Dual-Task Performance During Traverse Climbing: Human Factors Implications for Emergency-Response Organisations

A dissertation submitted in partial fulfilment of the requirements for the degree of

Masters of Science in Applied Psychology

at the

University of Canterbury

by

Alexander Louis Green

2012

Research Supervisors:

Dr. William (Deak) Helton

Dr. Nick Draper

Table of Contents

Acknowledgements

I would like to thank Deak Helton for all of his insight throughout the course of this research. I would also like to thank Nick Draper for his contribution of climbing expertise.

I would like to thank Kelvin Eder and his staff from the University of Canterbury Recreation Centre for being extremely accommodating in letting me use their indoor climbing facilities throughout the course of this research.

Finally, I would like to extend a big thank you to all of the climbers that participated in the study, as well as everyone who helped put me in contact with these climbers. Without the cooperation of all of you this research could not have happened.

Publication of Results

Some of the results presented in this dissertation have been published in the journal Experimental Brain Research. See:

Green, A. L., & Helton, W. S. (2011). Dual-task performance during a traverse climb. *Experimental Brain Research*, *215*, 307-313.

List of Figures

1. Abstract

Two experiments were conducted to investigate how performance on a primary rock climbing task is affected by the inclusion of a secondary word memory task. In Experiment 1, twelve experienced rock climbers completed a dual traverse climb and word memory task, with participants' performance analysed relative to their single task performance (climbing alone and word memory alone). Participants' climbing efficiency and word recall were significantly lower in the dual-task condition. Experiment 2 examined the effects of emotional content on climbing performance. Fifteen experienced rock climbers completed two dual-tasks, in which they were asked to recall negatively valenced or neutral words. Climbing efficiency, climbing distance, and word recall were all significantly lower in the dual-task conditions, relative to the single-task conditions. Climbing efficiency and climbing distance were also significantly lower in the negative word dual-task, relative to the neutral word dual-task. The findings from these two experiments have important human factors implications for occupational settings that require climbing-like operations, including search and rescue and fire-fighting.

2. Introduction

Rock climbing is physically and psychologically challenging activity that is performed both recreationally, and competitively, in a range of environments (Morrison & Schöffl, 2007; Sheel, 2004). There are a number of different styles of rock climbing, including: (a) top-rope climbing, where a safety rope passes through an anchor point located at the top of the route before returning to a belayer (a partner who stands at the base of the climb and helps support the climber in the case of a fall); (b) lead climbing, where the safety rope is clipped through a series of anchors along the route; (c) bouldering, which generally involves a short distance climb done without a safety rope, but usually with protective mats at the base of the climb (Draper, Jones, Fryer, Hodgson, & Blackwell, 2010; Sheel, 2004).

Rock climbing can vary greatly in difficulty. Climbing routes are given a difficulty rating based on factors such as the steepness of the terrain, the size and number of hand and foot holds, and the particular manoeuvres required in order to reach the holds (Sheel, 2004). A climb may have also been rehearsed by the climber, or done without prior practice, known as an 'on-sight' climb, which can add to the difficulty. The rating systems to grade climbing difficulty vary between countries, which can make it hard to compare climbs. New Zealand and Australia use the Ewbank grading system, which is an open-ended system based on the technical difficulty of the climb. Other rating systems include the Yosemite Decimal System, used in North America, and the British Technical grading system.

Developing a greater understanding of rock climbing through research into the physical and psychological factors involved in climbing is important in assisting the development of rock climbing as a sport. However, this research also has potentially important human factors applications for occupational settings requiring climbing-like operations. Such occupational settings include high-angle search and rescue, fire-fighting, and some military-law enforcement operations. For example, a high-angle search and rescue operation may involve descending, then ascending, a vertical rock surface in order to rescue a fallen hiker. These operations can also occur in urban environments, such as operations to rescue survivors in collapsed buildings, as was the case following the earthquake in Christchurch on February 22nd 2011. This type of work presents obvious dangers, not only to the life of the person, or persons, in need of rescue, but also the life of the rescue worker. By developing a greater understanding of the factors affecting human performance in activities such as climbing, organisations such as Land Search and Rescue New Zealand and the New Zealand Fire Service can implement additional steps to greater reduce the risk of harm to its workers, as well as those in need of rescue, ultimately resulting in more lives saved.

2.1 The Physical and Mental Demands of Climbing

Climbing is physically demanding, requiring strength (particularly in the forearms and digits), endurance, and flexibility (Giles, Rhodes, Taunton, 2006; Grant et al., 2001; Watts, 2004). Due to the particular physical demands of climbing, top-level climbers tend to be small in stature with a low percentage body fat, and therefore tend to have a high strength to body mass ratio (Giles et al., 2006; Watts, 2004). As much of the previous research on climbing has come from a sports science background, the literature has historically focused on climbers' physiological responses to the physical demands of the climb (Draper et al., 2011b). The findings regarding the physiological responses to climbing have been previously reviewed by Sheel (2004), Watts (2004) and Giles et al. (2006).

More recently there has been an increased focus on the psychological factors involved in climbing (Draper et al., 2010; Hardy & Hutchinson, 2007). Climbing presents a number of psychological challenges on top of the physical demands. Climbers are often required to manage the arousal of a difficult and possibly unknown route (as is the case in an on-sight climb), plan which holds to use and the particular manoeuvres to reach those holds, and overcome the potential anxiety regarding falling or possible injury (Morrison & Schöffl, 2007).

