# Defining Critical Safety Behaviors in a Point-of-view Video Observation Study of Tree Fallers at Work

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This study aimed to characterize the use of five critical safety behaviors by tree fallers at different skill levels, and to test the feasibility of using a helmet camera to observe work activities directly in a remote environment. Small cameras were mounted on standard hardhats. Video data were obtained for pairs of fallers at four different skill levels, from beginning students to professional fallers. Critical action steps during tree episodes were coded and compared. Critical action steps for fallers were successfully distinguished during work activities. Notable differences were observed among fallers in different skill categories and between individual fallers. This study found that the helmet camera worked well for observing faller work behavior, and that point-of-view video observation may be used to evaluate student loggers and training programs. We also found that professional fallers may have been exposed to increased hazard; care should be observed with helmet cameras designed for professionals. *Key words*: logging safety; fallers, video observation

**INT J OCCUP ENVIRON HEALTH 2011;17:301–306**

## INTRODUCTION

Working as a tree faller is one of the most hazardous occupations in the state of Oregon. The Oregon Fatality Assessment and Control Evaluation program (OR-FACE) recorded 17 fatal incidents for fallers in the six years between 2003–2008, and estimated the fatality rate for fallers in logging at 258 per 100,000 workers per year,[1] followed closely by log-truck drivers at 239 per 100,000—both far higher than the fatality rate for other logging occupations, and over 60 times higher than the average fatality rate of about 4 per 100,000 per year for all Oregon workers.[2] Traumatic injuries in logging are a well-recognized area of concern and focus for occupational safety research in the US Pacific Northwest[3] (including the states of Oregon and Washington) as well as the province of British Columbia, Canada, all of which have similar forests, terrain, and logging practices. Oregon Workers' Compensation data confirm that working as a faller is the most hazardous job in logging.[4]

OR-FACE introduced a five-step faller safety plan with a set of critical action steps in a safety booklet, *Fallers Logging Safety*.[1] The five-step plan was developed through many years of experience, observation, and discussion with fallers, but once set down, became a deductive model, or hypothesis, raising the question of how well it really existed in the working behavior of Oregon fallers.

The fallers' point-of-view video observation study was developed as a pilot project to test the feasibility of using new video technology to observe tree fallers at work in a remote environment and evaluate safe work behaviors; and in particular, to observe the applicability of the five-step faller safety plan set down in the fallers training booklet. As a pilot study, the main concern was to demonstrate the feasibility of using video observation as a research tool acceptable to fallers and capable of producing usefnl data.

Currently, evaluation of logging safety training programs has relied on outcomes represented by self-report satisfaction and knowledge surveys,[5] and analysis of aggregated workers' compensation injury data.[6] Direct observation of actual work practices is the most reliable method to evaluate safe behavior, but observing fallers at work poses unusual challenges and unacceptable risks. An observer may be exposed to danger traveling to a remote, unfamiliar location on unpaved mountain roads, and by the hazards involved in the logging operation. Direct observation can also modify performance. Fallers work alone or in pairs and would have a heightened concern for the presence and safety of an observer. Point-of-view video observation provides a way to gain access unobtrusively to the remote work situation in the woods.

Video observation studies are common in education research, and have been adopted in occupational settings in clinical studies of medical care,[7,8] and ergonomic assessments.[9,10] The most sophisticated use of video observation for scientific evaluation of safety behavior, to our knowledge, is the 100-Car Naturalistic Driving Study by the Virginia Tech Transportation Institute,[11] which produced the first reliable risk ratios for various distractions while driving. The study con-

*Received from*. Center for Research on Occupational and Environmental Toxicology, Oregon Health and Science University, Portland, OR (TH, GR), College of Forestry, Oregon State University, Corvallis, OR (JW). Funding for this study was provided by the Pacific Northwest Agricultural Safety and Health Center at the University of Washington (grant #: 5 U50 OH007544). Send correspondence to: Terry R. Hammond MPH, 7624 SE Hawthorne Blvd., Portland, OR 97215, USA; email: <terryh@pdx.edu>.

