ABSTRACT

HEATH, WILLIAM BURTON. An Assessment of Perceived Risk of Extension Ladder Set-Up Angles and Safety Label Effectiveness. (Under the direction of Dr. David B. Kaber and Dr. Simon M. Hsiang.)

Extension ladders are used every day by people in industry and at home. Unfortunately, there is a high prevalence of falls from elevation when using this tool. Over the years, there have been few changes in common usage practices, and accident rates have remained at relatively high levels. In 2010, there were 635 deaths among the U.S. labor force due to falls. Of these deaths, 20% of them were ladder falls (U.S. Department of Labor, 2011). Extension ladders were the focus of this study due to the number of associated fall risk factors. The overarching objective of this research was to assess and compare perceptions of risk when using such ladders. The study specifically examined: (1) levels of risk attributed to different causes of falls; (2) how users assess risk when presented with different risk conditions; and (3) the effectiveness of safety labeling for reducing risk-taking behavior.

Thirty-two inexperienced ladder users were tested through three experiments in order to assess their risk perceptions. The first experiment captured the absolute level of risk that novices associated with different causes of ladder falls. Participants completed a risk assessment questionnaire including rating scales. The second experiment was used to determine if users considered ladders with shallow setup angles as being safe to climb. A series of computer-generated images of ladder setups were presented to participants. They were asked to inspect the images and respond whether they thought the ladders were safe to climb. The final experiment was used to compare user relative risk assessments of different risk conditions and to test the effectiveness of safety labeling on producing a safe ladder

setup. Participants were presented with two risk conditions and asked to setup a ladder as if they were to climb it. The users were also tested with labeled and unlabeled ladders.

Results showed that the level of risk inexperienced users assigned to different causes of ladder falls was not significantly different. In addition, the presence of a shallow setup angle (65°) or an optimal setup angle (75°) did not prove to be a significant predictor in user decisions of whether ladders were safe to climb. The most commonly chosen angle for a ladder being safe to climb was 69°. The final experiment showed that users were more concerned with the risk of overreaching (outside of the work volume of the ladder) than with the risk of the ladder sliding at the base. This experiment also showed that the presence of safety labeling did not have any effect on the location of the ladder or the inclination angle of the ladder in setup.

Based on the results, it can be concluded that inexperienced users acknowledge the risk of using extension ladders, but are unaware of mechanisms that can cause accidents. This is particularly relevant to the lack of risk attributed to shallow inclination angles. It was also shown that safety labeling has no effect on producing a correct ladder setup, according to the standards. Future research should test experienced users as well as the effectiveness of training programs and additional safety interventions beyond ladder labeling.

An Assessment of Perceived Risk of Extension Ladder Set-Up Angles and Safety Label Effectiveness

by
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Biography

William Burton Heath was born on August 6, 1986 in Clinton, North Carolina. Ever since he was a boy, Will wanted to be like his father and brother and attend NC State. In December of 2010, Will graduated with a B.S. from the Edward P. Fitts Department of Industrial and Systems Engineering. Knowing that he wanted to continue his studies, Will decided to pursue a Masters in the same field at NC State. Due to his interest in ergonomics and safety, Will was awarded a National Institute for Occupational Safety and Health (NIOSH) Fellowship for graduate education and research. During the course of his studies, Will prepared a proposal for a NIOSH-sponsored pilot project on the perceptions of fall risk in ladder use. The grant he received supported, in part, his thesis research. Will plans to graduate the summer of 2012 with a M.S. in industrial engineering.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

BLS: Bureau of Labor and Statistics

OSHA: Occupational Safety and Health Administration

ANSI: American National Standards Institute

ASL: American Ladder Institute

COF: Coefficient of friction

CBT: Computer-based test

VBA: Visual Basic Application

RC1: Risk condition 1

RC2: Risk condition 2

1 Introduction

1.1 Motivation

Extension ladders are used every day by people in industry and at home. Unfortunately, there is a high prevalence of falls from elevation when using this tool. Over the years, there have been few changes in common usage practices, and accident rates have remained at relatively high levels. In 2010, there were 635 deaths among the U.S. labor force due to falls. Of these deaths, 20% of them were directly related to ladder falls. Since 1992, fatalities caused by falls have ranged between 600 (1992) and 847 (2007) (U.S. Department of Labor, 2011). In addition to the deaths associated with falls from ladders, injuries have also remained at high levels. In 2008 in U.S. private industry, there were 17,540 recordable injuries associated with falls from ladders.

In addition to the high number of accidents involving ladders, the severity of the injury is also a concern. Of the recordable accidents in 2008, 6,870 required that employees be away from work for more than 31 days with a median number of days away of 16. The large number of days away from work can be attributed to a high number of fractures associated with falls. Of the 17,540 accidents in 2008, 4,800 caused bone fractures (U.S. Department of Labor, 2008). In a study of workers compensation claims for a large insurance company between January 1, 2000 and December 31, 2000, Smith et al (2006) found that of the 9,826 cases involved ladders and 7% produced fractures.

This study focused on falls from extension ladders. In a previous Swedish study identifying 85 ladder accidents, 46% were falls with extension ladders (Axelsson & Carter, 1995). Another Swedish study analyzed ladder fall accident victims treated by a local hospital (with a primary admission area of 195,000 inhabitants). Of 114 ladder accident victims treated by the hospital over a one year period, 83 accidents resulted from use of extension ladders (Björnstig & Johnsson, 1992).

Due to the high number of injuries that occur from extension ladder falls, the overarching objective of this research was to assess the perception of risk when using these tools. The study specifically examined levels of risk attributed to different causes of falls and analysis of risk assessment when presented with different risk conditions. The effectiveness of current safety systems required by either industry standards or government regulations was also examined (more information is provided below).

1.2 Existing Ladder Safety Systems

For the purpose of this study, only required safety systems were analyzed. These systems are defined by the Occupational Safety and Health Administration (OSHA) and the American National Standards Institute (ANSI). Individual ladder manufactures provide optional equipment to prevent different types of falls. Since these interventions are not included on all extension ladders they were not included in the present study.

1.2.1 OSHA Regulations

Current safety regulations concerning the use of extension ladders are covered by OSHA. All OSHA regulations concerning the use of any portable metal ladder can be found in 29 CFR 1910.26. This regulation covers general specifications, care and maintenance, and use. The “use” regulations (29 CFR 1910.26(c)(3)(i-vii)) were directly relevant to the design of this study. The regulations state: (i) the extension ladder base should be placed at a distance of one-fourth the working length of the ladder [from the base of the top support], (ii) ladders are designed as a one-man working ladder, (iii) the base must be placed on secure footing, (iv) the top of the ladder must have two rails supported, (v) the climber must face the ladder during ascending and descending, (vi) ladders must not be tied or fastened together, and (vii) ladders should not be used as braces, skids, guy poles, gangways or for other uses for which they are not intended, unless specified by the manufacturer. It is important to note here that there is no mention of required labeling in this regulation.

1.2.2 ANSI Standards

ANSI is a private non-profit organization that oversees the development of consensus standards for products. ANSI collaborated with the American Ladder Institute (ALI) to develop technical Standard A14.2. This standard covers portable metal ladder safety requirements. The standard describes the safe design, construction, testing, care, and use of portable metal ladders. Of primary interest to this study, was the standard description of proper safe use and required labeling of portable metal ladders. In regards to the setup of an extension ladder, the standard states that they should have an angle of inclination of 75-1/2°. Ladders should be placed on level firm ground and use shoes, spikes, or spurs as needed for slip resistance. In regards to reaching while using a ladder, the standard states that, “The user shall not overreach, but shall descend and relocate the ladder instead (2007). Required labeling is addressed in the next subsection.

1.2.2.1 ANSI Required Labels

The ANSI standard also defines safety labels that are required for extension ladders. A total of five extension ladder specific labels are required by Standard A14.2 (Figures 1.1-1.5). These labels address proper setup (Figure 1.1), possibility of electrocution (Figure 1.2), maximum climbing height (Figure 1.3), improper use of the fly section (Figure 1.4), and detailed information on proper setup, climbing, care, and storage. ANSI also requires specific coloring for labels including the primary hazard “DANGER” and “CAUTION” labels. “DANGER” is circled with a red oval and has white letters on a black background. The remaining portion of the label has a white background with black letters (Figures 1.2 and 1.3). The word “CAUTION” uses yellow letters on a black background. The remainder of these labels have black letters on a yellow background (Figures 1.1 and 1.4).