2.2 Past Research on the Psychological Factors Involved in Climbing

One psychological variable that has received attention within the climbing literature is the effect that anxiety can have on climbing. Whilst engaging in most sports involves some risk of potential harm or physical injury, these risks are particularly salient in rock climbing. Despite the safety equipment used to minimise the risk of accidents, rock climbing is still considered a high-risk sport. One error during a climb has the potential to result in a fall that could produce serious injury. The perceived risk of falling or possible injury can produce anxiety that can affect a climber's physiological responses and performance, as illustrated by a series of experiments conducted by Pijpers and colleagues (Pijpers, Oudejans, Holsheimer, & Bakker, 2003; Pijpers, Oudejans, & Bakker, 2005; Pijpers, Oudejans, Bakker, & Beek, 2006). The experiments consisted of having novice climbers complete two identical top-roped traverse climbs (in terms of number of holds and distance between holds), but at differing heights. In the *low* condition the height of footholds ranged between 0.3 m - 0.44 m from the ground. In the *high* condition the height of footholds ranged between 3.6 m – 5.1 m from the ground. Participants reported experiencing significantly higher levels of anxiety in the *high* condition (Pijpers et al., 2003, 2005, 2006). These higher levels of subjectively reported anxiety in the *high* condition were accompanied by physiological responses including higher heart rates, higher blood lactate concentrations, and greater muscle fatigue (Pijpers et al., 2003, 2005). The increased anxiety in the *high* condition also had a negative impact on climbing performance. Participants had significantly longer climbing times and displayed less efficient movements in the *high* condition, with participants also using a greater number of holds when multiple holds were available (Pijpers et al., 2003, 2005, 2006). The increased anxiety generated in the *high* condition also resulted in the reduction of perceived and actual maximal reaching height in climbers (Pijpers et al., 2006).

Whilst the results from the series of experiments conducted by Pijpers et al. (2003; 2005; 2006) reveal the wide-ranging effects anxiety can have on physiological and climbing performance outcomes, the participants used in the experiments were completely novice climbers, limiting the degree to which these results can be generalised to more experienced climbers. However, studies using more experienced climbers have produced some similar patterns of results. Hodgson et al. (2009) found a difference in subjective anxiety scores and reported self-confidence amongst intermediate climbers across climbing conditions designed to produce low, moderate, and high levels of physical and mental stress (a top-rope climb, a combined top-rope and lead climb, and a lead climb respectively). The more anxiety-provoking lead climb also produced slightly higher levels of plasma cortisol, which is often used as a more objective physiological marker of stress (Hodgson et al., 2009). Draper, Jones, Fryer, Hodgson, and Blackwell (2008) found that the climbing times of intermediate level climbers significantly increased when completing a subjectively more anxiety-provoking on-sight climb, compared with a rehearsed climb.

Anxiety has been shown to impact not only on a climber’s physiological responses and climbing performance, but also visual attention. Pijpers et al. (2006) projected lights onto the climbing wall in the vicinity of novice climbers whilst they were performing a traverse climb. As participants detected fewer lights in the *high* condition, it was concluded that anxiety narrowed the attention of climbers. Expanding on this study, Nieuwenhuys, Pijpers, Oudejans, and Bakker (2008) equipped novice climbers with an eye-tracking device whilst they completed two traverse climbs. They found that the increased climbing times in the *high* condition were accompanied by an increase in the number and average duration of visual fixations on climbing holds by participants. As participants in the *high* condition had a lower ratio of total fixations to total duration of fixations, this appeared to show that participants' processing efficiency decreased as a result of anxiety, as more time was needed to extract the relevant information from the holds (Nieuwenhuys et al., 2008). Pijpers et al. (2006) and Nieuwenhuys et al. (2008) have demonstrated the effects anxiety can have on visual attention during climbing, yet despite the growing focus on the role of psychological factors in rock climbing, there appears to be very little other research examining cognitive processes during rock climbing.

2.3 The Current Experiments

The purpose of the current two experiments is to examine the costs of dual-tasking in a climbing environment. Recreational climbers are sometimes required to perform additional tasks whilst climbing, such as to communicate with a belayer. As such, investigating dual-task performance in a climbing situation can aid the sport of rock climbing. However, this type of dual-task is also common in occupational settings that require climbing-like operations, such as high-angle search and rescue. For example, a search and rescue worker may be required to climb whilst simultaneously assessing the condition of the person in need of rescue, or communicating information to other search and rescue workers. In particular, it is likely that emergency-response workers, such high-angle search and rescue workers or fire-fighters, will be relayed information, via radio, that is crucial to the success of the operation. Examples of such information may include details of the floor plan of a collapsed building, or the expected number of people on each floor of the building. Attempting to climb whilst simultaneously attending to, and later recalling, such information could impair both a person's climbing performance and memory performance, potentially increasing the likelihood of them making an error. Such errors could put the worker at greater risk of harm, as well as potentially delaying the rescue operation, which places more lives at risk, especially in situations where time is extremely limited. To investigate whether there are any performance costs associated with such a dual-task, Experiment 1 examined the performance of climbers in a combined traverse climb and auditory word recall task, compared with their performance on a climbing-only task and memory-only task. Both climbing distance and climbing efficiency (holds/metre) were measured, as well as number of words recalled. Participants also completed four scales of the Dundee Stress State Questionnaire (DSSQ; Appendix A; Matthews et al. 1999; Matthews et al. 2002), which assesses arousal and thoughts occurring during the tasks.

During emergency-response operations, such as search and rescue or fire-fighting operations, workers will likely encounter things that will cause them to experience negative emotional states, such as casualties, or reports of casualties. The changes in psychological state brought about by negative emotions could produce additional performance impairments for emergency-response workers. Experiment 2 investigated the effects of negative emotional stimuli on performance by having climbers perform a dual traverse climb and auditory word recall task with either negatively valenced or neutral words. Performance in the two dual-task conditions was compared to performance in two memory-only conditions and one climbing-only condition. As well as completing the abbreviated DSSQ, climbers also completed the NASA-TLX perceived workload measure (Appendix B; Hart & Staveland, 1988), a measure of perceived climbing efficiency, and a measure of subjective physical exertion (Appendix C).

3. Experiment 1

Pijpers et al. (2006) used a dual-task to examine the effects of anxiety on visual attention during low and high climbs. No other studies have used this approach to examine other cognitive processes, such as memory, during climbing. However, previous studies have demonstrated that a simultaneous cognitive task can impair performance on other physical activities, including a simple task such as walking. When required to perform a dual walking and memory task, a person's gait speed has been shown to decrease (Lindenberger, Marsiske, Baltes, 2000; Yogev-Seligmann et al., 2010). Lindenberger et al. (2000) demonstrated that not only does a person's gait speed reduce when completing a simultaneous memory task, but their word recall also decreases, relative to when perform the memory task either sitting or standing. In dual-tasks such as this, it is common for there to be greater performance detriments in the secondary cognitive task, as participants prioritise postural stability in the primary motor task (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). Studies that have made the walking task more challenging (thus making it harder to maintain postural stability) by raising the height of the walking platform, restricting movement, or by adding obstacles, have all demonstrated increases in dual-task costs (Gage, Sleik, Polych, McKenzie, & Brown, 2003; Sparrow, Bradshaw, Lamoureux, & Tirosh, 2002; Siu, Catena, Chou, Donkelaar, & Woollacott, 2008).