*Disclosures*: The authors declare no conflicts of interest.

firmed the observer effect as a matter of course, stating at the outset: "Furthermore, as demonstrated repeatedly in the 100-Car Study, the absence of an experimenter avoids potential modification of the driver's performance and behavior that may occur when a driver is directly observed" (p.xvii).

All of these other video studies used mounted cameras in a fixed location. A "digital hardhat" has been developed in the last few years for use in construction, engineering, and security work to allow interactive video contact with a remote office, but this system requires a reliable signal to a computer, which is usually not possible at a remote logging site. Lightweight "lipstick" cameras attached to a handlebar or helmet are common, and digital storage capacity has recently expanded dramatically. New developments are proceeding rapidly.

## METHODS

This pilot study using video equipment to observe workers in a remote, highly mobile, and hazardous work environment was guided by a set of interrelated research questions.

1. Can the five critical action steps in safe falling be observed and distinguished in faller work behavior? The five steps are:
   a. Assess the area.
   b. Assess the tree.
   c. Develop a safe work area.
   d. Fall the tree.
   e. Get in the clear.
2. Do fallers conscientiously follow the five critical action steps in safe falling?
3. Do fallers at different skill levels apply the five action steps differently?

A separate question in the study related to awareness of the environment, and coded the faller's direction of view during each episode falling a tree. That analysis is a separate issue and not reported here.

Four skill categories were selected for theoretical interest and potential differences: (a) beginning student loggers with previous training but little or no experience in the field; (b) the same beginning students with six months' experience; (c) advanced student loggers with one to three years of experience; and (d) professional fallers with 10 to 20 years of experience. All students were trained to observe the five critical action steps as a guide in the process of felling a tree. Professional fallers were expected to know the five steps from their own training and experience.

The camera unit for the study needed to meet the following requirements: ability to endure rugged, all-weather conditions; ability to record up to eight hours of continuous video and audio; and the ability to attach to a compact recorder/battery unit. In addition, the equipment had to be reliable and easy to service. Only the Viosport POV.1 camera unit met all of these criteria at the time. The POV.1 unit holds four AA batteries for up to 10 hours of recording. The recording device was adjusted to lower quality to achieve eight hours of recording on a 2 GB storage disk; the resulting video was completely adequate, and reduced file size for easier handling.

Two standard hardhats were purchased, along with hardware to bolt the camera mounts securely to the hardhats. Belt packs small enough to be worn unobtrusively were found to hold the recorder/battery unit. The five-foot cable connecting the camera to the recorder ran through a Velcro patch glued to the back rim of the helmet, then down the back of the neck under the jacket collar, leaving only a few inches of exposed cable.

The camera mounted on the helmet performed very well, without jostling or turning at a skewed angle, but was located about six inches above eye level and did not always record precisely what the faller was viewing. Direction of view was clear. Audio capacity provided valuable input for occasionally interpreting activity.

For video analysis, Transana qualitative analysis software was used (University of Wisconsin-Madison Center for Education Research: www.transana.org). Transana software performed very well for all functions, and exported data in a convenient format.

The study was approved by the Institutional Review Board of Oregon Health & Science University, Portland, OR, USA. All participants and other crew members observed in the video recordings signed a written consent form.

Two fallers participated in each of four skill categories: beginning students, the same students at six months, advanced students, and professionals. Four students were selected from volunteers in the Student Logging Training Program at Oregon State University, with the consent of the OSU Forest Engineering Department. The logging safety consultant for the study was the manager of the OSU student training program, which trains new loggers on its own forestland. The two professional fallers were recruited through personal acquaintance with a small contract cutter.

