there is a heavy reliance on PPE (e.g. ear muffs) to decrease noise exposure rather than implementing noise controls that do not depend on individual worker behaviour or workers’ access to equipment. Reliance on PPE may be due to the mobile and variable nature of the industry and the relatively low cost of PPE (Neitzel et al., 2008; Suter, 2002; Neitzel & Seixas, 2005). Reliance on PPE to reduce noise exposure comes with a number of shortcomings. Some studies have found that use of hearing protection devices among construction workers is low and imperfect. Seixas (2012) found that workers who self-reported always using hearing protection in high noise environment actually only used hearing protection one third of the time that noise levels exceeded 85 dB(A). Similarly, El Dib (2012) found that even on construction sites where noise levels were assessed as being well above the level at which hearing protection devices are required, usage was low. Neitzel et al. (2009) compared construction worksites, where noise was variable, to other workplaces where noise was continuous (for example, warehouses) and found that variation in noise exposure was associated with a lower use of PPE, even in circumstances where the mean noise exposure was high (90.6 dB(A)). Other studies have found that perceived discomfort, inconvenience and interference with communication negatively influence the use of PPE (Stephenson et al., 2011). Some research has also indicated that workplace culture and relationships among workers can influence decisions about the use of PPE (Robertson et al., 2007).

The perception of noise in the workplace and subjective assessment of risk of hearing loss is an essential issue in the design and implementation of hearing conservation programs (Arezes & Miguel, 2005). Several studies have shown that NIHL starts early in the career for construction workers (Seixas et al., 2012), which is why it is
important that young and new workers understand how noise can affect their hearing and what can be done to prevent life-long consequences.

Our study investigated construction apprentices’ perceptions of noise at work and how the hazard of noise was dealt with at their worksites. Our aim was to understand their perceptions of risk with regards to hearing loss, their views about noise exposure control and their knowledge about and self-reported use of hearing protection. We also wanted to investigate the role that training colleges have or could have in providing apprentices with information and resources that might lead to better protection of hearing.

**Methods**

The research focused on carpentry apprentices enrolled at a TAFE college in Melbourne, Australia. The apprentices were working in either the domestic or commercial construction sectors. Commercial sector companies are typically large, unionised organisations involved in large projects such as hospitals, shopping malls, etc. Domestic sector companies tend to be smaller. They are not unionised and the work involves smaller building projects such as private residences, and renovations. Apprentices participating in the study had been employed for at least one year and were attending the college. Details about the apprentice sample can be found in table one.

Fifty-one (51) people were recruited to participate in nine (9) focus groups. Participants self-nominated following presentations by the researchers to classes at the college. Focus groups were conducted at the TAFE college during lunch breaks.

The first focus group comprised instructors at the college and the other eight focus groups were with apprentices in the carpentry program. The instructor focus group explored apprenticeship pathways and training programs at the college and enabled the development of the questions used in the subsequent apprentice focus groups. Sampling and the questions posed in the apprentice focus groups were, in part, guided by emergent findings. For example, the first apprentice focus group included carpenters employed by domestic and commercial firms but later we conducted separate focus group with those in domestic and commercial sectors to tease out some of the differences between these groups of workers. Similarly, based on discussions in the first focus groups, we included specific questions about audiometry (“hearing tests”) in the last two focus groups.

**TABLE 1: DEMOGRAPHICS OF APPRENTICES**

<table>
<thead>
<tr>
<th>Apprentice age group</th>
<th>18-24 (n=32)</th>
<th>25-38 (n=12)</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Level</td>
<td></td>
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<td></td>
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<tr>
<td>1st year</td>
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<tr>
<td>2nd year</td>
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</tr>
<tr>
<td>Total</td>
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<td>12</td>
<td>44</td>
</tr>
<tr>
<td>Sector</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Domestic</td>
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<tr>
<td>Commercial</td>
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<td>3</td>
<td>4</td>
</tr>
<tr>
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<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>12</td>
<td>44</td>
</tr>
<tr>
<td>Number of different employers during apprenticeship</td>
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<td></td>
</tr>
<tr>
<td>0 employers*</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<tr>
<td>1 employer</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>29**</td>
<td>12</td>
<td>41</td>
</tr>
</tbody>
</table>