Walking is a cyclic exercise, generally considered to be 'automatic', as it has been rehearsed to the level where it requires only minimal on-line attention and control (Brisswalter, Collardeau, & René, 2002; Beilock, Carr, MacMahon, & Starkes, 2002a; Beilock, Wierenga, & Carr, 2002b). However, it would appear climbing is significantly more demanding of attention. Research by Bourdin, Teasdale, and Nougier (1998) has indicated that maintaining a static climbing position requires greater attentional control than standing. Bourdin et al. (1998) also found that the attentional demands of a reaching movement whilst climbing almost double compared with remaining in a static climbing position, even in expert climbers. As such, it would appear that climbing cannot be considered 'automatic', as it requires greater on-line attention and control than many other physical activities would. Given that there are performance costs associated with a dual cognitive and 'automatic' cyclic physical task, such as walking, then we should expect even greater dual-task costs in an activity such as climbing, where the climber is constantly at risk of postural instability (i.e. falling).

3.1 Hypotheses

3.1.1 Climbing and Free Recall Memory Performance

Based on the previous research on climbing, as well as the dual-task literature, several hypotheses were developed.

Hypothesis 1: Participants will climb less efficiently in the dual-task condition than in the single-task climbing condition.

Climbing efficiency decreases when climbers have the additional demand of processing higher levels of anxiety (Pijpers et al., 2006; Nieuwenhuys et al., 2008). Processing anxiety requires additional attentional resources that can reduce performance efficiency (Eysenck & Calvo, 1992). As the added load of a simultaneous memory task will also demand additional attentional resources, it is expected that participants will climb less efficiently in the dual-task condition.

Hypothesis 2: Participants will climb less distance in the dual-task condition than in the single-task climbing condition.

A decrease in climbing efficiency will mean that participants will need to make more movements during the climb. Given the physical demands of climbing, a decrease in climbing efficiency may result in greater climber fatigue during the dual-task condition. It is also possible that the memory task will cause climbers to pause more frequently in order to rehearse the words they have heard. As such, it is expected that the average total climbing distance will be lower in the dual-task condition.

Hypothesis 3: Participants will recall fewer words in the dual-task condition than in the single-task memory condition.

As word recall on a memory task has been shown to decrease when performing a simultaneous cyclic physical activity, such as walking (Lindenberger et al., 2000), it is expected that free memory recall performance will decrease in the dual climbing and memory task condition.

3.1.2 Dundee Stress State Questionnaire Results

Hypothesis 4: Participants' Energetic Arousal will increase in both climbing conditions (single-task climbing and dual-task conditions), relative to pre-task baseline levels.

Hypothesis 5: Participants' Tense Arousal will increase in both climbing conditions, relative to pre-task baseline levels.

As climbing puts participants at risk, it is expected that this will elevate arousal (both energetic and tense).

Hypothesis 6: Participants' Task-Related Thoughts will decrease in the memory-load conditions (single-task memory and dual-task conditions), relative to pre-task baseline levels.

Hypothesis 7: Participants' Task-Unrelated Thoughts will decrease in the memory-load conditions, relative to pre-task baseline levels.

As there is a cognitive load in both memory-load conditions, it is expected that this should prevent cognitive intrusions (both task-related and task-unrelated).

3.2 Method

3.2.1 Participants

Participants were twelve (9 men, 3 women) recreational climbers. The mean age of participants was 22.67 years (SD = 4.31 years). To be able to participate, participants were required to have enough climbing experience to be able to successfully climb a minimum New Zealand grade 17 indoor climbing route top-roped. As all participants could successfully climb grade 17 routes (and were now working on at least grade 18 routes) this meant that participants were climbing at an intermediate level or higher (Draper et al., 2011a). Although participants were bouldering, rather than performing a top-roped climb, participants' climbing ability was assessed based on a top-roped grade, as participants tended to be much more familiar with this grading system than the bouldering grading system. The mean maximum grade route that participants reported that they could successfully climb top-toped was 22 (SD = 3.29). Participants were recruited through known climbing associates and through advertisements at local indoor climbing centres. All participants were fluent speakers of English. Permission was granted by the University of Canterbury's Human Ethics Committee prior to commencing this research.

3.2.2 Materials

The experiment was conducted at the indoor climbing facility at the University of Canterbury Recreation Centre. The area of the climbing wall used for the experiment was 8.25 m in length. As participants were bouldering, and thus not harnessed, the height of the wall was restricted to a black-taped line set at a height of approximately 3.3 m. For safety reasons no climbing was allowed above this height. Large mats surrounded the base of the wall, providing protection in the case of a fall. The wall contained a variety of differing climbing holds, including larger jug holds and smaller crimp holds. Some sections of the surface of the wall were also protruding, allowing for additional climbing support. Participants brought their own climbing shoes.

The words used for the memory tasks were taken from the Paivio, Yuille, & Madigan (1968) Word Pool. The word pool contains a total of 925 nouns. Three word lists of 20 words were generated, with words randomly allocated to one of the three lists. To ensure that each of the word lists contained words that were equally memorable, only words within the range of following variable parameters were selected: Number of syllables: 2; Number of letters: 5-7; Meaningfulness rating: 6-8; Concreteness rating: 6-7; Imagery rating: 5-7; Kucera-Francis word frequency: 0-30. The word lists appear in Appendix D.

The word lists were recorded by a New Zealand male speaker. The words were recorded using a Behringer C-1 studio condenser microphone and the computer recording program Ableton Live. Scrambled versions of each of the words lists were created by cutting and rearranging the recorded sound file of each word using Ableton Live, creating words that were no longer recognisable as English speech. The recorded word lists were played to participants using Altec Lansing 121I dual speakers.

The four scales of the DSSQ that were used were: Energetic Arousal (EA), Tense Arousal (TA), Task-Related Thoughts (TRT), and Task-Unrelated Thoughts (TUT). Each scale measured self-reported subjective states. The DSSQ instructions emphasise immediate responding to ensure respondents are reporting task-related subjective states, rather than traits.