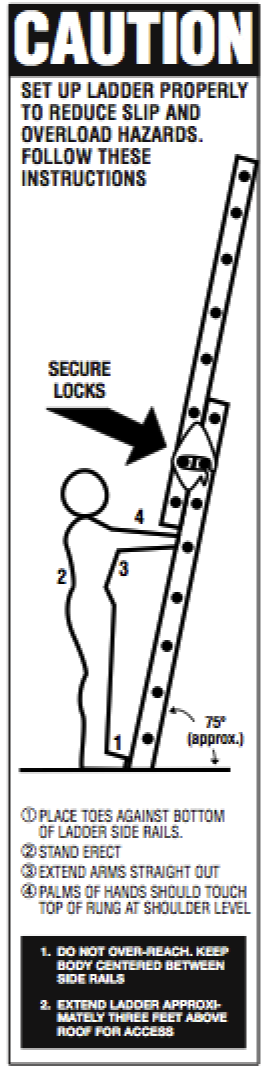
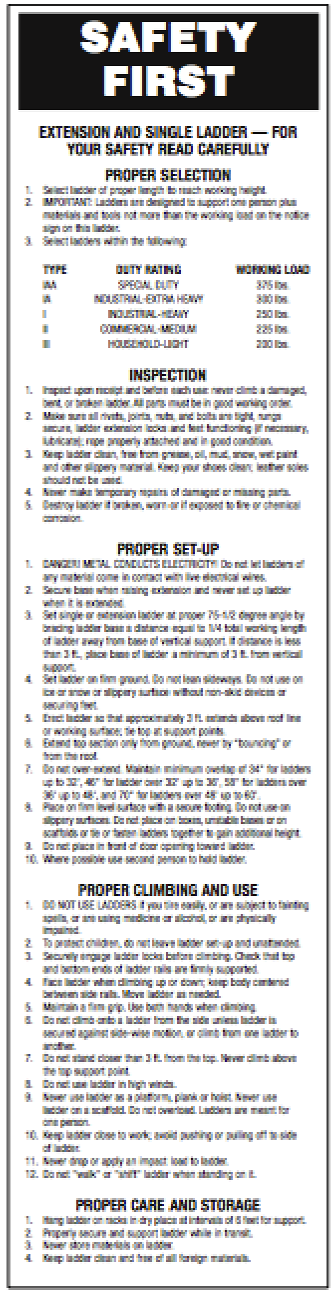


Figure 1.1: Required Label 1

Figure 1.2: Required Label 2

Figure 1.3: Required Label 3

Figure 1.4: Required Label 4



SAFETY FIRST

EXTENSION AND SINGLE LADDER — FOR YOUR SAFETY READ CAREFULLY

PROPER SELECTION

1. Select ladder of proper length to reach working height.
2. IMPORTANT: Ladders are designed to support one person plus materials and tools not more than the working load on the notice sign on this ladder.
3. Select ladders within the following:

TYPE	DUTY RATING	WORKING LOAD
IAA	SPECIAL DUTY	375 lbs.
IA	INDUSTRIAL-EXTRA HEAVY	300 lbs.
I	INDUSTRIAL-HEAVY	250 lbs.
II	COMMERCIAL-MEDIUM	225 lbs.
III	HOUSEHOLD-LIGHT	200 lbs.

INSPECTION

1. Inspect upon receipt and before each use: never climb a damaged, bent, or broken ladder. All parts must be in good working order.
2. Make sure all rivets, joints, nuts, and bolts are tight, rungs secure, ladder extension locks and feet functioning (if necessary, lubricate); rope properly attached and in good condition.
3. Keep ladder clean, free from grease, oil, mud, snow, wet paint and other slippery material. Keep your shoes clean; leather soles should not be used.
4. Never make temporary repairs of damaged or missing parts.
5. Destroy ladder if broken, worn or if exposed to fire or chemical corrosion.

PROPER SET-UP

1. DANGER! METAL CONDUCTS ELECTRICITY! Do not let ladders of any material come in contact with live electrical wires.
2. Secure base when raising extension and never set up ladder when it is extended.
3. Set single or extension ladder at proper 75-1/2 degree angle by bracing ladder base a distance equal to 1/4 total working length of ladder away from base of vertical support. If distance is less than 3 ft., place base of ladder a minimum of 3 ft. from vertical support.
4. Set ladder on firm ground. Do not lean sideways. Do not use on ice or snow or slippery surface without non-skid devices or securing feet.
5. Erect ladder so that approximately 3 ft. extends above roof line or working surface; tie top at support points.
6. Extend top section only from ground, never by "bouncing" or from the roof.
7. Do not over-extend. Maintain minimum overlap of 34" for ladders up to 32', 46" for ladder over 32' up to 36', 58" for ladders over 36' up to 48', and 70" for ladders over 48' up to 60'.
8. Place on firm level surface with a secure footing. Do not use on slippery surfaces. Do not place on boxes, unstable bases or on scaffolds or tie or fasten ladders together to gain additional height.
9. Do not place in front of door opening toward ladder.
10. Where possible use second person to hold ladder.

PROPER CLIMBING AND USE

1. DO NOT USE LADDERS if you tire easily, or are subject to fainting spells, or are using medicine or alcohol, or are physically impaired.
2. To protect children, do not leave ladder set-up and unattended.
3. Securely engage ladder locks before climbing. Check that top and bottom ends of ladder rails are firmly supported.
4. Face ladder when climbing up or down; keep body centered between side rails. Move ladder as needed.
5. Maintain a firm grip. Use both hands when climbing.
6. Do not climb onto a ladder from the side unless ladder is secured against side-wise motion, or climb from one ladder to another.
7. Do not stand closer than 3 ft. from the top. Never climb above the top support point.
8. Do not use ladder in high winds.
9. Never use ladder as a platform, plank or hoist. Never use ladder on a scaffold. Do not overload. Ladders are meant for one person.
10. Keep ladder close to work; avoid pushing or pulling off to side of ladder.
11. Never drop or apply an impact load to ladder.
12. Do not "walk" or "shift" ladder when standing on it.

PROPER CARE AND STORAGE

1. Hang ladder on racks in dry place at intervals of 6 feet for support.
2. Properly secure and support ladder while in transit.
3. Never store materials on ladder.
4. Keep ladder clean and free of all foreign materials.

Figure 1.5: Required Label 5

1.3 Literature Review

A literature review was conducted in an attempt to identify root causes of extension ladder falls. After reviewing a number of articles, it was found that a high fraction of accidents were due to the ladders slipping at the base. Additional articles were reviewed to identify the main factors in base slips. Article were also reviewed that focused on field investigations documenting the use of extension ladders by professionals and common behaviors.

1.3.1 Fall Causes

Using a database of workers' compensation claims from a large insurance company, Smith et al. (2006) analyzed 536 instances of ladder falls resulting in bone fractures. Of these accidents, 25.3% of the cases were due to slipping or losing balance, and 22.9% of the cases were due ladder instability. The category of slipping or losing balance included: missed step, slip on rung, or falling over backwards. Ladder instability cases included: ladder slipping, sliding out, tipped backwards, collapsed or bumped. There were also a significant number of cases that did not have a specified reason for the fall (29.3%). Some reporting of cases to the insurer was incomplete.

Another study of 306 workers, who had experienced an injury from a ladder fall, analyzed causes of the falls. The top three reasons for falls included: ladder moving (40%), foot miss/slip (24%), and losing balance (18%). Relevant to the present study, slips at the base were included in the "ladder moved" category and accounted for 25% of all falls (Perry 2010).

A retrospective observational study was conducted on ladder accidents between 1993 and 1995. Records were obtained from emergency room patients from a community that had a daytime workforce of 150,000. Participant patient records were reviewed and follow-up phone interviews were conducted. The study found that the two main causes of falling were incorrect ladder placement (45%) and excessive reaching (33%) (n=42). A similar study was carried out by Björnstig & Johnsson (1992), also using emergency room data. The emergency room in this study had a primary admissions area of 195,000 and recorded 114 ladder related accidents. The study found that of extension ladder accidents (n=83) the main cause of falling was the ladder sliding at the base (41%). The second largest cause was the ladder tipping or sliding at the top (20%) and in some cases this was due to over-reaching.

1.3.2 Factors affecting sliding

Based on the high number of accidents due to ladders sliding at the base, studies have been conducted to determine underlying causes of slips. The effectiveness of the different types of ladder shoes and floor types were examined by Pesonen and Häkkinen (1988). A laboratory test was conducted to assess how these factors affect the required friction for the ladder to not slip. The angle of the ladder was held constant at 68°, and it was discovered that the required friction coefficient was 0.17-0.28. It was found that rubber shoes were generally better than plastic or no shoes; however, in the presence of oil, these shoes may not provide enough friction. A similar experiment conducted by Häkkinen, Pesonen and Rajamäki (1988) confirmed these findings. The authors also used six male subjects to test ladder slip potential under different ladder angles and climbing conditions. They found that normal and shear forces at the interface decreased as the angle of inclination increased.

Building off of this research Chang, Chang, Matz and Son (2004) sought to test the effects of different climbing conditions and provide an adequate sample size. In this study three different subject weight groups, two climbing speeds (fast/slow), two inclination angles (65°/75°), two types of ladders (aluminum/fiberglass), and two different top supports (reduced/normal friction) were tested. Seventeen subjects were divided into light (5), intermediate (6) and heavy (6) weight, and asked to climb up 10 steps of each of the 16 different climbing conditions. Trials were repeated five times for a total of 80 trials per subject. Results showed that the ladder inclination angle was the most important factor in the coefficient of friction (COF). Climbing speed was also shown to have an effect. On average, the required COF increased 77% when the inclination angle was reduced from 75° to 65°.

In a continuation of the pervious study, Chang, Chang and Matz (2005a) conducted a similar experiment that added two new conditions. To provide a more comprehensive view of climbing conditions and understanding of the effect on the required COF, they examined two additional independent variables. In addition to the five variables mentioned above, climbing direction (ascending/descending) and climbing height (rung) were added to the experiment. Results confirmed prior findings. Regardless of climbing direction, the inclination angle was the most important factor in regard to the required COF. As the inclination angle was reduced from 75° to 65°, the required COF increased 73%.

Chang, Chang and Matz (2005b) also produced another work that focused on the friction provided by different types of rubber ladder shoes. A laboratory experiment was conducted that used a hand drill to pull a weighted extension ladder until it slipped. Four independent variables were tested, including: static weight on the ladder (heavy/light), floor type (tile/stainless steel), ladder shoe (six types), and pulling speed (high/low). Each of these conditions were tested on dry and oily floors. The friction required from each of these combinations was compared with the friction requirements discovered in previous studies. Fourteen of 46 results revealed an available COF that was less than the maximum required COF when the ladder was positioned at 75°. Reducing the angle to 65° resulted in 31 of the 46 conditions having a COF less than the maximum required COF. For all the dry floor conditions, there was a small slip probability regardless of the inclination angle. However, the authors noted that due to the dynamic forces of a climbing person, these slip probabilities should only be used for relative comparisons. The slip probability on a dry floor increased 20 times when the inclination angle was reduced from 75° to 65°. When positioned on an oily surface, the majority of ladder shoes did not provide sufficient friction to climb the ladder when erected at 65°.