Data collection occurred in natural work conditions during one four-hour work day. No efforts were made to standardize the type of forest, trees, or equipment of the fallers. Video data files for each observation session were usually 3–4 hours. All student fallers wore the camera from entry to exit from the woods, often in segments with brief intervals when the camera was turned off. One professional faller wore the camera for four hours, and then switched to his regular hardhat for the remaining half of the day; the second professional faller switched off the camera after 1 hour 15 minutes. Both professional fallers were distracted by some combination of the weight of the camera, the cord, the

**TABLE 1 Percentage of Tree Events With Specific Safety Actions**

| Faller Skill Categories | | Number of Trees | 1. Assess Area (as first act) | 2. Assess Tree (as first act) | 3. Safe Work Area (as first act) | 4. Fall Tree (as first act) | 5. Get in Clear |
|---|---|---|---|---|---|---|---|
| 1. Beginning students | Faller 1 | 2 | 50% (50%) | 100% (50%) | 100% | 100% | 100% |
| | Faller 2 | 10 | 80% (80%) | 100% (10%) | 80% (10%) | 100% | 100% |
| 2. 6-month students | Faller 1 | 7 | 100% (100%) | 100% | 86% | 100% | 100% |
| | Faller 2 | 9 | 89% (78%) | 89% | 67% (22%) | 100% | 89% |
| 3. Advanced students | Faller 1 | 11 | 100% (91%) | 100% | 91% (9%) | 100% | 100% |
| | Faller 2 | 10 | 70% (60%) | 100% (40%) | 50% | 100% | 90% |
| 4. Professionals | Faller 1 | 22 | 55% (45%) | 91% (14%) | 96% (41%) | 100% | 100% |
| | Faller 2 | 125 | 29% (21%) | 70% (26%) | 67% (44%) | 100% (9%) | 85% |

unfamiliar hardhat, and perhaps consciousness of being observed, and ended the session early.

In the collected video data, each felled tree was an event. The five action steps were identified as they occurred for each tree, by the following definitions.

1. *Assess the area.* Identify hazards in the work area, including snags, danger trees, hanging limbs, uneven ground, power lines, or roads. *Operational definition:* View up and around the area.
2. *Assess the tree.* Look up at the tree to determine the lean, canopy weight, and other forces that will influence the falling direction; find an opening; assess wind, terrain, and potential impacts. *Operational definition:* View directly at tree, up at tree, and ahead in the direction of fall; may involve discussion with others.
3. *Establish a safe work area.* Clear the area around the tree and plan at least one escape route back and to the side of the falling direction. *Operational definition:* View ground area behind and around tree, or use saw to clear brush, branches, and stumps in the area.
4. *Fall the tree.* Make a clean face cut, make a back cut that protects the hinge; and keep the wedges within reach. *Operational definition:* Begin when the saw is applied to the tree, and end at the move away from tree.
5. *Get in clear.* Get away from the stump as soon as the tree is committed to fall; keep an eye on the tree and watch for impacts. *Operational definition:* Begin at the move away from the tree during the fall, end when the tree hits ground (or in some instances, when the view up at the tree indicates that the tree is hung up and not falling).

## DATA

All data in the study corresponded to tree events. Each tree was associated with a particular faller in one of the skill categories and numbered. All coded action steps contained time information for start, end, and duration. Coding accuracy for the action steps was established through expert review by a logging safety consultant, and a final review by the original coder. The contributions of an expert consultant in the study was important to interpret and code the action steps reliably. The completed data files were exported to Excel and SPSS for final statistical analysis and reporting. From the base data, variables were constructed to characterize behavior per tree, including total time, proportion of total time per action, count of each action, and first actions.

Descriptive statistics were obtained for each faller and skill category, including mean time and standard deviation in the performance of each action. A statistical test to distinguish significant differences between the fallers in different skill categories was not possible, due to the small number of participants. Distinctions between individual fallers were recognized by computing a 95% confidence interval (CI) for performance times, indicating differences not likely to be due to chance.

## RESULTS

The total number of observed trees felled was 196, ranging from 2 to 125 per faller. The average number of trees was 24 per faller, with a median of 10. The faller with 125 trees was an outlier (this professional faller kept the camera running for four hours, while the other professional faller switched off early). An example of the video collected can be viewed at http://www.ijoeh.com/fallervideo/.

Observing the presence of the five action steps in faller safety—assess the area, assess the tree, develop a safe work area, fall the tree, and get in the clear—showed general, but not complete, correspondence in the behavior of fallers. Even critical actions that could be expected to occur without exception, such as "assess tree" and "get in clear" were not performed for every tree (see Table I). Consistent use of the five steps was observed for both beginning students, one advanced student, and one professional faller.