3.2.3 Procedure

Upon arrival, participants were presented with an information sheet outlining the purpose of the experiment and instructions for the tasks they would be completing. Participants were also presented with a consent form. Participants were informed that they would be completing three separate conditions: a seated memory task; a traverse climbing task; and dual traverse climbing and memory task. Prior to beginning the experiment, participants warmed up by traversing back and forth along the climbing wall. This also allowed participants to become familiar with the layout of the holds on the wall. Once participants stated that they were sufficiently warmed up and familiar with the layout of the climbing wall, participants came down off the wall and completed the pre-task DSSQ. The pre-task DSSQ asked the participant to report experienced thoughts and feelings during the last 10 minutes. Following the completion of the pre-task DSSQ, participants began the first condition. The order of conditions was counterbalanced between participants, as was the order of the word lists.

For the memory task, participants were instructed to sit on the protective mat at the base of the climbing wall, facing the wall. Participants were informed that they would be played 20 words of a period of three minutes and that they would be asked to recall as many words as possible immediately after the three minute period. A high-pitched tone, preceded by three lower pitched tones, signalled the beginning of the task. The first word was played to participants 14 seconds into the task, with subsequent words played every 8 seconds. After the final word was played, there was an additional 14 seconds of silence before another high-pitched tone signalled the end of the three minute period. The words were played over the speakers that were located at the back wall of the climbing facility, approximately five metres from where participants were seated. Immediately following the final tone, participants were asked to write down as many of the 20 words as they could recall hearing on paper that was provided to them. Participants were given 90 seconds to recall as many of the words as they could.

Figure 1. Participants' starting position on the wall.

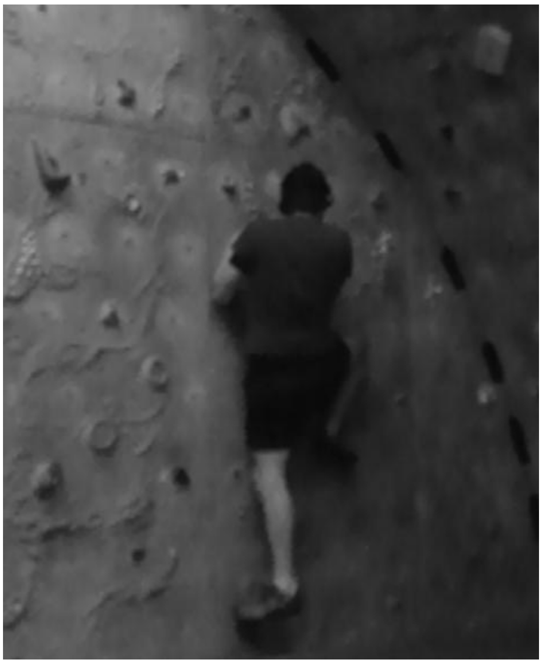

Figure 2. Participants' position on far right side of wall.

For the climbing task, participants were instructed to take position on the climbing wall prior beginning. Participants took position on the left side of the wall, where the main wall met the adjoining wall, with their left hand and left foot on separate holds on the adjoining wall, and their right hand and right foot on separate holds on the main climbing wall (see Figure 1). The task would begin once participants stated they were set in their position on the wall. The start of the climbing task was signalled by a high-pitched tone, preceded by three lower pitched tones. Upon hearing the higher pitched tone, participants began traversing towards the opposite side of the climbing wall. Participants were instructed that they could use any hold on the wall, and that they could ascend as high as the 3.3 metre black tape line that indicated the maximum safe bouldering height. Participants traversed across the climbing wall until they reached the final major panel on the far right side of the wall (see Figure 2). Once the participant had both hands and both feet on separate holds within the far right panel, they were instructed to traverse back to the left side of the wall. Once the participant had placed both hands and both feet on separate holds within the major panel on the far left side of the wall, they were instructed to again traverse back towards the right side of the climbing wall. Participants performed this continual traverse climb for the duration of the three minutes. If, at any stage during the traverse, a participant slipped off the wall, they were instructed to climb back on at the point where they slipped and continue the climb. During the traverse, participants were played 20 scrambled words from one of the scrambled word lists. The scrambled words were played so that participants were still receiving auditory input during the climb (as they would be receiving auditory input in the dual-task condition). However, as the scrambled words had been cut and spliced so that they no longer possessed meaning, it was expected that these words would be less likely to interfere with participants' climbing than meaningful words. Participants were instructed that they would not be required to recall anything they heard during the climb. As in the memory task, the first scrambled word was played to participants 14 seconds after the high-pitched tone signalling the start of the task. Subsequent words were played after every 8 seconds, with an additional 14 seconds of silence before the high-pitched tone signalled the end of the task. The scrambled words were played to participants through the same speakers located at the back of the climbing facility. Upon hearing the tone signalling the end of the task, participants were instructed to come down off the climbing wall. Participants were filmed during the climbing task in order to count the total number of hand holds and foot holds used in the traverse. Any time a participant removed his/her hand or foot from a hold, even if he/she placed it back on the same hold after removing it, this was counted as the use of a new hold. The total horizontal distance climbed was measured based on the number of climbing wall panels each participant crossed during the traverse. The climbing wall had six 1200 millimetre panels and one 1050 millimetre panel. The final location of the participant was measured by taking the mean distance between the two holds on which the participant had his/her feet placed at the sound of the tone that signalled the end of the task. The measurement between these two holds was taken from the point on the hold where the bolt anchored it to the wall.

The dual-task condition consisted of a combination of the memory task and climbing task. Participants performed the same traverse as in the climbing task. However, rather than being played scrambled words, participants were instead played 20 regular words. Participants were told that they would be asked to recall as many words as they could at the end of the climb. Participants were not instructed to prioritise either task. As in the memory task, there was a 14 second period of silence before the first word was played, with subsequent words played every 8 seconds, and a 14 second period of silence following the final word before a high-pitched tone signalled the end of the three minutes. Upon hearing the tone, participants came down off the wall and were immediately asked to write down as many words as they could recall hearing on the paper provided. As in the memory task, participants were given 90 seconds for recall. Participants were filmed during the dual task to measure the total number of holds used during the climb. The total horizontal distance climbed was also measured.