* One apprentice had been laid off

**Three apprentices did not report number of employers.

Each focus group was facilitated by two researchers. One researcher led the group discussion based on a set of open-ended questions about work, training at the college and in the workplace, attitudes toward noise, hearing protection and noise control and exposure reduction. The second researcher took notes and asked follow up questions where necessary. The focus group discussions were audio-taped and subsequently transcribed. Participants received a $20 gift voucher at the conclusion of the focus group.
Field notes were transcribed and entered into Nvivo10, a program for the management of qualitative data. Transcripts were reviewed and a preliminary list of codes was developed and then refined through discussions with the research team. An initial selection of transcripts was independently coded by all members of the research team to ensure the codes were being used correctly and consistently. Then, each subsequent transcript was coded by two researchers. Once the coding was complete, a thematic analysis was done for each code to identify key themes, contradictions and similarities/difference in the data and between focus groups. The thematic analysis of the data, along with the field notes forms the basis of our findings.

The project was approved by the Human Research Ethics Committees of Monash University and the college.

**Findings**

Apprentices reported working at a variety of different worksites and carrying out a wide range of tasks. They described many differences between work on domestic and commercial sites. Those working in the domestic sector reported working on individual house builds or multiple dwellings on the same estate. Work involved building a house from the ground up or undertaking renovation work within an existing dwelling. Early stages of building (such as framing) involved working outdoors, while renovations tended to be indoor work. Domestic sector jobs were usually short – lasting only a few weeks or months. Those working within the commercial sector reported working in office buildings, shopping centres, factories or on public buildings such as swimming pools or community centres. Commercial work tended to take place indoors. Commercial apprentices could expect to work at the same site for many months or sometimes years. Those in the commercial sector reported working in large teams, whose members were constantly changing with the needs of the job. In the domestic sector, work teams were much smaller, often only two or three workers and they typically stayed together for the duration of the project. Some domestic sector apprentices reported working alone for extended periods.

Apprentices in both sectors reported working with a large range of power tools including routers, planers, drop saws, grinders, nail guns, drills and jack hammers. They described doing many different types of tasks such as framing, roofing, decking, cutting timber and steel, grinding, constructing form work for concrete, pouring concrete and fixing internal features (e.g. coving/mouldings, skirtings/baseboards etc). Those in the commercial sector said they tended to do work that involved “a lot of steel and minimal timber” (FG#4). Working with metal was viewed as being particularly noisy:

> “Using power actuated tools, they’re very harsh on the ears, especially, like, [working on] schools and stuff. It’s mainly steel frames, so a lot of your work is getting nailed straight into the steel so you have to wear ear protection and stuff and even with that you still hear it” (commercial sector apprentice; FG#5).

Commercial sector work tended to be more repetitive, where an apprentice or qualified carpenter might work just on one single type of task throughout the whole build. One commercial sector apprentice said “all he ever did was form work” (FG#5), and another said he knew of “some guys who were solely doing skirting for three years” (FG#4). This differed from the domestic sector, where there was greater day-to-day variety in the tasks. Domestic apprentices said that they “did everything” except work they were not legally licensed to do (FG#7), for example, electrical work.