1.3.3 Observed Usage in the field

Due to the number of injuries related to ladders sliding at the base, Knox and Van Bree (2010) conducted a field study of ladder use around the suburban Chicago area. They collected data that included ladder make, model, size, ground conditions, upper support point, ladder length at the top support, angle of inclination, activity being conducted, and if there were any extenuating circumstances that affected setup. Here, it is important to note that the OSHA standard states that the ladder length should extend 3 ft. above the top support. Data was collected until a total of 100 observations had been made. Of the data points obtained, 77% were from residential construction sites, 21% were commercial use (e.g. painters), and 2% were non-professional use. The mean angle of inclination observed was 67.2° with a standard deviation of 4.8°. The median and mode were 65.5° and 67° respectively. A minimum angle of 53.6° was found along with a maximum of 75.8°. Only 3% of the ladders observed were set up at 75° or greater. The data did not show any correlation between the angle of inclination and the ladder length at the top support. Meaning that a relatively consistent length of ladder beyond the top support was used with variations in inclination angle.

In addition to the objective measure of angle of inclination, Knox and Van Bree also asked participants to provide open-ended comments on ladder usage. Users indicated that they did not read the labels and relied on “what looked right from past experience”. Users indicated that if the ladder was erected on grass or dirt, “spiking the feet of the ladder” was adequate protection against slide-out. If the ground was firm and flat and not considered a safety issue, then users indicated they would set the ladder at a shallower angle. It was noted that users preferred a shallower setup angle because they could lean into the ladder and feel more “on top” of it. Many users felt that climbing a steep ladder gave them a feeling of the ladder “pulling-over backwards”.

Another field study was conducted with citrus workers in California. Miles and Steinke (1996) sought to implement ergonomic and human factors interventions on a citrus picking ladder. During the initial field observations, they found the actual mean angle of inclination to be approximately 65° (n=46). They also found that no ladder observed was erected at the correct setup angle of 75°, according to the standards. The maximum and minimum angles observed were 72° and 55°, respectively (Miles & Steinke, 1996).

A Swedish based retrospective interview study was conducted by Axelsson & Carter (1995). The study used a standardized phone interview to review cases of portable ladder accidents in the Swedish construction industry with accident victims. Eighty-five portable ladder accidents were reviewed, and of these cases, 39 involved extension ladders. The main cause of falls from the extension ladders was found to be sliding at the base (22, 56.4%). The study found that among the 39 extension ladder cases, 49% of angles of inclination were less than 65°. The authors concluded that while waiting for the availability of alternatives to portable ladders, users needed to be informed of the risks and safe practices of using portable ladders. None of the interviewed subjects recalled any training on the safe use of ladders, and few were familiar with the risks associated with a shallow inclination angle.

A Finnish study was conducted with the maintenance personnel of a power plant. This study was not a field investigation, but data was collected on regular users of extension ladders. The experiment was also conducted in their usual working environment. Participants were asked to use a ladder to move a sign-plate that was 3 meters high from one designated area to another. The study presented participants with seven ladders, ranging in length from

3.4 to 4 meters. It was observed that the average angle of setup inclination was 66.3° (n=147). The maximum angle recorded was 76°, while the minimum angle was 57°. Of the seven ladders used, there was no correlation between inclination angle and a specific ladder type (Häkkinen et al., 1988).

In summary, it was found that regular users of extension ladders do not follow the recommended inclination angle of 75°. It should also be noted that users were unaware of the potential risks of shallow inclination angles. This could be the result of either poor training or failure to read safety labels affixed to ladders.

1.3.4 Summary

The literature review confirmed accident data provided by the Bureau of Labor and Statistics, indicating a substantial number of injuries related to extension ladder falls. It was also discovered that one of the main reasons for falls is ladders sliding-out at the base. Research into the friction requirements of extension ladders revealed that there are multiple factors determining the required COF with the most important and influential of these being the angle of inclination. Previous studies also found that users in the field primarily prefer extension ladders to be set at shallower angles than the recommended angle of 75° (per the ANSI standard). Many professional users prefer ladder setup angles between 65° and 67°. These angles actually represent a serious safety risk depending on floor conditions and ladder foot types.

1.4 Objectives

The first objective of this study was to assess the absolute level of risk that novice users associate with different causes of ladder falls. The second objective of the study was to determine if users consider ladders with improper setup angles as being safe. The final objective of the study was to examine user relative risk assessment of slip-out vs. overreaching and to test the effect of safety labels on this assessment.

2 Methods

2.1 Participants

The participants recruited for this study were 16 males and 16 females ranging in age from 18 to 59. All participants were required to be in good health with no major upper or lower extremity impairments in order to allow them to physical setup an extension ladder. They were also required to have 20/20 or corrected vision in order to view virtual ladder setup angles on a computer screen as well as physical ladder setup angles at a building. Health state and vision were confirmed upon initial contact with potential participants. The motor capabilities of participants were assessed through training of a ladder setup task. Upon arrival at the experiment facility, all participants were presented with a consent form prior to participating in the study (see Appendix A).

To recruit participants, fliers were posted across campus and online. All participants had no professional experience in the use of extension ladders so as not to bias the sample in terms of level of awareness of ladder safety principles.

Table 1 shows the mean and standard deviations of the participant age and experience. This information was collected using a demographic questionnaire (see Appendix B)

Table 2.1: Participant demographic data

	Mean	Std. Dev.	Min.	Max.
Age	27.4	10.7	18	59
Experience (Uses per Year)	0.6	0.9	0	3

2.2 Tasks

This study was comprised of a survey of the participants and two tasks. The survey was a risk assessment questionnaire designed to determine the level of risk participants attributed to different causes of ladder falls. The first task was a computer-based test, which required participants to look at images of erected extension ladders and judge whether they are safe to climb or not. The final task involved an actual extension ladder setup against a building. The task presented different risk conditions and different safety labels to participants. Detailed information was recorded how participants setup the extension ladder.

2.3 Experiment 1: Survey Analysis

The administration of each task, recording of data and subsequent analyses were considered as separate experiments and are presented as such from here forward. The results and discussion section are organized in a similar manner.

2.3.1 Apparatus

The first experiment for the participants involved the risk assessment survey, which can be found in Appendix C. The survey identified the five main causes of ladder falls. These causes included: “Ladder tilting sideways”, “Losing balance due to overreaching”, “Ladder sliding out at the base”, “Foot misstep/slip”, and “Ladder mechanical failure (ladder broke).” A risk rating scale was presented with each category. The scale ranged from 0 to 10 with 0 considered as “No Risk” and 10 considered as “Extreme Risk.”

2.3.2 Experimental Design

The independent variable for this experiment was the risk condition, including the five levels. The response variable was the participant perceived level of risk for each cause of ladder fall. Participant ratings could range from 1 to 10, as noted above.

2.3.3 Procedure

All experiments took place at Daniels Hall on North Carolina State University’s main campus. Participants were instructed to arrive at Daniels Hall, Room 457. Upon arrival all participants were presented with the informed consent form (Appendix A) and they reviewed and agreed to the content. Participants then completed the demographic questionnaire (Appendix B). Next, participants were instructed to complete the risk assessment questionnaire. Participants were given an unlimited amount of time to complete all ratings.

2.3.4 Hypothesis

Accident data provided from the BLS identified several different causes of ladder accidents. Two of the most common were slips at the base and overreaching. Although several previous research studies have demonstrated slip-outs to account for a substantial portion of extension ladder falls (Björnstig & Johnsson, 1992), other research has revealed that users do not prioritize slip-outs (Häkkinen et al., 1988) as a greater risk to, for example, overreaching. Based on these findings, the first hypothesis for this study was as follows:

> Hypothesis 1: Ladder users will consider there to be no difference in the level of risk of falling due to slip-outs or overreaching.

2.4 Experiment 2: Computer Based Test

The second experiment involved a computer-based test (CBT) that required participants to view different ladder setups and determine if the setup was safe to climb. Based on Häkkinen et al. (1988) research, the test was conducted to assess whether participants judged dangerously shallow setups (65°) to be safe to climb as often as they judged safe setups (75°) as being safe to climb.

2.4.1 Apparatus

The test presented participants with 12 images of extension ladders setup at the different angles between 65° and 76° (with single degree increments in angle). The selection of this range was based on the actual setup angle values obtained from field studies (Axelsson & Carter, 1995; Häkkinen et al., 1988; Knox & Van Bree, 2010; Miles & Steinke, 1996). (The inclination angles of 65° and 76° were also included in the task stimuli.) All images were created by using the representation of an extension ladder included in the current ANSI approved labeling. Each participant was presented with a random order of images, generated by a random number generator. In the event that a duplicate order was generated, that order was discarded and another took its place. No participant saw the same order of images as any other.

2.4.2 Experimental Design

The independent variable for the experiment was the setup inclination angle with 12 levels presented to participants in the images of ladders. The response variable was whether the participant judged ladder setup angle presented on the computer screen to be safe to climb or not. This was a binary response with the only acceptable answers being "Yes" or "No".

2.4.3 Procedure

All participants having completed Experiment 1 immediately began participation in Experiment 2. Once the risk assessment surveys had been collected from participants, they were presented with a laptop that contained the CBT application. The test application was executed using a Visual Basic (VBA) program in Microsoft Excel 2010. Figure 2.1 shows an example of the test application interface presenting an extension ladder with a setup angle of 65°. Figure 2.2 shows the application interface presenting an extension ladder with a setup angle of 75°. Participants were given the response options of "Yes" or "No", presented as radio buttons, to answer the question presented along with the image, "Would you climb this ladder?" To prevent a relative judgments based on prior images, once a participant responded to the question, the ladder image was removed and a pop-up asked the user to proceed to the next question and required them to click "OK." After participants completed the 12 yes/no questions, they were presented with a final question that asked, “What would you consider an optimal angle of inclination for an extension ladder?” Figure 2.3 shows this final question.