Variations occurred partly due to differences in the environment. The beginning student fallers worked in

**TABLE 2 Proportion of Tree Events With Safety Actions Present (exclude Fall Tree)**

| Faller Skill Categories | | Number of Trees | 4 of 4 Acts | 3 of 4 Acts | 2 of 4 Acts | 1 of 4 Acts | 0 Acts |
|---|---|---|---|---|---|---|---|
| 1. Beginning students | Faller 1 | 2 | 50% | 50% | — | — | — |
| | Faller 2 | 10 | 60% | 40% | — | — | — |
| 2. 6-month students | Faller 1 | 7 | 86% | 14% | — | — | — |
| | Faller 2 | 9 | 44% | 44% | 11% | — | — |
| 3. Advanced students | Faller 1 | 11 | 91% | 9% | — | — | — |
| | Faller 2 | 10 | 40% | 30% | 30% | — | — |
| 4. Professionals | Faller 1 | 22 | 50% | 41% | 9% | — | — |
| | Faller 2 | 125 | 14% | 38% | 34% | 14% | 1% |

a group, and others helped develop a safe work area. For all student fallers, cutting occurred as a thinning operation in the midst of standing timber; the forest floor was often open and clear. The professional fallers worked alone on different sides of a hill, falling trees downhill on the edge of a clearcut, only occasionally surrounded by a worrisome canopy.

Despite situational differences, the low use of safety actions by the second professional faller is notable (see Table 2). Observing the two professional fallers produced an impression of different work styles, and coding for critical actions detected quantifiable differences.

Common sequences were observed in the way fallers applied the action steps, though the stated order in the model was not always the order followed in practice (see "first acts" in Table 1). Assessing the area was commonly the first act as expected, but developing a safe work area was also a common beginning. Occasionally, a faller went directly to assess the tree. Only the second professional faller chose to fall a number of trees directly without any preparatory actions.

Performance times for each action step reveal notable differences between the faller skill categories (see Table 3). Most clearly, the time falling the tree was much faster for the professional fallers. Beginning students spent an average of 6–7 minutes falling a tree, professional fallers averaged 48.6 seconds. The beginning students at six months drew much closer to the advanced students in time at the tree, and the previous difference between them was no longer detectable.

An apparent difference between the two professional fallers occurred in the action to get in the clear. The mean 2.7 second difference is small, but the standard practice of the first, older and more experienced professional faller with a mean value of 6.9 seconds (95%CI, 6.1 to 7.6), was clearly different from the second, younger professional faller with a mean value of 4.2 seconds (95%CI, 3.8 to 4.6). The second professional faller was observed over a longer period and cut a total of 125 trees, compared to 22 for the first professional faller; but the difference in time to get in the clear was not due to a gradual degradation of behavior. The distinct difference remains when the comparison is restricted to the first 22 trees for the second faller, showing a nearly identical mean value of 4.4 seconds (95%CI, 3.5 to 5.3). The brief but definite difference in time to get in the clear suggests the second faller was exposed to increased risk by remaining too long near the stump of a falling tree, where most serious injuries to fallers occur.

In the count of action steps per tree event (data not shown), some differences occurred by collapsing tasks. The professional fallers on arrival worked to develop a safe work area around several trees. Assessing the area (viewing up and around) tended to occur with dedication upon approaching a new area, and was repeated only after a few trees were felled. The professional fallers worked rapidly, and assessing the following tree sometimes occurred in the moment of getting in the clear of the previous tree. Student fallers were more uncertain and needed repeated efforts and discussion to assess a tree. Lower counts for professional fallers to assess the tree correspond to findings in previous studies of expert attention.[12] Their degree of confidence was directly observable. Professional fallers approached a tree like a golfer, erect and sure: view up, then ahead, up the tree again, and set the saw.