**Education and Training**

Instructors and apprentices were asked about the education and training provided by the college, particularly related to OHS and noise. Curriculum materials related to OHS provided by TAFE college staff were also reviewed. Instructors noted that it was difficult to get apprentices interested and engaged in OHS and this was a barrier to teaching:

> “I know that I’ve had a couple of groups, the last couple of weeks, and just trying to keep them interested in that two or three days when you run through the OHS, it’s pretty hard work.” (FG#1)

One way that instructors attempted to overcome this problem and attract the attention of apprentices was to personalise health and safety messages, for example, not relying on statistics but rather inviting an apprentice who had previously suffered a work injury to present OHS information. A number of apprentices mentioned that information presented in this manner resonated with them. Instructors reported that they discussed noise and hearing with apprentices because they themselves suffered from NIHL.

Both instructors and apprentices said that while a health and safety course was part of the pre-apprenticeship program, OHS information was integrated throughout the training in a “hands on” manner. This involved showing the apprentices how to correctly undertake a task, reminding them to wear safety equipment and talking to them about tool use. Most apprentices working in the domestic sector said that this was the only formal training they received.
The TAFE college safety curriculum reviewed at the time of the study was mainly focussed on acute hazards (e.g. falls risk associated with working at heights, structural collapse etc). Health consequences of long-term exposures to hazards such as crystalline silica and solar radiation were mentioned but were not the main focus of the curriculum.

Protecting oneself from hazards was often discussed in the apprentice training materials, with a specific reference to use of personal protective equipment (PPE). A review of the safety training materials revealed an underlying assumption that responsibility with regard to PPE seemed to lie mainly with employees. Statements found in the training materials such as “you should always wear PPE and clothing that has been given to you” and “you should check with your supervisor or other industry person or authority to make sure that you know what you need to have to be able to carry out your work” underscore this approach.

A brief section on noise was included in the training, under the broader topic of risk management. It included an overview of the types of noise exposures that are harmful, when to wear hearing protection, appropriate types of hearing protection and duration of exposure to reach the maximum acceptable daily dose. While the training directed apprentices to use hearing and eye protection with all power tools, this statement was only reiterated under some of the power tool summaries (reciprocating saw, explosives, power tools etc). There was limited information about the type of hearing protection to be used with each type of power tool. From the focus groups, it emerged that apprentices had very little knowledge about different types of hearing protection or noise exposure (for example, when it was acceptable to use ear plugs versus ear muffs and the different levels of protection offered by both). Little information was provided in the training materials about noise elimination, engineering or administrative controls.

The health consequences (e.g potential hearing loss) of not wearing hearing protection were also not addressed in the curriculum reviewed, nor was there any information about claiming workers’ compensation in the event of work-related hearing loss.

Many participants reported that apprentices who worked in the commercial sector received extensive on-site OHS training on safe tool use, injury reporting procedures and general worksite safety. Most commercial workplaces were unionised and apprentices reported that workplace safety representatives enforced compliance with safety regulations and site rules. Those who worked in the domestic sector said they rarely received any on-site safety training or general site induction. Further, the approach to compliance and safety rules was described as quite laissez-faire:

“[No training], that’s pretty much every site for me. There’s never been an induction or anything. We just go there, do what we got to do and go home.” (FG#2)

“On a domestic site some guy will look at you and go, ‘Do you feel safe doing that?’ And if you nod your head he’ll go, ‘Yeah, carry on’. Rather than, ‘No, you need a safety harness; put it on’ “(FG#3)

“...At the end of the day it’s all on you. If you don’t want to wear safety glasses, you don’t wear safety glasses. If you don’t want to wear earplugs, you don’t wear earplugs; it’s up to you at the end of the day. I’ve seen guys cut concrete with nothing on their face ...that’s just shooting out concrete everywhere.” (FG #4)

In a few instances, apprentices working on domestic sites said that older carpenters or their employer would show them how to do a task or give them eye or ear protection to wear. However, a vast majority of domestic sector apprentices noted that they received no formal safety education in the workplace and often their employer was not present on the job site to provide them with even informal guidance.

A number of apprentices, in both sectors, viewed OHS training with some scepticism, wondering if the training was there to protect the employer from litigation or the client from property damage rather than to protect the apprentice from injury.