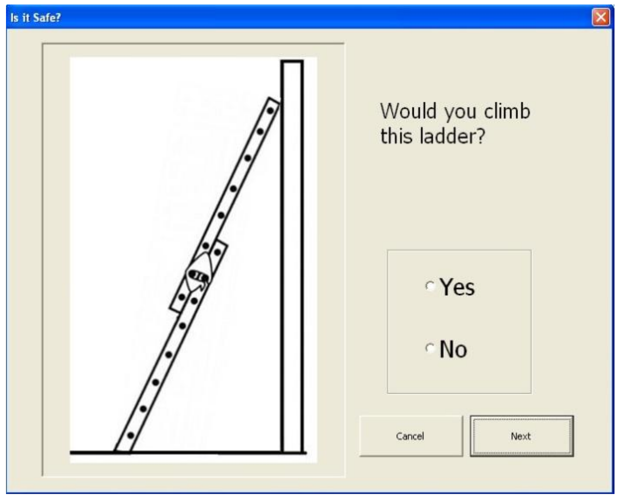


Figure 2.1: CBT question - 65°

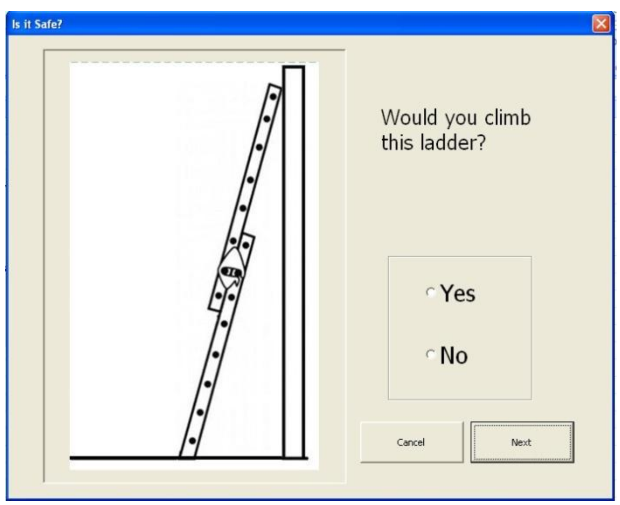


Figure 2.2: CBT question - 75°

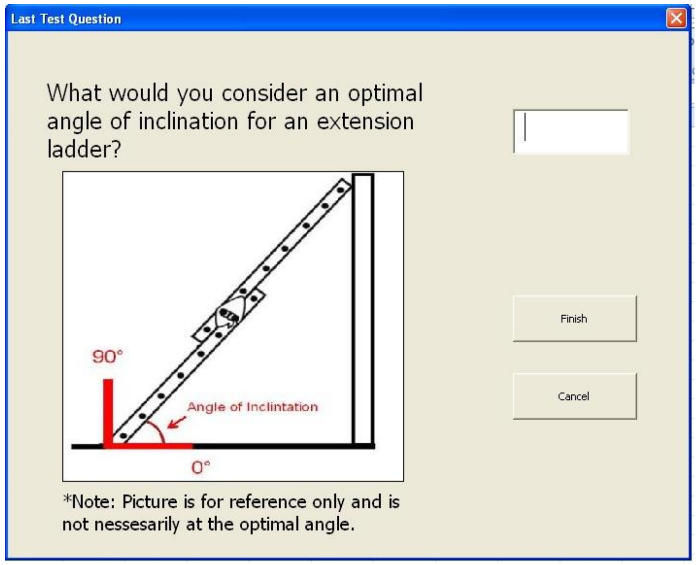


Figure 2.3: CBT question: Optimal Angle

2.4.4 Hypothesis

The literature revealed that professional users of extension ladders preferred shallow setup angles to the recommended 75°. The shallowest angle that was tested for its slip potential was 65°. Based on the friction requirements for a 65° angle of ladder inclination, it can be said this angle represents a significantly greater risk than the recommended angle of 75°, according to the standards. With all this in mind, the second hypothesis for the research was as follows:

Hypothesis 2: Ladder users will not consider a shallow angle (65°) (with a higher required COF) to be more dangerous than the recommended/optimal setup angle (75°).

2.5 Experiment 3: Field Test

The final experiment was a field test and was conducted to evaluate how different risk conditions and ladder labels might affect user setup location and angle of ladder inclination. The test was designed to simulate a painting task. Each participant was asked to setup extension ladders so that they could reach designated targets areas that were to be painted. During this experiment, two risk conditions along with two differently labeled ladders were used (see condition descriptions below).

2.5.1 Apparatus

The apparatus for Experiment 3 consisted of two ladders and two target identifiers to be mounted on the wall of a building. The ladders were identical, commercially available 16-foot aluminum extension ladders. Both ladders were Type-III ladders and rated for a 200-pound load. Since ladder height was shown to have no significant effect on inclination angle (Häkkinen et al., 1988; Knox & Van Bree, 2010; Young & Wogalter, 2000), the smallest ladder available was selected. This was also to allow all participants to easily move and position the ladder.

2.5.1.1 Risk Conditions

In order to pose participants with a risk-taking decision, the targets were prepared and mounted on a building wall to create specific fall risk conditions, depending on the ladder position. In order to ensure that there was only one correct or safe placement of a ladder for a given target situation, the length of the ladder was fixed at its full extension. Each risk condition was defined by two factors, including the height of the target on the wall and the presence of an obstruction, each with two levels. To pose participants with conditions that would affect the angle of inclination of the ladder, the height of the target was set at either a high or low position. The high target was12.7 ft. above the ground and would produce a ladder inclination angle of 75°, if the fully extended ladder was positioned directly under the target. The low target as 11.9 ft. above ground and would cause the inclination angle of the ladder to be 65°, if the ladder was erected directly under the target. Therefore, the low target posed a potential slip-out risk.

In order to also pose the risk of overreaching, an obstruction was added to either the high or low target. This obstruction was a 3 ft in width to the left and right of a target, where the ladder could not be placed. If a subject placed a ladder to either the right or left of the obstruction with the high target, this indicated that they traded a safe setup beneath the target for an overreaching risk. More importantly to this study, if a subject placed a ladder to either the right or left of the obstruction with the low target, this indicated that they considered the risk of overreaching to be less than that posed by a shallow setup angle.

A 2 X 2 matrix of the risk conditions and the location of a correct setup can be found in Table 2.2. Of the four possible risk conditions, two did not present participants with the possibility of being right or wrong. The risk condition with a high target with no obstructions would allow the user to either place the ladder below or left/right and still be safe in the setup. The condition with a low target with obstructions would not allow the user to create a correct or safe setup. For these reasons, these two risk conditions were not evaluated in the experiment. Recall that objective of this experiment was to determine how ladder users prioritize specific fall risks, including ladder slip-out and overreaching.

Table 2.2: Risk conditions

	Low Target	High Target
No Obstruction	Ladder Underneath: Incorrect Ladder to Left/Right: Correct	Ladder Underneath: Correct Ladder Left/Right: Correct
Obstructions	Ladder Underneath: Incorrect Ladder Left/Right: Incorrect	Ladder Underneath: Correct Ladder Left/Right: Incorrect

The risk condition that included a low target with no obstructions (upper-left quadrant of Table 2.2) was identified as risk condition 1 (RC1), and the risk condition consisting of a high target with obstructions (lower-right quadrant of Table 2.2) was identified as risk condition 2 (RC2). The two wall target positions, which were tested in the experiment, can be seen in the left and right images in Figure 2.4. The risk condition configurations, RC1 and RC2, can be seen individually in Figures 2.5 and 2.6, respectively.

Figure 2.4: Wall target positions and obstructions (in pink)

Figure 2.5: Risk condition 1

Figure 2.6: Risk condition 2

2.5.1.2 Ladder Labels

Along with the two risk conditions that were tested, two ladders with different safety labels were used. The first ladder carried all the labels that are required under the ANSI (2007) standard. Along with the required labels, an additional label presenting a visual representation of the results of a shallow setup angle was also included (Figure 2.7). In compliance with ANSI Z535.6 this label describes the type of hazard and conveys the potential consequence of the hazard. It also provides a picture of the hazardous condition to assist the user in identifying the conditions. The label's pictorial nature is particularly effective in conveying information to users who may speak different languages.

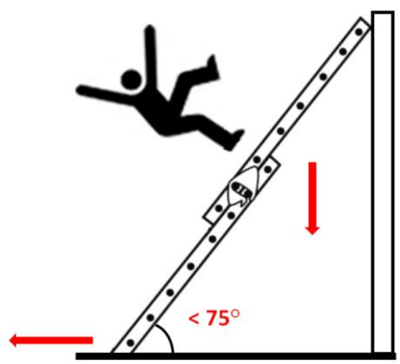


Figure 2.7: Additional safety label

The second ladder was stripped of all safety labels, originally included on the ladder at purchase. Figure 2.8 shows the ladder (left and right sides) with safety labels and Figure 2.9 shows the ladder (left and right sides) without safety labels.

Figure 2.8: Ladder with labels

Figure 2.9: Ladder without labels

2.5.1.3 Anagram Worksheets

In an effort to prevent participants from observing an experimenter measuring the distance of the ladder base from the supporting wall (in order to determine inclination angle, given the fixed extension length) between trials, anagram puzzles were presented. Participants were required to view letters of words in random order and to write the target word on the puzzle sheet. These puzzles were designed to demand visual attention and participant mental resources to prevent learning carryover (in terms of setup angle) from the prior trial. The anagram worksheets can be seen in Appendix E.

2.5.2 Experimental Design

2.5.2.1 Independent Variables

There were two independent variables for this experiment. The first variable was the risk condition with two levels: RC1 and RC2. The second independent variable was the ladder safety label condition with two levels including: labels and no labels. The experiment followed a completely within-subjects 2 x 2 block design. There were a total of four different orders of conditions presented throughout the experiment constructed to control for learning effects. An equal number of participants performed the ladder setup tasks following each order.