Participants completed the post-task DSSQ at the end of each condition. The post-task DSSQ asked participants to report feelings and thoughts that they had experienced during the task. In the memory-only and dual-task conditions, participants completed the post-task DSSQ immediately after they had finished recalling the words. However, as there was no recall required after the climbing-only condition, participants waited 90 seconds before completing the post-task DSSQ.

Participants were given at least 5 minutes between climbs to minimise the effects of fatigue in the second climb, with the option of additional rest time if needed. However, given the climbing ability of participants, and the relative ease of the traverse climb, no participant reported significant levels of fatigue before beginning the second climb.

3.3 Results

3.3.1 Climbing and Free Recall Memory Performance

As a priori directional hypotheses had been made, one-tailed directional *t*-tests were used in performance comparisons across the three conditions, as this provided a more powerful test of effects (Darlington & Carlson, 1987; Gaines & Rice, 1990; Hays, 1994). Differences in climbing efficiency (number of holds used per metre climbed), climbing distance (number of horizontal metres climbed), and memory performance (number of correctly recalled words) were each examined. As hypothesised, participants climbed more efficiently in the climbing-only condition (M = 5.80, SD = 2.50) than in the dual-task condition (M = 6.26, SD = 2.34), t_{11} = 1.94, p = 0.040, Cohen’s d = 0.20. However, no significant difference in total climbing distance was found between the climbing-only condition (M = 27.60, SD = 11.11) and dual-task condition (M = 25.79, SD = 11.40), t_{11} = 1.49, p = 0.082 [1]. As hypothesised, free recall memory performance was significantly better

[1] Whilst slips did occur in the climbing conditions, these were too infrequent to analyse.

in the memory-only condition (M = 11.83, SD = 2.73) than in the dual-task condition (M = 6.00, SD = 2.30), t_{11} = 10.14, p < 0.001, Cohen's d = 2.31.

3.3.2 Dundee Stress State Questionnaire Results

The four DSSQ subscales were analysed for differences across the four time points (pre-task baseline, post-memory task, post-climbing task, and post-dual-task) using a repeated measures analysis of variance. The analyses were significant for Energetic Arousal $F_{3,30}$ = 3.52, p = 0.027, Tense Arousal $F_{3,30}$ = 4.44, p = 0.011, and Task-Unrelated Thoughts $F_{3,27}$ = 4.67, p = 0.009. The analysis for Task-Related Thoughts was not significant, $F_{3,27}$ = 0.28, p = 0.842.

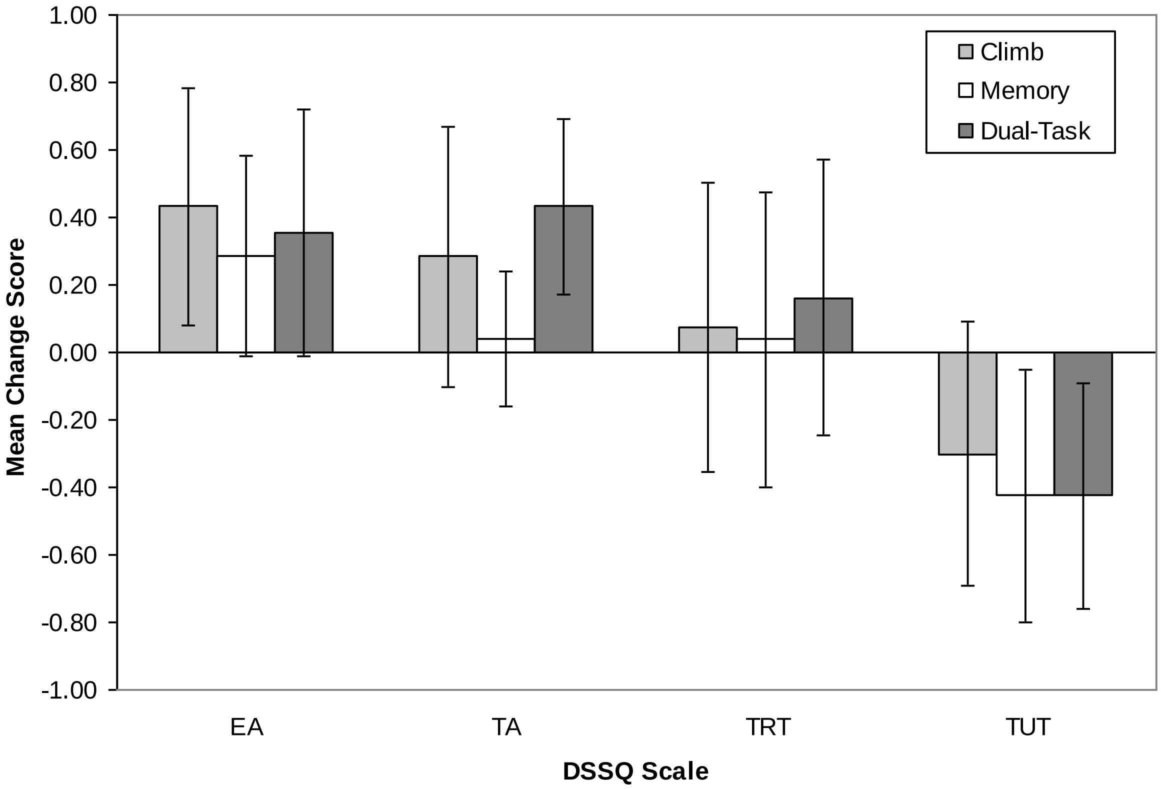

Figure 3. The mean DSSQ change scores for the three conditions.

Each participant's individual change scores for each scale were calculated. This was done using the formula d = (individual post-score – individual baseline-score), as has been performed in previous studies (Helton, Dember, Warm, & Matthews, 2000; Helton & Warm, 2008; Szalma, Hancock, Dember, & Warm, 2006). As all items were measured on the same five-point response scale, the unstandardised change scores were used, as has been recommended (Rogosa, 1995). A summary of the mean change scores is presented in Figure 3. In the figure, zero represents no change from the pre-task baseline. The errors bars represent 95% confidence intervals.