Participant 5: ‘There are probably walks onsite and we’ve got to sign in where we work. And on that it says – it’s got a list of the daily activities - everything that’s happening and then it goes: safety equipment, hearing protection must be worn when using such and such – danger – so it’s all covered in there. And then everyone to actually start working onsite has to sign in. So, if something does happen to them, through, say hearing protection, or they haven’t been wearing glasses, we’re all covered completely...

Participant 3: It’s not you being covered; it’s their company being covered.

Participant 5: It’s the company saying “we’ve warned them”.
Hazards at work
During the focus groups participants were asked to discuss the types of hazards they encountered in the course of their jobs. The hazards most often mentioned were those that could lead to acute and potentially career-ending injuries such as a loss of a limb, spinal cord injury or blindness. Generally, focus group participants said they did not spend a great deal of time worrying about what could cause them harm at work. Many noted that hazards could be found everywhere and it was best to simply focus on the job at hand:

“You try not to think about that stuff. You just try and concentrate on what you got to do, otherwise you’d be worrying too much all day” (FG#5)

Participants were asked how hazards were avoided in the course of their job and what helped them stay safe at work. Apprentices tended to emphasize using “common sense”, doing only what felt safe and stopping a task when they felt physical pain. Their navigation of the workplace and safety behaviour seemed to be based on learning from mistakes and changing behaviour based on previous negative events (e.g. an accident or near miss). Apprentices also said they sometimes considered possible outcomes when doing a task. The perceived seriousness of a hazard, judged by the severity of a possible outcome, seemed to dictate behaviour to a certain extent. For example, one participant described cutting metal without eye protection; a shard of steel became lodged in his eye resulting in attendance at hospital and time off while he recovered. This incident changed both his and his employer’s behaviour. The worker said that after the accident he was fastidious about using eye protection, knowing that cutting without eye protection could lead to serious injury and possibly end his career as a carpenter. After the accident his employer also became insistent that he use safety equipment while cutting wood or steel. The participant felt that one reason for this was that the employer’s insurance premium increased after the accident.

Noise at work
As with some of the other hazards on the job, noise was viewed as being ubiquitous, constant and a normal part of work. Apprentices identified many sources of noise, with power tools, machinery and trucks being the most common. Many noted that high noise levels were associated with working in enclosed spaces and working alongside others:

“All the machinery, the power tools, all the trucks that come past: the concrete trucks, the delivery trucks. Yeah, all around you is noise 24/7” (FG4).

“You have up to 100 people on the floor and you’ve got the plant moving around, all the bells and whistles going from that. You’ve got Ramset guns, the plasterers cutting…the drop cut offs, which is unbearable. And you’re cutting aluminium, then you’ve got a concrete pump running next to it.” (FG8)

The majority of focus group participants reported experiencing temporary ringing in the ears, with a smaller number reporting persistent ringing and headaches they attributed to noise:

“Occasionally I have ringing of the ears. It tends to go normally on the weekend when you haven’t heard it [noise] in a couple of days” (FG#5).

“I had ringing noises. If it’s like dead quiet, I just hear ringing, no good with that - turn the telly up louder! ([Laughs])” (FG#3).

“I think your first year, or first couple of weeks you get home and your ears might be ringing a bit just because you’re not used to it. I don’t think about it anymore though” (FG#8).

Despite the ubiquity of noise and the ringing in the ears that was reported, noise at work was viewed with a degree of complacency:

“You kind of get used to it, you stop noticing it. It just gets normal.” (FG#5)

“Mine have rung for days, but I had the mentality that it’s what I signed up for. So I just cop it.” (FG#6)

“There’s no way around it. The job requires you to make lots of noise. like, there’s no part of the job that doesn’t make noise. There’s nothing [that can be done]. I can’t think of one thing” (FG#8).