2.5.2.2 Dependent Variables

Experiment 3 captured two different response measures. Both were objective in nature. The first measure was the location of the ladder relative to the target location. There were two possible responses, including: correct or incorrect. The correct and incorrect locations for each ladder for a given risk condition are presented in Table 2.2, above.

The second response variable was the angle of inclination. The angle was determined based on the fixed ladder length and the base position set by participants during each trial. The value of this measure was determined to the nearest degree. In post-processing of the experiment data, this variable was transformed to a categorical response with three levels, including: (1) Level 1 – considered as a safe setup, including angles that were equal to or greater than 75°; (2) Level 2 - angles ranging between 66° and 74° that were not optimal but were not immediately dangerous; and (3) Level 3 - angles less than or equal to 65° and deemed to be unsafe.

2.5.3 Experimental Procedure

This experiment took place immediately after participant completed the second CBT experiment described above. Participants were escorted to the exterior of Daniels Hall where the wall targets and ladders were already in place.

Once outside, participants were provided brief training on the basic mechanisms of the extension ladder. The training session used the ladder with all of the ANSI required labels intact. Before beginning training, the participants were instructed to inspect the ladder and make note of the location of the safety labels. Participants were not instructed to read the labels, but they were given time to read them while they were inspecting the ladder, as instructed. The training only included the procedure for erecting the ladder. It is important to note here that there was no actually climbing of ladders during the study. Consequently, there was no mention of optimal ladder setup or safety considerations. After observing the experimenter erecting the ladder once, the subject was instructed to do the same. After this, the participant was allowed to ask any questions about the technique used for the erection of the ladder. For a detailed description of the training the participants received, please refer to the experimental script found in Appendix D.

Participants subsequently completed four trials of setting up the ladder. The four trials included erecting one of each ladder (label/no label) under each of the risk conditions (RC1/RC2). Once the participant erected the ladder, they were asked, “Would you feel safe climbing this ladder, by yourself, to paint the entire target area in one trip?" If the participant answered, "Yes," the trial was complete. In the event of a "No" response, the participant was asked to reposition the ladder so that they would feel safe climbing the ladder to complete the designated task.

Upon completion of a trial, the participant was escorted around the corner of the building (out-of-sight of the ladder) to a chair where they were instructed to sit and rest. Each participant was required to take at least 2 minutes of rest time between trials. During the rest time, the participant was instructed to complete an anagram work sheet (see Appendix E). While the subject was completing the worksheet, the experimenter was able to note the location of the ladder, measure the distance of the base from the base of the top support and calculate the angle of inclination without the participant viewing the recording of the measures. The angle of inclination was also measured using a manual goniometer from Nowlin, Inc. (Columbus, OH). Before the start of the next trial, participants were asked if they would like more rest time.

Once the experiment was completed, each participant was given a brief interview. Three identical questions were asked of each participant, including:

1. What were the objectives you wanted to accomplish before determining if the extension ladder was safe to climb?
2. Did you notice any differences between the two ladders?
3. Did you read the safety labels? Why or why not?

Upon completion of the brief interview, the participants were informed that the experiment was complete. Participants were then escorted back to Daniels Hall, Room 457 where they completed a payment form and were thanked for their participation.

2.5.4 Hypotheses

In previous studies reported in the literature, it was found that many users did not understand a shallow inclination angle could result in the ladder slipping at the base. There are currently no safety systems other than warning labels required by the ANSI standards or OSHA regulations. Based on these findings, the last three hypotheses of the experiment were formulated:

Hypothesis 3: Ladder users will judge positions that have a potential for slip-out as being safe more than they will judge a ladder that has a potential for overreach as being safe.

Hypothesis 4: Ladders that include safety labels will produce more safe ladder setup locations than ladders without safety labels.

Hypothesis 5: Of the ladders located in a safe setup location, ladders with safety labels will produce more safe inclination angles than unsafe.

2.6 Data Handling

All the risk assessment ratings from Experiment 1 were entered into an Excel spreadsheet for analysis purposes. The VBA program developed for Experiment 2 automatically recorded the results of the CBT. Once all participant data was collected, it was transferred to a summary table in Excel for ease of analysis. In Experiment 3, all data was collected through direct observation. Once the observations were complete, the data were entered into a separate Excel spreadsheet for analysis.

2.7 Statistical Analysis

Three different methods of statistical analysis were applied to the survey and observational data. The methods included descriptive statistics on the risk assessment ratings and judgments from the CBT, nonparametric analyses of the responses to the risk assessment questionnaire, and contingency tables on responses to the CBT stimuli and those collected during the field test. Statistical analyses were carried out using JMP 10 (SAS Corporation, Cary, NC) and Microsoft Excel.

Descriptive statistics were used to identify the level of perceived risk that was associated with each risk factor. Descriptive statistics were also used to establish which ladder angles users felt were safe to climb.

As the data produced with the risk assessment rating scale proved to be non-normal in nature, a nonparametric test was used to compare ratings of risk associated with each fall factor. A Wilcoxon signed-rank test was used to test if there were any differences in the levels of risk that participants attributed to each fall risk factor.

Contingency tables were used to assess the effect of each predictor variable on each response measure. It was necessary to test if there was a significant difference between the results of the 65° image and the 75° image. For this test, the presentation of the image was considered to be a predictor variable, and the judgment decision of safe or unsafe was the response measure.

For Hypotheses 3-5, the predictor variables were either the risk condition or the type of ladder used. The response measure that was tested was either the number of correct setup locations selected by participants or the number of ladder setups categorized in each of the three levels of inclination angles (L1, L2, L3). To determine if there was an effect of the predictor variable on the response measure, a likelihood ratio (χ^2 – value) was examined.

3 Results

3.1 Experiment 1

The descriptive statistics and nonparametric analyses were conducted to determine the levels of perceived risk associated with each fall risk factor. The results presented here are related to Hypothesis 1. Table 3.1 shows the average and standard deviation of participant risk ratings for each risk factor. It can be noted that the greatest perceived risk was assigned to overreaching (mean=7.53, S.D. 1.67) and the least risk was attributed to the ladder breaking (mean=6.06, S.D. 2.18).

Table 3.1: Descriptive statistics for various fall risk factors

	Tilt Sideways	Overreach	Slip at Base	Misstep	Broke
Mean	6.97	7.53	6.75	6.81	6.06
St. Dev.	2.29	1.67	2.82	2.18	3.08

In addition to the descriptive statistics, inferential statistics were used to determine if there were any statistically significant differences among risk factors. Related to this, we initially tested for an effect of gender on the ratings of perceived risk. Gender was found to have no effect on the values for each risk factor ($\chi^2 = 0.56$). Consequently, gender was removed from the statistical model of perceived risk. A Wilcoxon signed-rank test revealed no difference between fall risk factors ($\chi^2 = 0.501$, $\beta = 0.66$). Therefore, all risks were perceived as being comparable from a statistical perspective.

3.2 Experiment 2

As with the Experiment 1 data, descriptive statistics were generated on participant responses regarding whether various ladder angles of inclination were safe to climb. Inferential statistics were used to identify any significant differences in percentage of “yes” responses among the angles of inclination. The results presented in this section are related to Hypothesis 2. Figure 3.1 shows the number of participants that would feel safe to climb each defined angle that was presented in the CBT. The greatest number of users said that they would climb a ladder positioned at 69° (26 respondents, 81%). This angle was followed closely by the next most accepted angles of 70°, 71°, and 72° (25 respondents, 78%).

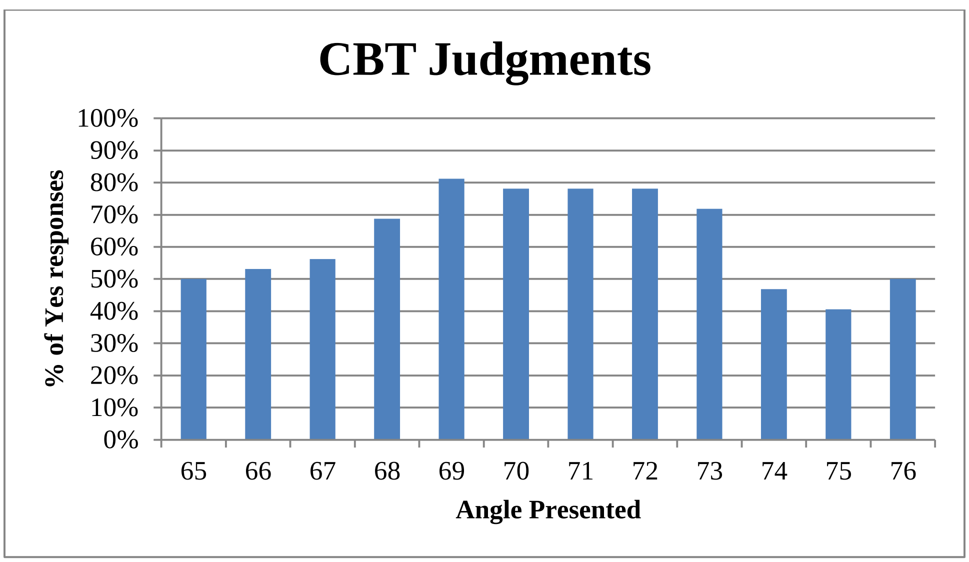


Figure 3.1: CBT judgment results

Regarding the difference between the shallow setup angle of 65° and the recommended angle of 75°, 16 participants (50%) agreed that they would feel safe climbing a ladder erected at 65° while only 13 (41%) agreed they would feel safe climbing a ladder erected at 75° (Table 3.2). A contingency table analysis was used to determine if a participant was more likely to say a ladder was safe to climb when presented with a shallow angle (65°) than when presented with the recommended ladder angle (75°). The analysis revealed no significant difference between the two angle conditions ($\chi^2 = 0.4509$, $\beta = 0.677$), or that participants perceived them to comparably safe.