3.4 Discussion

The results of this experiment indicate that performing a dual climbing and word memory task impairs both climbing and word recall performance. Climbing efficiency was significantly lower in the dual-task condition than in the single-task climbing condition, supporting Hypothesis 1. The increased memory load in the dual-task condition appears to have negatively affected the climbing movements of participants. This finding is consistent with Pijpers et al. (2006) and Nieuwenhuys et al. (2008), whose studies found that climbers were less efficient when processing higher levels of anxiety during a climb. A significant decrease in free memory recall in the dual-task condition was also found, supporting Hypothesis 3. Given that free memory recall was close to 50% lower in the dual-task condition, relative to the single-task memory condition, this decrease was particularly large. Participants had reported, anecdotally, finding word recall in the dual-task condition much more difficult than they had expected. The decrease in word recall in the dual-task condition is consistent with the results of Lindenberger et al. (2000), who found that performance on a memory task decreased when participants performed a simultaneous walking task. However, the decrease in memory performance found in the dual-task condition used by Lindenberger et al. (2000) was not nearly as pronounced as the decrease in this experiment. This is likely due, in part, to the high attentional demands of climbing.

Despite a decrease in climbing efficiency, a significant difference in total climbing distance between the dual-task condition and single-task climbing condition was not found, as had been hypothesised. One explanation for this result may be that climbers prioritised the climbing task. Participants were not given instructions to prioritise either task in the dual-task condition. However, given that not climbing well put participants at risk of falling, it would not be unexpected that priority was given to climbing. This is consistent with the notion that priority is given to maintaining postural stability in a dual physical and cognitive task when there is a perceived threat of injury (Shumway-Cook et al., 1997). If priority was given to the climbing task, this would also help explain why there was such a significant decrease in word recall in the dual-task condition, relative to the single-task memory condition.

It had been hypothesised that a decrease in climbing efficiency in the dual-task condition would lead to a greater level of fatigue and thus result in less total average distance climbed, compared with the single-task climbing condition. An additional possible explanation as to why no significant difference in climbing distance was found is that the duration of the climbing task was not long enough for the effects of fatigue to set in. Given that participants were all proficient climbers, it could be that the three minute duration of the climb was not long enough to detect the effects of fatigue resulting from less efficient movements. Whilst the difference found in average total distance climbed between the dual-task and single-task climbing conditions was not significant, it was in the hypothesised direction. Had the two climbs lasted longer than three minutes, we may have expected to find a significantly lower average total distance climbed in the dual-task condition.

The results of the DSSQ show that participants' Energetic Arousal was elevated following the single-task climbing condition, relative to the baseline, providing partial support for Hypothesis 4. Participants' Tense Arousal was elevated following the dual-task condition, relative to the baseline, providing partial support for Hypothesis 5. The memory load of the single-task memory and dual-task conditions suppressed Task-Unrelated Thoughts, supporting Hypothesis 7. The demand of focusing on the words to recall appeared to prevent participants from thinking about task-irrelevant information. However, there was no reduction in Task-Related Thoughts in either the single-task memory or dual-task conditions, as had been hypothesised.

4. Experiment 2

Emergency-response workers frequently face exposure to potentially traumatic situations, with the knowledge that peoples' lives may depend on their performance. Given the hazardous environments that emergency-response workers may find themselves working in, it is not only the lives of those in need of rescue that may be at risk, but also the life of the worker. As such, emergency-response operations can present a stressful and emotionally-charged working environment. Given the types of situation that an emergency-response worker may face, it is possible that they will experience negative emotional states during an operation. Such changes in an emergency-response worker's psychological state could potentially affect their performance during an operation, thus affecting the overall success of the operation.

Past research examining psychological states has tended to focus on the effects of arousal and stress on performance (Coombes, Janelle, & Duley, 2005). As stress and emotion have generally been treated as separate dimensions, the impact of emotion on performance has been relatively neglected (Lazarus, 2000). More recently, however, research has begun to further examine the relationship between emotion and performance, including the relationship between emotion and motor action (Eccles et al., 2011). The relationship between emotion and motor action is believed to originate in circuitry that automatically primes approach behaviour towards pleasant stimuli, and avoidant behaviour away from unpleasant stimuli (Chen & Bargh, 1999; Eccles at al., 2011). This was supported in two experiments by Chen and Bargh (1999), in which participants were required to push or pull a lever in response to stimuli. Participants were found to be faster to push the lever away from them (avoidant behaviour) in response to negatively valenced stimuli, but faster to pull the lever towards them (approach behaviour) in response to positively valenced stimuli.

Other studies have also demonstrated a relationship between emotional stimuli and fine motor control. Coombes et al. (2005) had participants complete a square tracing task immediately following exposure to pleasant, unpleasant, or neutral images. It was found that a short exposure to negative images resulted in an increase in tracing task errors, whilst a long exposure to negative images resulted in an increase in tracing task speed. Coombes, Gamble, Cauraugh, & Janelle (2008) had participants complete a pinch-grip task whilst simultaneously exposing them to pleasant, unpleasant, or neutral images. They found that pinch-grip force increased in response to both the pleasant and unpleasant images, relative to the neutral images. The results of Coombes et al. (2008) demonstrate that emotion can affect motor control even when force is not directed towards, or away from, the body.

Whilst the studies conducted by Chen and Bargh (1999) and Coombes et al. (2005, 2008) provide evidence of emotional stimuli affecting motor action, the physical tasks used in these experiments were relatively simple. To my knowledge, there have been no experiments that have examined the effects of emotion on more complex physical tasks, such as climbing. Successful climbing obviously requires the climber to maintain stability throughout the duration of the climb. There is evidence to suggest that negative emotional stimuli can produce changes in postural control and stability. People have been shown to demonstrate immobility, or ‘postural-freezing’, when presented with images of mutilation (Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Azevedo et al., 2005). Other studies have also demonstrated effects of negative emotional stimuli on postural control, however, the results have been somewhat mixed (Hillman, Rosengren, & Smith, 2004; Stins & Beek, 2007; Horslen & Carpenter, 2011).

Whilst the precise effects of emotion on postural stability are unclear, it does appear that negative emotional stimuli do have some effect on postural stability. If postural stability were to be affected during a climbing activity, such as by the occurrence of postural freezing at the presentation of negative emotional stimuli, then it could be expected that this will make the physical movement of climbing more difficult. Negative emotional stimuli may also result in climbers making more errors in reaching movements for holds, or using excessive force in gripping holds, in line with the results of Coombes et al. (2005, 2008). This is likely to disrupt overall climbing efficiency. Climbing also presents a number of cognitive challenges, as well as physical challenges, as has been previously described. As negative emotional stimuli have been shown to interfere with performance on a primary cognitive task (Schimmack, 2005; Helton & Russell, 2011), it could be expected that negative emotional stimuli may also interfere with a climber's ability to plan their climbing route, further impeding climbing ability.