In the count of the action falling the tree, student fallers were more likely to interrupt the falling process to reconsider, get instruction, or retrieve a wedge or ax from a distance away. The professional fallers almost never interrupted the action. A safety rule in logging requires that wedges and the ax to hammer them be kept within reach to avoid leaving the tree once a cut is made. The action count indicated the professional fallers were careful to follow this rule.

## DISCUSSION

Conducting point-of-view video observation of fallers at work in a remote location proved technically feasible. The five critical action steps for fallers were identified and quantified by time and count. Analysis showed notable differences in behavior among fallers at different skills levels, and between individual fallers. The data also characterized patterns of how fallers applied the five action steps. Beginning students were different than all

**TABLE 3 Performance Time for Specific Action Steps per Tree Event**

| | Mean Time in Seconds (Standard Deviation) | | | | | |
|---|---|---|---|---|---|---|
| **Faller Skill Categories** | **All Actions** | **Assess Area** | **Assess Tree** | **Safe Work Area** | **Fall Tree** | **Get in Clear** |
| 1. Beginning students | 742<br>(281.8) | 58.4<br>(60.3) | 157.4<br>(119.7) | 109.2<br>(86.2) | 407.8<br>(168.5) | 9.2<br>(5.7) |
| Faller 1, $n = 2$ | 780.7<br>(215.4) | 15.8<br>(22.3) | 299.6<br>(225.1) | 59.5<br>(69) | 396.8<br>(39.3) | 9<br>(2.3) |
| Faller 2, $n = 10$ | 734.3<br>(302.5) | 66.9<br>(62.5) | 129<br>(80.5) | 119.2<br>(88.9) | 410<br>(185.7) | 9.2<br>(6.2) |
| 2. 6-month students | 320.3<br>(218.3) | 33.7<br>(32.5) | 46.4<br>(54.2) | 32.1<br>(44.6) | 200.5<br>(163.6) | 7.5<br>(3.9) |
| Faller 1, $n = 7$ | 395.6<br>(265.3) | 41<br>(32.1) | 73.6<br>(70.9) | 20.5<br>(14.4) | 252.3<br>(212.9) | 8.2<br>(3) |
| Faller 2, $n = 9$ | 261.7<br>(166.6) | 28.1<br>(33.7) | 25.3<br>(24.1) | 41.1<br>(57.9) | 160.3<br>(109.7) | 6.9<br>(4.5) |
| 3. Advanced students | 246.1<br>(121.3) | 51.9<br>(47.3) | 35.3<br>(25.8) | 55.9<br>(70.6) | 96.6<br>(58.7) | 5.8<br>(4) |
| Faller 1, $n = 11$ | 272.4<br>(141.3) | 69.4<br>(46.5) | 22.7<br>(15.9) | 60.3<br>(80.5) | 112.7<br>(62.1) | 7.3<br>(3.3) |
| Faller 2, $n = 10$ | 217.1<br>(93.5) | 32.5<br>(42.1) | 49<br>(28.2) | 51.1<br>(61.9) | 78.8<br>(52.1) | 5.6<br>(4.7) |
| 4. Professionals | 89.3<br>(50.6) | 7.3<br>(24.3) | 5.9<br>(7.6) | 22.9<br>(32.9) | 48.6<br>(16.6) | 4.6<br>(2.5) |
| Faller 1, $n = 22$ | 124.7<br>(61.1) | 13.5<br>(27.6) | 9<br>(8.5) | 42.4<br>(40.9) | 53<br>(16.3) | 6.9<br>(1.7) |
| Faller 2, $n = 125$ | 83.1<br>(46) | 6.3<br>(23.7) | 5.4<br>(7.3) | 19.4<br>(30.2) | 47.8<br>(16.5) | 4.2<br>(2.3) |

other skill categories, working very slowly under close supervision, with frequent interruptions for advice.

In addition, direct observation of the video files showed differences in style that were particularly interesting in regard to the professional fallers—offering a rare look at how they work. The study demonstrated the remarkably rapid pace of work for professional fallers.

One issue made clear from viewing different sets of fallers is the need to standardize the logging environment to achieve comparable results. Work patterns are susceptible to variation due to type of logging, terrain, and trees. Heightened hazards in a thinning operation with surrounding trees and canopy were evident, and affected faller behavior.