Table 3.2: Contingency table (response by angle presented)

Count Col %	**65°**	**75°**	
Safe Location	16 50.00%	13 40.63%	29
Unsafe Location	16 50.00%	19 59.38%	35
	32	32	64

3.3 Experiment 3

Contingency table analyses were also conducted on the data from Experiment 3. These analyses related to Hypotheses 3, 4, and 5. We initially tested for potential effects of gender and order on participant positioning of ladders relative to targets; that is, in “safe” or “unsafe” locations, given the potential fall risks of overreaching or shallow setup angle.

Using a contingency table to compare the proportions of safe setup locations among males and females, gender was found to have no effect ($\chi^2 = 0.2211$) on the response. Experimental order was tested in a similar manner. A contingency table was structured to compare the proportions of safe setup locations among the four condition orders defined for the study. The analysis confirmed no effect of order ($\chi^2 = 0.2752$) on the safe location judgments. Based on these results, gender and order were not considered as predictor or grouping variables in any subsequent statistical analyses.

In regards to Hypothesis 3 (i.e., participants considering ladders with shallow setup angles to be more safe than ladder locations posing an overreach risk), no participant chose the incorrect setup location for RC2. Therefore, participants always located the ladder safely beneath the target painting area vs. positioning it to the left or right of the obstructions, creating an overreaching hazard. In fact, all improper setups observed in the study were associated with RC1. That is, participant located ladders underneath the low target painting area, creating an unsafe angle of inclination and base slip-out hazard, when the ladder could have been safely located to the left or right of the target with no overreaching hazard. This indicates that significantly more participants judged a ladder with a potential for slip-out as safe more than a ladder with a potential for overreach ($\chi^2 = <0.0001$). The results of the contingency table analysis can be seen in Table 3.3.

Table 3.3: Contingency table (location by risk condition)

Count Col %	**RC1**	**RC2**	
Safe Location	52 81.25%	64 100.00%	116
Unsafe Location	12 18.75%	0 0.00%	12
	64	64	128

With respect to Hypothesis 4, it was expected that safety labels on the ladders would lead to more safe setup locations than when participants used ladders without labels. Another contingency table was used to test the effect of ladder labels on the setup location of ladders under the various risk conditions. Table 3.4 presents the results of the analysis. There was no effect whatsoever of ladder labeling on participant positioning of ladders relative to targets ($\chi^2 = 1$). It should be noted that of the 36 participants tested, only two verbally noted the difference between the labeled and unlabeled ladders during the course of test trials.

Table 3.4: Contingency table (location by label)

Count Col %	**No Labels**	**Labels**	
Safe Location	58 90.63%	58 90.63%	116
Unsafe Location	6 9.38%	6 9.38%	12
	64	64	128

Regarding Hypothesis 5, it was also expected that, among ladders in "safe" setup locations relative to targets, those with labels would more often be set at recommended or "not immediately dangerous" angles of inclinations than those without labels. Data from the field test was sorted into subsets of safe ladder locations and unsafe locations. For the purpose of this analysis, only the safe locations were considered. As previously mentioned, angles of inclination were categorized as L1, safe setup angle equal to or greater than 75°, L2 not immediately dangerous angles ranging between 66° and 74°, and L3, angles less than or equal to 65° with the potential for ladder slip-out. The results of the contingency table analysis can be seen in Table 3.5. The effectiveness of labels in regards to proper angle of inclination were examined and found to have no effect at any of the three levels ($\chi^2 = 0.4904$, $\beta = 0.212$). That is, there were on significant differences in angles of inclination between labeled and unlabeled ladders that were located safely relative to wall targets.

Table 3.5: Contingency table (angle level by label)

Count Col %	**No Labels**	**Labels**	
L1	8 13.79%	8 13.79%	16
L2	48 82.76%	45 77.59%	93
L3	2 3.45%	5 8.62%	7
	58	58	116

4 Discussion

Experiment 1 was used to test one hypothesis. It was expected that participants would consider there to be no difference in the level of risk of falling due to slip-outs or overreaching. For this hypothesis, the results of the risk assessment survey are discussed. The results of the survey supported the hypothesis as there was no significant difference between any of the fall risk factors. This finding indicates that inexperienced users judge all potential fall risks to be equally risky or serious. The finding could be the result of lack of use of extension ladders by the participants. In general, users appear to recognize that the use of extension ladders can be dangerous. However, they do not appear to discriminate in terms of what actions will result in ladder falls.

Experiment 2 also tested one hypothesis. It was expected that participants would not consider a shallow setup angle (65°) to be more dangerous than an optimal angle (75°). This hypothesis was supported by the fact that users showed no difference in their choice of climbing a shallow ladder or a properly erected ladder. This implies that the participants in this study did not view an angle of 65° to be shallow enough to constitute a significant fall risk.

It should also be noted that the results of Experiment 2, using the CBT application, revealed users to prefer a stepper setup angle than the prior field studies. The angle that was selected as safe by the most participants was 69°. Field studies have shown average inclination angles of 67.2° (Knox & Van Bree, 2010), 65° (Miles & Steinke, 1996), and 66.3° (Häkkinen et al., 1988). This difference could be due to the fact that the users tested in the present study did not have any significant experience with extension ladders or that the test was conducted using images of extension ladder setups rather than a physical example. In either case, the novices tended to prefer angles that were closer to the recommended safe setup angle. Another reason for the discrepancy in results among studies could be the range of images presented by the CBT application. In the physical test conducted in Experiment 3, 10 of 36 participants indicated that a median angle (not too shallow or steep) was a factor they considered in positioning ladders. When using the CBT application, participants may have been searching for the middle angle among the range of stimuli presented (70°/71°).

In an effort to assess the validity of the CBT, a post-hoc correlation analysis was conducted between the median angle that was considered safe to climb by participants in the CBT and the measured angle from the physical setup task. Only responses from a correct location under RC1 were used in this analysis. These responses were selected since a correct placement in this condition had no upper obstruction; therefore, the user was unrestricted in the ladder setup angle. A pairwise correlation showed that the two data sets were positively correlated ($r = 0.4267$; $p = 0.0297$). Participants that judged shallow angles as safe in the CBT were more likely to physically setup a ladder at a shallow angle.

The results of this experiment should also be discussed in relation to the results of Experiment 1. It was shown in the first experiment that the participants judged slips at the base as equally risky as all other fall risk conditions. Prior research showed that inclination angle is the most important factor in determining the required COF to prevent slips at a ladder base (Chang et al., 2005; Chang et al., 2004). From these findings and the literature, it can be inferred that inexperienced users do not recognize the importance of a proper (75°) inclination angle. The combined results of Experiments 1 and 2 suggest that users understand there is a serious risk of slips at the base; however, they do not understand the importance of the angle of inclination as a factor in this risk.

Experiment 3 tested three separate hypotheses. The first hypothesis was that participants would judge ladders that have a potential for slip-outs as being safe more than they would judge a ladder location creating the need for overreaching as being safe. This hypothesis was supported by the fact that there were no recorded unsafe ladder locations for RC2 (high target with lateral obstructions) but there were a substantial number of unsafe locations for RC1 (low target with no obstructions). (Again, the definitions of “safe” and “unsafe” ladder locations, relative to the risk conditions, can be found in Table 2.2.) Participants were more cautious when presented with RC2 and were more risky when presented with RC1, electing shallow setup angles vs. left or right reaching from the ladder.

It can be inferred from these finding that users are able to identify the risk of overreaching better than the risk for slips at the base of a ladder. The low target height for RC1 caused a significant fraction of participants to erect the ladder at an inclination angle of 65° or less. This finding reaffirms the results of Experiment 2; not all extension ladder users deem an inclination angle of 65° to be immediately dangerous. The results show that all users understand that overreaching can result in a ladder fall (i.e., no unsafe ladder locations for RC2), but some users do not understand that a shallow ladder angle can result in a ladder fall.

The second hypothesis tested by Experiment 3 stated that ladders affixed with ANSI required safety labels would produce more safe ladder setup locations than ladders without safety labels. The results of the experiment refuted this hypothesis. Among all test trials, there were an identical number of safe setups for the labeled and unlabeled ladders. From these results, it can be inferred that participants did not read, understand, or comply with the safety labels. This finding is counter to the expectations of the technical standard.

The final hypothesis examined was that when ladders were placed in a safe setup location, ladders with safety labels would produce more safe inclination angles than unsafe. This hypothesis was not supported by the results of Experiment 3. The safety labels did not increase the number of safe inclination angles, across conditions, when ladders were setup in a location that was considered safe. Ladders with safety labeling actually produced more angles in the Level 3, immediate danger, category ($\leq 65°$) than did the ladders with no safety labels. It is possible that minor variations in each individual setup also accounted for some of the observed "dangerous" setup angles.

The lack of an effect of safety labeling observed in this study is of particular concern, given the labeling requirements identified in the ANSI standards. That is to say, the technical standards organization considers labeling to be important to the safety of ladder users, but in this study users did not use the labeling. It would, therefore, be useful to know why the labeling was not used. Related to this, in a post-experiment interview, each subject was asked if they noticed the difference between the labeled and unlabeled ladders. Of the 32 participants, only two noticed that one ladder was labeled and the other was not. Both of these participants stated that even though they noticed the difference, neither took the time to read the labels. These observations suggest that the inclusion of safety labels on extension ladders should not be the only form of hazard control used to convey safe ladder setup.

In another question, participants were asked if they took the time to read the labels on the ladders. Only one participant said that he read the labels. His reasoning for reading was his fear of injuring himself. The other 31 participants were subsequently asked why they chose not to read the labels. Twenty-three participants (72%) said they did not think that the labels were important. Five participants (16%) claimed that they had used a ladder before and did not feel the need to read the labels. Three participants (9%) did not notice the presence of the labels during the trials. From these findings, it can be inferred that users are well aware of the safety markings but do not feel the need to pay attention to them. This may be attributed to ladders being a common piece of equipment in everyday life. One user said that, "It's just a ladder. No one reads those labels." Even though only one participant thoroughly read the labels, six stated that they glanced-over them. Related to this, it is possible that if labels expressed vital safety information in a quicker more concise form, they might have an effect on ladder user behavior.