4.1 Hypotheses

4.1.1 Climbing and Free Recall Memory Performance

Based on the results of Experiment 1, and the previous findings on the effects of negative emotional stimuli on motor action, postural stability, and cognitive performance, several hypotheses were developed.

Hypothesis 1: Participants will climb less efficiently in the two dual-task conditions than in the single-task climbing condition.

Hypothesis 2: Participants will climb less distance in the two dual-task conditions than in the single-task climbing condition.

As participants climbed less efficiently in the dual-task condition than in the single-task climbing condition in Experiment 1, a similar pattern of results is expected in this experiment. Despite not finding a significant difference in the average total distance climbed between the dual-task condition and single-task climbing condition in Experiment 1, a significant difference in climbing distance is expected in this experiment, as the inclusion of an additional climbing condition is expected to accentuate the effects of fatigue (as a result of climbing inefficiently).

Hypothesis 3: Participants will climb less efficiently in the dual-task condition with negatively valenced words than in the dual-task condition with neutral words.

Hypothesis 4: Participants will climb less distance in the dual-task condition with negatively valenced words than in the dual-task condition with neutral words.

As the negative words are expected to cause interference to participants' motor control and postural stability, as well as potentially causing increased disruption to their ability to plan their moves, climbing efficiency is expected to be lower in the dual-task condition with negatively valenced words, relative to the dual-task condition with neutral words. This decrease in efficiency is expected to be accompanied by a lower average total distance climbed in the dual-task condition with negatively valenced words, relative to the dual-task condition with neutral words.

Hypothesis 5: Participants will recall fewer words in the two dual-task conditions than in the two single-task memory conditions.

As participants recalled significantly fewer words in the dual-task condition, relative to the single-task memory condition, in Experiment 1, it is expected that in this experiment participants will also recall fewer words in the two dual-task conditions, relative to the two single-task memory conditions.

4.1.2 Participant Self Reports

The main purpose for use of the subjective scales is to investigate whether any changes in climbing performance across conditions is accompanied by similar changes in reported climbing performance by participants. That is, whether participants are aware of any changes in their climbing performance as a result of the particular condition. The specific performance scales of interest include the NASA-TLX Performance scale, the Climbing Efficiency scale, and the Physical Exertion scale. Changes in participants' level of arousal, as measured by the Energetic Arousal and Tense Arousal scales of the DSSQ, in each of the three climbing conditions are also of interest. As the use of the self-report scales in this experiment is for exploratory purposes, no specific directional hypotheses were made.

4.2 Method

4.2.1 Participants

Participants were fifteen (10 male, 5 female) rock climbers. The mean age of participants was 23.4 years (*SD* = 4.97). The climbing ability criterion for participation in this experiment was set slightly higher than in Experiment 1, with participants required to be able to successfully ascend a Ewbank grade 19 top-roped climb in order to be able to participate. The mean maximum grade route that participants reported that they could successfully climb on-sight was 23 (SD = 2.12). Participants were recruited through known climbing associates and through the University of Canterbury Climbing Club. Some of the participants had participated in Experiment 1. All participants were fluent speakers of English. Permission was granted by the University of Canterbury's Human Ethics Committee prior to commencing this research.

4.2.2 Materials

The experiment was conducted using the same indoor climbing wall as was used in Experiment 1. The positions of holds on the wall also remained identical to Experiment 1.

The word lists used for the memory tasks were created using words from the list of Affective Norms for English Words (ANEW; Stevenson, Mikels, & James, 2007a, 2007b). The ANEW list contains 1,034 nouns, verbs, and adjectives that have been rated on five emotional categories: happiness, sadness, disgust, anger, and fear. Each word has a mean rating of between 1 and 5 on each of the emotional categories. The two negative word lists used in the experiment were created by taking the 40 words that had the highest mean fear rating (combined for both males and females). The list of 40 negative words was randomly split, creating two lists of 20 words. The negative word lists appear in Appendix E. The neutral word lists were created by taking a random sample of 40 words (out of 82) that had a mean rating of less than 2 on each of the five emotional categories. Any words that had appeared in the word lists used in Experiment 1 were excluded. The list of 40 neutral words was also randomly split, creating two lists of 20 words. The neutral word lists appear in Appendix F. The list of 20 scrambled words used in the single-task climbing condition was created by randomly selecting five words from each of the four word lists.

The words lists were recorded using a Behringer C-1 studio condenser microphone and the recording program Ableton Live. The words were recorded by a New Zealand male speaker. The scrambled word sound files were modified using the same audio splicing technique as used in Experiment 1, so that the list of words was no longer recognisable as English speech. The words were played to participants using a Logitech ClearChat PC Wireless headset that was connected to an HP ProBook laptop. The headset cancelled out a significant amount of external noise.

The same four scales of the DSSQ used in Experiment 1 were used. The NASA-TLX was also used as a measure of perceived workload during the tasks. The NASA-TLX consists of six scales: Physical Demand; Mental Demand; Temporal Demand; Effort; Performance; and Frustration Level (Hart & Staveland, 1988). Two other subjective scales were also developed for the purpose of Experiment 2. The first scale was a climbing efficiency scale. Participants were asked to rate how efficiently they felt they had climbed on a 10-point Likert scale. The second scale was a physical exertion scale relating specifically to climbing. The scale asked participants to rate how 'pumped' their arms were on a 10-point Likert scale. The term 'pumped' is a colloquial term used by climbers to describe their level of fatigue following a climb.