Noise reduction at work
Focus group participants were asked to consider how their work might be made less noisy but, as indicated above, there was a general feeling that little could be done. Participants identified a number of barriers to reducing noise. First, noise was viewed as largely out of their control. So while some said they would alert other workers before starting a noisy task or try to move themselves away from other workers, often other noise-reduction solutions, such as moving machinery or isolating groups of workers were seen as being up to the employer. Apprentices felt that noise reduction was not always a priority for employers and some believed that employers were unaware of noise levels on the worksite because:

“They’re literally running from site-to-site…they might not get a sense of how much noise there is” (FG#2).
Second, noise reduction strategies such as purchasing newer and better quality (quieter) tools, reconfiguring the worksite to make it quieter or using quieter materials often resulted in higher costs. Apprentices felt that employers working in a competitive market were not eager to bear these costs. Third, some participants believed that the distal consequences of hearing loss were a disincentive to noise reduction at work. One participant from the instructor focus group noted the following:

“With hearing, employers almost have the opinion of ‘oh he’ll be gone out of the work, I don’t have to worry about him, we’re not going to pay any fines for him”’ (FG1)

According to some participants, even employers who were concerned about health and safety tended to focus on acute and significant risks that could have immediate consequences on their insurance premiums.

Finally, many apprentices did not think that the type of work they did was easily amenable to changes that would help reduce noise. Many tasks, such as digging or fixing mouldings had to be done in a specified spot and could not be relocated to avoid noise exposure. Similarly, moving workers was not viewed as a feasible means to manage noise exposure given the production and time pressures of construction work.

**Hearing protection**

Typically when the issue of noise and its impact on hearing was discussed, apprentices focused almost entirely on hearing protection (as opposed to noise reduction). Most apprentices reported using hearing protection at least in some instances at work. However, use was not consistent and the type of protection was varied. The type of hearing protection apprentices used depended on a number of factors. Not surprisingly, convenience was often mentioned. Apprentices were more likely to use hearing protection that was nearby and easily accessible.

“Having those banded earplugs with you, it takes no time to put them in, take them out….if it was a matter of having to go and look for your earmuffs every time there was noise then there would be times when you wouldn’t bother.” (FG#6)

Apprentices discussed getting into the habit of wearing hearing protection — bringing it to work, taking it out of their car and having it on their body ready for use. These sorts of practices reinforced and normalized hearing protection use, at least in certain circumstances. Most apprentices noted that they wore hearing protection only when working with tools or doing jobs that produced intense noise, for example jack hammering, working near an air compressor or cutting steel.

Workplace factors also had an impact on the use of hearing protection. In workplaces where there was direct enforcement of hearing protection use — for example, a safety representative or an employer who insisted workers wear hearing protection — apprentices reported using hearing protection consistently. Seeing that co-workers wore hearing protection also seemed to have an impact on some apprentices, as one participant described below:

“I started seeing the other boys wearing them, over stupid little things, and then I thought ‘I might as well put the show up’, and your day goes so much smoother because it’s quieter and it seems more laidback...so less stress.”(FG#7)

Hearing personal stories of hearing loss and tinnitus also had an effect on apprentices. A number of the apprentices described witnessing firsthand how hearing loss affected their teachers and, in some instances, employers. Those apprentices who described learning about the psychological effects of tinnitus from older carpenters often said that this glimpse into the potential effects of hearing loss made them more likely to wear hearing protection consistently:

“Some of them can’t hear properly. I think ‘I don’t want to be like them’ All the teachers say...’Wear your earmuffs because you get tinnitus’ It’s always in the back of your mind. So that influences your decision to put them on. You don’t want to become like them.” (FG#7)

A similar perspective was offered by an instructor:

“The thing that triggers me to wear ear protection was I met a guy and he said, ‘I’ve got tinnitus.’ He aged about 10 years in 6 months…it really affected him psychologically and I thought, crikey, I better put them on.” (FG#1)