5 Conclusion

The objectives of this study were to: (1) asses the absolute level of risk that inexperienced users associate with different causes of ladder falls, (2) determine if users consider ladders with improper setup angles as being safe, and (3) examine users relative risk assessment of slip-out vs. overreaching and test the effect of safety labels on this assessment. Three different experiments were conducted to examine these objectives.

Experiment 1 was used to determine the absolute risk that inexperienced users perceive for each of five different causes of ladder falls. Survey results showed that participants associated similar risk values with each of the five risk factors: overreaching (7.53), ladder tilting sideways (6.97), misstepping (6.81), slipping at the base (6.75), and ladder breaking (6.06). Even though results showed that, on average, overreaching was considered the greatest risk by most users, statistical analysis showed there were no significant differences between any of the risk factors. It should be noted that inexperienced users do not consider any one risk factor greater than another, based on an absolute risk assessment.

Experiment 2 consisted of a CBT (computer-based test) that asked participants to make a judgments as to whether ladders at various angles of inclination were safe to climb. This test was used to determine if inexperienced users would judge improperly setup ladders as being safe to climb. If the angle of inclination was 75° or greater, the ladder was considered safe to climb (according to the current ANSI technical standard). Most users preferred an inclination angle less than 75° with the majority indicating 69° was safe, and half of the participants said the shallowest angle presented (65°) would also be safe to climb. When asked what they thought was the optimal angle of inclination, the average response was 61.78°. These findings indicated that inexperienced extension ladder users do not associate a high fall risk with ladders that are erected at angles below 75°. The results motivate the need for ladder safety training or enhanced labeling (beyond the current requirements of the ANSI standard; also see below).

Experiment 3 examined the relative risk assessment of ladder slip-outs vs. overreaching and tested the effects of safety labels on this assessment. When presented with a risk of overreaching (i.e., a high wall target area with lateral obstructions), inexperienced users were more cautious than when presented with a risk of ladder slip-out at the base (i.e., a low wall target with no lateral obstructions). Most surprisingly, this user behavior was also unaffected by the presence or absence of safety labels. It was found that the inclusion of safety labeling on the extension ladders had no effect on participant safe setup of ladders, according to the standards. All but two participants did not notice that one of the ladders carried any safety labeling. The most common response to why users did not read the ladder labels was that they did not consider the labels to be important. These findings indicate a clear lack of user attention to labels, even given current labeling requirements for content and presentation.

The findings of this study show that novice users of extension ladders recognize many risks that are associated with ladder falls. One of the main reasons for extension ladder falls is the ladder sliding at the base. While participants did recognize this as a serious risk (based on perceived ratings), they did not understand the influence of the inclination angle in the fall risk. The addition of safety labels to ladders to address this problem was found to have no effect. Participants appeared to be accustomed to seeing warning labels on equipment and felt they were not important to ladder location or setup.

As one implication of this research, it might be beneficial to add a device to ladders, similar to a bubble level, to inform users of whether a ladder is erected at an appropriate or safe angle for use in order to prevent fall risk due to base slip-outs. If such a device is included in future ladder designs, future lab and field research would need to be conducted in order to determine effectiveness relative, and in addition to, ladder labeling.

While additional ladder design interventions might be the most effective solution for inexperienced user risk-taking with extension ladders, new training regimens could be designed for professional users of extension ladders. These regimens should stress the importance of the ladder inclination angle as a key contributing factor in the potential for falls due to base slips. The findings of this research show that stressing the importance of proper inclination angles as well as teaching effective setup methods (e.g., ANSI recommended "stand and reach") might lead to greater safety in extension ladder use. It is important to recall here that previous field studies of professionals (Knox and Van Bree, 2010; Miles and Steinke, 1996) revealed significant preferences for inclination angles that were significantly less than the recommended 75°.

5.1 Limitations

There are several limitations to this study that need to be identified, which primarily stem from the fact that the experiment was only a setup task with no climbing. It is possible that the lack of an actual fall risk might cause participants to take less care in ensuring that the extension ladder was erected in a safe position for climbing. Of the 32 participants, one said that they would have read the labels in detail if they were going to actually climb the ladder. Consequently, caution should be taken when comparing the results presented here to results obtained in field settings with users climbing actual ladders.

Another limitation attributable to the simulated task was the presence of, and training provided by, the researcher. It is possible that participants felt any and all risks would have been pointed out to them by the researcher during the training trials. Five subjects said that they did not read the safety labels due to the fact that the researcher had provided them with training.

There was also a limitation of the study due to the type of participants. Only persons with little to no experience working with extension ladders were tested in the study. These participants had never received any professional training in the use of extension ladders and had made limited (if any) use of such equipment before participating in the experiment. Therefore, caution should be taken in applying these results to an occupational setting with professional users.

The design of the additional label used in the study may also be considered a limitation. The label indicated the direction of motion of the ladder in the event of a slip at the base. The label could have shown users what to do if the ladder is inclined less than 75°. The arrows in the label could have been directed to indicate how to elevate the top of the ladder in the event that the inclination angle was less than the suggested optimal angle of 75°. Because of this design, the effectiveness of the labels may have been reduced. However, since all required ANSI labels were present on one test ladder and they were not read or considered by the vast majority of participants, the additional label design may not have had a significant effect on the study results.

In the results of the CBT, there was no significance found when testing the effects of the presence of a shallow angle (65°) and the recommended angle (75°) on a user's perceived risk. There was a large rate of Type-II error associated with this test ($\beta = 0.677$). There was also a high rate of Type-II error ($\beta = 0.66$) associated with the survey results on the perceived risk of different risk factors. To prevent these high levels and produce a more acceptable Type-II error rate ($\beta = 0.2$) a larger sample size would be needed.

The final limitation of this study was the use of a CBT (computer-based test) application for assessing participant judgments of safe ladder setup angles. Participants may have produced different responses if a physical ladder was present as a basis for judgments. The diagrams provided as part of the CBT only provided one view of a ladder. There is a possibility that multiple views along with physical inspection might have altered participant perception of risk of specific setup angles.

5.2 Future Research

Future research on the perception of risk associated with extension ladders should address the aforementioned limitations. The easiest way to address all the identified limitations would be to conduct a worksite field study. This would allow experimenters to test experienced users. In addition, participants would be able to climb ladders and provide actual risk assessment rather than perceptions based on simulated ladder setups. Based on past studies of ladder inclination angles (Irving & Vejvoda, 1977; Simeonov, Hsiao, Kim, &

Powers, 2012), it is anticipated that experienced users would produce inclination angles that are similar to the novice user responses in the present study.

A second line of future research should be to test the effectiveness of different ladder safety training regimens on user behavior, including label reading. The cheapest and easiest intervention would be a training program that places emphasizes proper extension ladder angle of inclination in setup. Since it was shown that the ladder labels had no effect on the safety of ladder setup, it is necessary to determine whether the presentation or the content of the label is a predictor of lack of usage. An experiment should be designed in which half of the participants are instructed to read the labels and the others are not. This would allow researchers to determine if there is a problem with formatting or content included in the labels that dictates usage behavior.

Finally, future research should focus on the effectiveness and feasibility of engineering controls to ensure a proper ladder setup. A bubble level has already been tested and proved to produce setup angles extremely close to the recommended 75° (Young & Wogalter, 2000). However, even if the intervention is effective, its usage in the field needs to be examined.

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Appendices

Appendix A: Informed Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Title of Study
An Investigation of Risk Perception in the Use of Extension Ladders

Principal Investigators	Faculty Sponsor
Will Heath	Prof. David B. Kaber

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in the study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?
Extension ladders are used everyday by people in industry as well as at home. In the event of no fixed stairs or other ladders, they are a portable alternative. Ladders are designed, manufactured, and delivered for safe use; however, falls from elevation have been recorded when using extension ladders. Ladder usage practices are well established; however, several user factors can lead to falls including misjudgment of ladder position and stability.

This purpose of this study is to assess your awareness of potential risk factors in relation to using extension ladders. We are interested in identifying levels of perceived risk that users identify for different ladder configurations.

What will happen if you take part in the study?
From the results of recruitment screening, you agree that you are in good health, do not have any major upper or lower extremity impairments, and are able to perform dexterous actions with both hands. You also agree that you do not have any professional experience in the use of extension ladders and you have 20/20 or corrected vision. Please initial to confirm that these statements are true. ___________

If you meet the criteria noted above and you agree to participate in this study, you will be asked to complete a computer based test and experimental test trials in the Ergonomics Lab in Daniels Hall (room 457) and in the courtyard of the same building. To begin, you will be asked to fill out a demographic and risk perception questionnaire. This questionnaire will be used to identify any information on your experience in using extension ladders. Next, you will complete a computer-based test where you will view pictures of ladder setup configurations and make decisions on the safety of the configurations. This test will last approximately 30 minutes.

You will then proceed to the courtyard of Daniels Hall where the experiment will involve physically setting up a 16-ft. extension ladder. The experimenter will describe to you the basic parts of the ladder and the location of the safety labeling. The experimenter will then provide a demonstration on the proper technique for raising the ladder. If you have no questions, you will be given a training trial to familiarize you with the task you will perform during the test trials. If you need help physically moving the ladder the experimenter will be available to help.

During the experimental testing, you will finish 4 test trials. Each trial will last less than 15 minutes. During a trial, you will be instructed to setup a ladder to reach a specific target painting area. The trial will be complete when the ladder is set up according to your judgment. There will be no climbing of a ladder at any point in the experiment. Between trials, a two-minute rest will be required. During this rest, a list of anagrams will be provided for you to study. You may be tested on these anagrams at the end of the experiment. If at any point during these trials you feel fatigued, additional rest periods will be provided.