Data on times and counts for faller action steps suggested ways to quantify observed behaviors. One example of a meaningful quantitative difference was related to the time interval for getting in the clear as the tree falls. Action to get in the clear from a falling tree should be the same in any instance, regardless of environment, but a few exceptions occur. Cutting a hanging tree, caught in a canopy, requires closer attention at the stump. In some instances, professional fallers may stay longer at the stump to guide a falling tree into a precise position, possibly for safety, but also for harvest efficiency and as a matter of pride.

In other cases, using quantities to characterize observed activities does not necessarily indicate an ideal value, because the measures are not directly related to increased risk of injury. How often the faller should look up and around in different circumstances needs to be interpreted by loggers and trainers according to issues they understand as important.

Detecting differences between groups was restricted by the small number of fallers in the skill categories, and the small number of trees for some of the fallers. A power analysis was performed to determine how many observations of tree events would be needed to detect the distinct difference in mean time to get in the clear that was observed between the professional fallers, but using the standard deviation measured for student fallers, who exhibited more erratic behavior. To detect a two-second difference for the action to "get in the clear" for student fallers, 10 tree events for each faller would need to be observed (power 0.8, 95% confidence level). To detect the change among a group of fallers following training or an intervention, 10 fallers would need to be observed. In some instances, student fallers exhibited wider variation in behavior on each tree, and a larger sample of 20 trees, or 20 students could be required to detect significant differences. Considering the slow pace of work for student fallers, this would require several days of observation.

Distraction may have been a problem with the camera setup. Student fallers had no apparent difficulties or complaints with the camera-mounted hardhats, but the two professional fallers, working at a very rapid pace amidst heavy brush and branches, complained about the camera and cord. Since this study was conducted, a new cordless camera has appeared with 16 GB of storage capacity and battery power for up to three hours. A cordless camera appears preferable for this kind of study and may be more acceptable to experienced fallers. Additionally, it may be possible to mount the camera on the underside of the brim of the helmet to reduce contact with obstructions and also place the camera closer to eye level. One point the study intended to report—whether the faller looked at the stump after the tree was down—was impossible to observe reliably, due to the inability to detect eye glances.

In general, the point-of-view video camera captured a wealth of detail on worker behavior that an observer at the scene could not possibly witness—particularly in a hazardous work setting where the observer must maintain a safe distance. Resulting video data were well suited to assessing complex details, such as attentiveness and task orientation. Quality improvement initiatives may find it useful to measure performance count and time for key tasks as in this study. With an independent worker wearing a camera, the observer effect is diminished, if not entirely removed. The function of analyzing and coding video data, however, is time intensive (about six hours per one hour of video in this study); an expert observer at the scene could have noticed some results more rapidly. In safety assessment, video would be most efficient for observing a specific performance indicator that occurs periodically, as shown here for getting in the clear.

## CONCLUSIONS

Results of the video observation confirmed the use of the five action steps in safe falling and provided details on how the actions are conducted in practice. The point-of-view perspective of the camera gave a close, direct experience of the faller's actions and direction of view.

Camera hardhats could be used to evaluate employee behavior and training effectiveness. Other work and environmental factors could also be tested. For example, the clear observation of critical safety behaviors per tree episode, and particularly for getting in the clear, could be used to test for differences in faller behavior under different pay structures (salary versus piece rates) to determine if incentive pay structures improve the pace of work as intended, without compromising safety.

Resulting video files could also be used for training new fallers. In other work situations, value has been demonstrated for students to view their own work behavior on video.[13] Utilizing this technology, according to the study's logging safety consultant, could be useful to train new cutters, allowing them to see the steps taken by professional fallers: the fluidity of motion and pace required for effective cutting. Applications in other fields are also possible. The camera hardhats are presently on loan to a pesticide education program for use in creating farm safety videos.


### *Acknowledgements*

We appreciate the contributions to this study by the student and professional fallers who consented to wear the camera hardhat during their work activities. Student fallers participated with the cooperation of the Student Logging Training Program in the Forest Engineering Department at Oregon State University.


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