**Barriers to hearing protection use**

The focus group discussions revealed a number of barriers to using hearing protection. One raised consistently by apprentices was the view that wearing hearing protection decreased their ability to communicate on the worksite. Communication was vital to their safety and the safety of others. Further, as new workers, apprentices had to be able to hear instructions from their employer — this was both a safety and job performance issue:

“You sort of just need to be alert all the time because even if there’s no dangers around, you might have a delivery coming or something and your boss will shout at you to come and unpack it...so if you don’t hear him he won’t be too happy with you.” (FG#9)
“If you don’t have earmuffs or glasses and your boss wants something cut or something done really fast, you don’t want to go out of your way to your car and go get it.” (FG#6)

Many apprentices noted that if they were doing a quick but noisy job, they typically would not bother with hearing protection. For some, the perceived risk of hearing loss was not sufficiently great to outweigh the inconvenience associated with wearing protective equipment. The effects of NIHL seemed distant and intangible to some and the effort of wearing hearing protection “not worth it” (FG#3).

“It’s not happening to you now...it’s 6:30 in the morning, like, I can’t be bothered [to bring ear muffs]...that’s pretty much it.” (FG#8)

Peer influence also led to some apprentices not using hearing protection. When no one used hearing protection, it was sometimes difficult for new workers to go out on their own and wear it. Several participants argued that the wearing of protective equipment is seen to signify “weakness”:

Participant 3: “There’s a bit of a cultural thing, that it’s sort of gung-ho, that you don’t get too worked up about being really fastidious about your hearing, and if you haven’t got your earmuffs, don’t worry...”

Participant 2: “I still think it’s un-cool on a building site...it’s seen as a weakness.” (FG#1)

Finally, having ready access to hearing protection seemed to influence its use. With a few exceptions, domestic sector apprentices noted that deciding on types of hearing protection and purchasing it was up to them. Their employer did not provide PPE as part of the job. As such, it was up to the individual worker to decide what sort of protection was needed and purchase it. Apprentices noted that this period of their career (the apprenticeship) was one where they built up their tool kit and decisions about their PPE purchases had to be considered alongside other expenses. Since many apprentices did not have an in-depth knowledge of the sort of hearing protection they needed, cost often seemed to drive their purchasing decisions and they would buy “whatever’s cheap” (FG#9).

Instructors also noted that if hearing protection was not supplied by the employer it would be unlikely that an apprentice would buy it due to the cost:

“They’re expensive. You might have one out of 100 [apprentices] that would buy them. Because of the cost factor...” (FG#1)

Hearing and hearing loss
The focus groups concluded with a discussion about apprentices’ hearing. As discussed earlier, most apprentices did not worry a great deal about hearing loss, except perhaps when they experienced prolonged ringing in the ears or encountered another carpenter who had severe hearing loss or tinnitus. However, there was a lot of interest in getting audiometric tests. Most apprentices did not know whether they had suffered hearing loss already, although a number reported having to increase the volume on the television and having persistent ringing in the ears. Workers were keen to find out if their hearing was in fact being damaged and how it compared to the general population. Almost all apprentices responded positively when asked whether they would undergo a audiometric test if it were provided as part of the training program.

Participant 5: “If you ladies came today and said ’We’re offering a free hearing test’ I would go. No worries.”
Participant 3: “I would have gone.”
Participant 6. “You’d have a line I reckon. A line of chippies [carpenters] coming outside.” (FG#2)

A number of participants noted that if an audiometric test demonstrated that their hearing was diminished, this would have an impact on their work practices and use of PPE:

“If I knew I was going deaf I would definitely wear them – every day. But not seeing any effects or anything, or feeling it, then it doesn’t really come first thing to your mind.” (FG#8)

“If you knew you were going deaf, like losing your hearing, you’d probably start to think about it a lot more. You’d start putting on either earmuffs or plugs, or something like that.” (FG#9)

Discussion
Through focus groups, we examined the views and experiences of carpentry apprentices who were enrolled in a training program and also working in the construction sector. Our purpose was to understand how they viewed the hazards of their jobs, focussing specifically on the issue of noise.