Lastly, you will fill out a payment form and depart the lab.

Risks
The risks associated with participation in this study are unlikely and minimal. The risk may include potential physical fatigue from setting up extension ladders, soreness of upper extremities from controlling and moving the ladder, and some fatigue from standing up. In the event you indicate fatigue or discomfort during the experiment, a rest period will be provided. If you ever feel too uncomfortable to continue, your participation in the experiment will be terminated and you will be compensated for the time you already committed.

Benefits
There is no direct benefit of this research to you. However, you may indirectly gain knowledge about ergonomics research methods as well as safe configurations of extension ladders.

Confidentiality
The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in a locked cabinet and password-protected computers in the Ergonomics Lab in Daniels Hall (room 457). You will be assigned a subject number at the beginning of the experiment, and there will be a link between your identification and your subject number. You will NOT be asked to write your name on any study materials so that no one can match your identity to the answers that you provide. If any pictures taken from this study are shown for academic demonstration, the image related to your identity will be blurred and protected. No reference will be made in oral or written reports which could link you to the study. Any link of your subject number with your identity will be destroyed at the completion of the research.

Compensation
For participating in this study you will receive compensation at the rate of $10/hour. It is expected that the study will take 2 hours and that you will receive $20. If you withdraw from the study prior to its completion, you will receive compensation at a rate of $10/hour for the time committed to the experiment up to that point. In the event that the experiment takes more than 2 hours, you will be paid a prorated amount for any time provided at the aforementioned rate.

Emergency Medical Treatment
If you need emergency medical treatment during the study session(s), the researcher(s) will contact the University's emergency medical services at 515-3333 for necessary care. There is no provision for free medical care for you if you are injured as a result of this study.

What if you are a NCSU student?
Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you are a NCSU employee?

Participation in this study is not a requirement of your employment at NCSU, and your participation or lack thereof, will not affect your job.

What if you have questions about this study?
If you have questions at any time about the study or the procedures, you may contact Dr. David Kaber, at the Department of Industrial and Systems Engineering, Box 7906, North Carolina State University, or (919) 515 3086.

What if you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled. I confirm that I am at least 18 years of age."

Subject's signature____ Date _________________

Investigator's signature____________________________________ Date _________________

Appendix B: Demographic Questionnaire

Subject #:___ Date:_______
Researchers Present:__________

Demographic Questionnaire

Age: ________
Gender: ________

Have you ever used an extension ladder before? If so, how many times per year?

Have you ever been injured while using a ladder? If so, please describe the incident and your resulting injury.

Do you know of anyone who has been injured while using a ladder? If so, please describe the incident and the resulting injury.

Appendix C: Risk Assessment Questionnaire

Subject #:___ Date:_______
Researchers Present:__________

Risk Assessment Questionnaire

Below you will find a list of different factors that could lead to falls from a ladder. A scale from 1 to 10 is provided under each factor. For each factor please circle the number that represents your perception of the risk of fall and injury due to the particular factor. Consider 1 to be "no risk" and 10 to be "extreme risk."

<u>Ladder tilting sideways</u>

1 2 3 4 5 6 7 8 9 10
No risk Extreme risk

<u>Losing balance due to overreaching</u>

1 2 3 4 5 6 7 8 9 10
No risk Extreme risk

<u>Ladder sliding out at the base</u>

1 2 3 4 5 6 7 8 9 10
No risk Extreme risk

<u>Foot misstep/slip</u>

1 2 3 4 5 6 7 8 9 10
No risk Extreme risk

<u>Ladder mechanical failure (ladder broke)</u>

1 2 3 4 5 6 7 8 9 10
No risk Extreme risk

Appendix D: Experiment Script

Instructions for Experimenter and Participants

[Place the clipboard with instructions, consent forms, background information survey, and risk questionnaire on the table next to the laptop for the computer-based test. Follow the preparation procedures.]

Materials:

2 Copies of Consent Form
2 Copies of Payment Form
Demographic questionnaire
Survey
Will’s laptop (or another source of the CBT)
2 Ladders
Set up 2 target areas outside
Anagram Test
Manual goniometer
Tape Measure
Camera

Introduction

Hello, thank you for participating in our study. The purpose of this study is to assess your awareness of potential risk factors in relation to using extension ladders. We are interested in identifying levels of perceived risk that users associate with different ladder configurations. The total time for the study will be around 2 hours without interruptions. You may be photographed during the experiment, but you anonymity will be preserved by blocking your face in any images that might be disseminated. (Please turn off your cell phone for the experiment to prevent distraction. Please also place your watch or other jewelry in a pocket to prevent damage.)

Informed Consent

[Prepare the informed consent form (2 copies; one for the subject and one for the university) and a pen.]

This form summarizes information you need to know about the experiment. Please read it. If you have any questions, feel free to ask me. Please note that in order to participate in this study you should be between ages 18 and 65 years, have 20/20 vision (with or without correction) be able to perform dexterous actions with both hands, have no major upper or lower extremity impairments, and have no professional experience working with extension ladders. You will receive $10/hour for your participation. If you consent to participate, please sign and date the form.

Overview of the Experiment
The experiment consists of two sessions: a computer based test and formal testing. In the formal testing, there will be **4** test trials.

The steps as part of the experimental procedure include:

1. Completion of an informed consent form (10 mins)
2. Completion of questionnaires (10 mins)
   A. a background survey
   B. a ladder configuration risk assessment questionnaire
3. Computer-based testing of ladder climbing safety (30 mins)
4. Training session: Explanation of test trials and exposure to ladder equipment setup (15 mins)
5. Formal testing (50 mins) with completion of an anagram worksheet between each trial
6. Completion of experiment, payment and debriefing (5 mins)

Questionnaire

[Have a subject sit at the table, and present them with the clipboard with the background information survey and risk questionnaire]

Please answer the following questions honestly and to the best of your ability. Answers to questions will be kept strictly confidential. If you have any questions please feel free to ask me.

CBT

[Collect questionnaire sheets and start the computer-based test]

Once this test begins, you will be shown a series of images of ladders setup as if a person was to climb to the top. On each computer screen, you will have the option to click “Yes” or

"No." A "Yes" answer will indicate that you would climb this ladder. A "No" answer will indicate that you deem this ladder unsafe and would not climb. Please take you time and answer each question to the best of your ability.

[Upon completion]

We will now walk to the courtyard of Daniels Hall for the completion of the formal experiment testing. Please bring a jacket if necessary. You may leave your personal belongings in the Lab. We will return to fill-out payment forms.

Training: Explanation of test trials

[Obtain both ladders, the manual goniometer, camera, notepad for the experimenter, tape measure. Bring all equipment to the courtyard. Also bring the clipboard and the anagram test.]

Please inspect this ladder. Make note of all warning labels.

[Allow time for inspection]

I will now show you the basic steps in setting-up the ladder. Basic ladder setup is achieved by lifting it into position, raising the fly section, and placing the ladder against the building. For this experiment, we will be extending the ladder to its full length in each trial. I will now demonstrate this for you.

[Erect ladder, and then take down].

Now for your training you will replicate the same procedure with my assistance.

[Assist them in erecting the ladder, and then taking it down].

Formal Testing

You will now begin the formal testing.

[Repeat four times.]
[Retrieve desired ladder (label Y/N) and bring to the setup area]

You will now setup this ladder to reach the target area marked on the wall. The target area is marked with a white piece of poster board and will say "Target 1" or "Target 2". Your goal is to paint the entire white target area. During each trial, you will extend the ladder to its maximum length, as previously demonstrated.

For this trial, you will be painting the area marked with [Insert Target 1 or Target 2 based on the trial a subject is to complete.] In all trials, you may not place the ladder over the marked target area, and you may not reach though the rungs to paint. The pink areas of the wall represent wet paint, on which you may not set the ladder. Please setup the ladder based on your training and the earlier demonstration. An experimenter will help you in positioning the ladder but will provide no advice during the trial.

[Once setup is complete, measure the ladder setup angle with the goniometer and note the location of the ladder (below or left/right).]

Please come and sit down over here (on this seat) and take a 2-minute break. During the break, please fill out this worksheet.

[Lead subject over to bench and present anagram worksheet.]

Do you need anymore time to rest? If not we will proceed with the next trial.
[Repeat.]

We are now complete with the experiment. Please come with me back to the Lab to fill out your payment information.

[Return to lab.]

Departure and thank you

Now the experimental session has finished. Please fill-out this payment form. The compensation for you today is $XX.

[Let the participant fill-out the payment form.]

The data we collected today will be used to study risk perception while using extension ladders. If you are interested in future information about this study or have any questions, please contact Dr. Kaber. His contact information is listed in the consent form that you will bring home with you today.

[Give the participant a copy of the consent form and their payment form. Give them directions to Hakan Sungur's office to collect their payment.]
Thank you for participating in this study.

Appendix E: Anagram Tests

Subject #:___ Date:_______

Researchers Present:__________

Anagram Test 1

Please rearrange the letters on the left to make a new word. Please use all the letters. Write your answers to the right.

1. O G D ________________
2. T A C ________________
3. N A E K S ________________
4. O I N L ________________
5. G I E T R ________________
6. L F O W ________________
7. N A H P E E T L ________________

Subject #:___ Date:_______
Researchers Present:__________

Anagram Test 2

Please rearrange the letters on the left to make a new word. Please use all the letters. Write your answers to the right.

1. R C A ________________

2. N T R A I ________________

3. U R K T C ________________

4. E L P A N ________________

5. O A T B ________________

6. R C A T T O R ________________

7. Y C R O T M L E O C ________________

Subject #:___ Date:_______
Researchers Present:__________

Anagram Test 3

Please rearrange the letters on the left to make a new word. Please use all the letters. Write your answers to the right.

1. L O C D ________________

2. O W N S ________________

3. D S E L ________________

4. I N T E R W ________________

5. C E I ________________

6. I K S A C J E T K ________________

7. T I M T E N S ________________