The risk of noise
While noise was reported as being ubiquitous at work, many apprentices were more concerned about avoiding hazards that could lead to dramatic and career-ending injuries. Their general approach to risk management, including learning from past experience and near misses, weighing the potential seriousness of an outcome and using “common sense”, did not serve to protect them from noise in many instances. The outcome of noise
exposure, for example, seemed distant to many participants and its seriousness questionable. A few apprentices joked “Who will I want to hear when I’m 60?!” Further, “common sense” was not easily applied to preventing noise exposure. Apprentices themselves recognised that their assessment of noise levels was imperfect and many reported getting “used to noise” over time. It is important that apprentices learn about the consequences, both psychological and physical, of noise exposure and hearing loss. The training college, peers and older apprentices can be mobilised to teach apprentices about noise and hearing and provide concrete examples of how hearing loss affects quality of life. Audiometric tests can also be used to provide apprentices with benchmarks about changes in their hearing and to raise awareness about hearing loss.

Focus is on PPE, not noise reduction
Very few apprentices had any knowledge about how noise could be reduced in the workplace and many felt that little could be done to make their work quieter. This may be due to their perception that, as workers, they have little control over high level controls, such as engineering or administrative measures. Further, it was reported that some employers did not view noise as a problem on the worksite, eschewing hearing protection even for themselves. Finally, given that workers reported the absence of even basic measures such as scaffolding when they were working at heights on some worksites, the view that their employer would not invest in quieter machinery or engineering processes, is understandable. The notion that PPE is the key way of preventing NIHL was also re-iterated implicitly in apprentice training at the college. As we noted above, many of the materials on the OHS curriculum we reviewed focussed on the use of PPE to protect oneself against injury or illness. Health and safety regulators should emphasise the hierarchy of controls when it comes to noise reduction and hearing protection, particularly when interacting with employers. Similarly, education programs should provide examples of what can be done to reduce noise in the workplace. Of note is the expressed interest of some participants in eventually starting their own businesses and the importance of the education of these individuals as potential employers.

Little understanding or training in choosing hearing protection
Since PPE was viewed by participants as one of the only ways to prevent hearing loss, it is particularly troubling that apprentices knew very little about classes of hearing protection, how to chose hearing protection appropriate to specific tasks and how to fit hearing protection correctly. On domestic sites in particular, there seemed to be little formal oversight in terms of safety practices and little formal induction/training. As such, it is unlikely that workers were given instructions about how to use hearing protection correctly. Further, it was reported that many domestic-sector businesses did not provide PPE at all. Therefore, if workers chose to purchase PPE, they would be the ones who chose the quality and class of protection. It is important that training institutions and Health and Safety authorities provide clear guidance to these new workers so that cost and comfort are not the only drivers of purchasing decisions.

Differences in domestic and commercial sectors
Our study highlighted major differences in the experiences of apprentices in the domestic and commercial sectors. Apprentices described how conditions of work, training practices and access to safety equipment differed in the two sectors. Those working in the commercial sector reported being exposed to more noise due to working with a large number of other tradespeople and in enclosed spaces. They tended to work doing the same task and with co-workers who changed frequently depending on the phase of the project. Formal training and safety protocols were in place and often enforced by a safety representative. In the domestic sector, work was more flexible with apprentices doing many different tasks and working with the same team of co-workers. These apprentices tended to learn “on the job” from more experienced carpenters but formal training was rarely provided in the workplace.

While the apprentices in our study working in the domestic and commercial sectors were all doing “carpentry work”, their specific tasks, the social relations of their work and the physical conditions of their job sites varied widely. It is important that hearing protection programs and policies be tailored to the realities of carpentry work in these different sectors.

OHS training at the college
For the domestic apprentices in this study, the education and mentorship they received in school was often the last time they were given formal OHS training. Even commercial sector apprentices, many of whom received formal inductions at their job sites, reported having little knowledge about classes of hearing protection and NIHL. Significantly, apprentices in both groups were sceptical that training in the workplace was there to protect their health, viewing it rather as a mechanism for decreasing employer liability (i.e. protecting employers from costly
fines or insurance premium increases). The college, on the other hand was not viewed as being affiliated with the employer or as having other interests beyond training apprentices. Attendance at training being required for certification means that the college is well-positioned to deliver OHS training that will be viewed by apprentices as being done for the benefit of their well-being and not other motives. It is important for this training to be applicable to the types of worksites and conditions apprentices work in. As identified, the use of apprentices and other carpenters as conveyors of OHS information can make the training more engaging, relevant and memorable.

**Little information about making a complaint or filing a claim**
Given that noise exposure is a common hazard in the construction industry and a number of studies have confirmed a high prevalence of NIHL among construction workers, it is concerning that apprentices had little information about what to do if they experienced NIHL. For example, we found little evidence that apprentices had clear information about how to file a workers’ compensation claim. While one training presentation reviewed had an example of an incident report form, there was no information about how a worker with a gradual-onset work-related illness (such as hearing loss) should proceed. Workers also did not seem to have information about steps they could take if their employer was engaging in practices that contravened the Health and Safety Act. In Victoria, Australia, employers are required to make sure “workers have adequate information, instruction, training and supervision to work in a safe and healthy manner” and “adequately monitor workers’ health (such as providing hearing tests for workers exposed to high noise levels)” (Occupational Health and Safety Act 2004). While apprentices reported a lack of training (in the domestic sector) and health surveillance, it did not appear that they understood that this was a duty of their employer (and their right as a worker). It is important that new and young workers in particular receive comprehensive information about their OHS rights and responsibilities and that of their employers. Workers should also know what to do in the event of a work-related injury or illness.

**Audiometric tests**
Possibly due to the ubiquity of noise, apprentices were very interested in getting an audiometric test, especially if it was free and done as part of their apprenticeship program. A number of studies with construction workers have indicated that measurable levels of hearing loss can occur after just a few years of exposure. Audiometric tests at the beginning and toward the end of the apprenticeship program could provide apprentices with some indication of hearing threshold level increases. Even a one-time test could provide apprentices with an indication how their hearing compares to the general population. Importantly, providing tests at the college would be an opportunity to provide apprentices with information about hearing loss and hearing conservation.

**Strengths and limitations**
This was a small study involving one group of instructors and apprentices at a single college in the state of Victoria (Australia). It is possible that different colleges customize their courses to include different information about noise reduction and hearing loss prevention. A qualitative approach was well-suited for this study since our aim was to understand participants’ experiences, beliefs and practices. Through this approach, the researchers were able to probe the motivations, intentions and logic of participants in a way that would not have been possible through closed-ended survey questions. However, there are certain questions that qualitative studies cannot answer. For example, we cannot speak to rates of PPE use or incidence of NIHL. It is also important to note that we tried to engage female carpenters in our focus groups but were unsuccessful. Gender plays a role in shaping the types of jobs workers do (even within a single trade), as well as, disease prevention activities (Messing et al., 1995). It is important that future studies on NIHL include women.

**Conclusion**
Our study provides insight into the work done by carpentry apprentices and how they view risk in their jobs. The ubiquity of noise and a focus on hazards that can cause career ending injuries means that noise is not always taken seriously by these workers. The findings in this study suggest that construction apprentices require more opportunities to learn about hazards, such as noise, that may have long-term, non-immediate health consequences. The importance of hearing conservation should be reinforced through several avenues such as during apprentice training, at work, via regulation and through health promotion messages. A focus on the correct use of hearing protection must be accompanied by information about strategies to decrease noise in the workplace.

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Reference List