4.2.3 Procedure

Upon arrival, participants were presented with an information sheet outlining the purpose of the experiment and instructions for the tasks they would be completing. Participants were also presented with a consent form. Participants were informed that they would be completing five separate conditions: a traverse climb task; a seated memory task with neutral words; a seated memory task with negatively valenced words; a dual traverse climb and memory task with neutral words; and a dual traverse climb and memory task with negatively valenced words. A 5 X 5 Latin square design was used to determine the order of conditions completed participants (Giesbrecht & Gumpertz, 2011). Two complete squares of conditions were completed by the ten male participants and one complete square was completed by the five female participants, thus balancing the order across sexes. The words lists were counterbalanced between the seated memory task conditions and dual-task conditions. Participants were informed of the order in which they would be completing the conditions prior to commencing. Participants were also informed that they would be given at least 5 minutes between climbing conditions to minimise the effects of fatigue, with the option of taking additional time if needed.

As in Experiment 1, participants warmed up prior to commencing the first condition by traversing back and forth along the climbing wall. Once participants stated they were sufficiently warmed up and familiar with the layout of the climbing wall, participants climbed down off the wall and completed the pre-task DSSQ. After completing the pre-task DSSQ, participants began the first condition.

The climbing task used was identical to Experiment 1. Participants received the same instructions as were given in Experiment 1. During the climbing-only condition, participants were played the scrambled word list so that they were still receiving auditory input during the climb, although this auditory information lacked meaning. The distance climbed by participants was measured using the same approach as Experiment 1. Participants were again filmed in each of the climbing conditions, in order to determine the number of holds they had used during the climb. The same instructions were given for the memory tasks as were given in Experiment 1. However, instead of a single memory-only condition, participants completed two separate memory-only conditions: one in which they were played neutral words, and one in which they were played negative words. The same instructions were also given for the dual-tasks as were given in Experiment 1. However, instead of completing a single dual-task condition, participants completed two dual-task conditions: one in which they were asked to played neutral words during the climb, and one in which they were played negative words during the climb.

The beginning and end of each task was signalled to participants by the same series of tones used in Experiment 1. The words played to participants in each of the five conditions were kept to the same intervals as used in Experiment 1. The words played during each of the tasks were randomly selected to play to either the left ear of input or right ear of input. White noise sounded in the other ear of input whenever a word was played. This was designed to make the task slightly more difficult, as well as more closely simulating a potential real-world situation. The words were played to participants through the wireless headset. The headset was held in place by an adjustable Velcro strap that wrapped around the back of participants' heads to prevent it from slipping off during the climbing conditions.

Participants completed the post-task DSSQ and NASA-TLX at the end of each condition. The Climbing Efficiency and Physical Exertion scales were also completed following the climbing-only and dual-task conditions. Participants began completing the scales immediately after the 90 seconds that was given for word recall. However, as no recall was required in the climbing-only condition, participants waited 90 sec after coming down off the wall before they were given the scales to complete, in order to keep the timing consistent across each condition.

4.3 Results

4.3.1 Climbing and Free Recall Memory Performance

To test the hypotheses regarding climbing performance, pre-planned one-tailed orthogonal contrasts were conducted (Darlington & Carlson, 1987; Gaines & Rice, 1990; Hays, 1994). Climbing efficiency (number of holds used per metre climbed) and climbing distance (number of horizontal metres climbed) were compared between the climbing-only condition and combined dual-task conditions. Participants were significantly more efficient in the climbing-only condition (M = 5.01 holds/metre, SE = 0.19) than in the combined dual-task conditions (M = 5.22 holds/metre, SE = 0.13), $t(14) = 2.25$, $p = 0.02$, Cohen's $d = 0.33$. Participants also climbed significantly more distance in the climbing-only condition (M = 29.47 m, SE = 1.57) than in the combined dual-task conditions (M = 27.12 m, SE = 1.07), $t(14) = 3.88$, $p < 0.001$, Cohen's $d = 0.45$. Climbing performance was then compared between the two dual-task conditions. Participants climbed more efficiently in the neutral word dual-task condition (M = 5.10 holds/metre, SE = 0.15) than in the negative word dual-task condition (M = 5.34 holds/metre, SE = 0.15), $t(14) = 2.06$, $p = 0.03$, Cohen's $d = 0.41$. Participants also climbed significantly more distance in the neutral word dual-task condition (M = 27.88 m, SE = 1.31) than in the negative word dual-task condition (M = 26.37 m, SE = 0.93), $t(14) = 1.91$, $p = 0.04$, Cohen's $d = 0.34$[2].

To investigate the possibility of an interaction between emotional word content and task condition in memory performance, the number of words recalled were analysed with a 2 emotional content (negative versus neutral words) by 2 task condition (climbing versus seated) repeated measures Analysis of Variance (ANOVA). Significantly more words were recalled in the two memory-only conditions (M = 12.77, SE = 0.74) than in the two dual-task conditions (M = 7.27, SE = 0.47), $F(1, 14) = 55.97$, $p < 0.001$, $\eta_p^2 = .80$. All other results were non-significant, p > 0.05.

4.3.2 Participant Self Reports

The mean post-task self reports for the NASA-TLX Performance scale, Physical Exertion scale (feeling 'pumped), Climbing Efficiency scale, DSSQ Tense Arousal scale, and DSSQ Energetic Arousal scale for the three climbing conditions are displayed in Figure 4. As the focus was on whether participants appeared aware of any effects that the negative words

[2] As in Experiment 1, slips that occurred during the climbing conditions were too infrequent to analyse.

had on their climbing, pre-planned orthogonal contrasts were conducted in a similar manner as used for climbing performance to test for differences in self-reports made following the climbing conditions. However, as there were no specific directional hypotheses, two-tailed contrasts were used. Helmert contrasts in repeated measures ANOVA were used (Field, 2000). For the NASA-TLX Performance scale, a significant difference was found between the climbing-only condition and the combined dual-tasks, $F(1, 14) = 11.39$, $p < 0.01$, but not between the negative dual-task and neutral dual-task conditions, $p > 0.05$. Neither contrast was significant for the Physical Exertion scale, $p > 0.05$. For the Climbing Efficiency scale, a significant difference was found between the climbing-only condition and the combined dual-tasks, $F(1, 14) = 8.75$, $p < 0.01$, but not between the negative dual-task and neutral dual-task conditions, $p > 0.05$. Neither contrast was significant for the DSSQ Energetic Arousal scale, $p > 0.05$. For the DSSQ Tense Arousal scale, a significant difference was found between the climbing-only condition and the dual-tasks, $F(1, 14) = 23.05$, $p < .01$, but not between the negative and neutral word climbing conditions, $p > .05$.

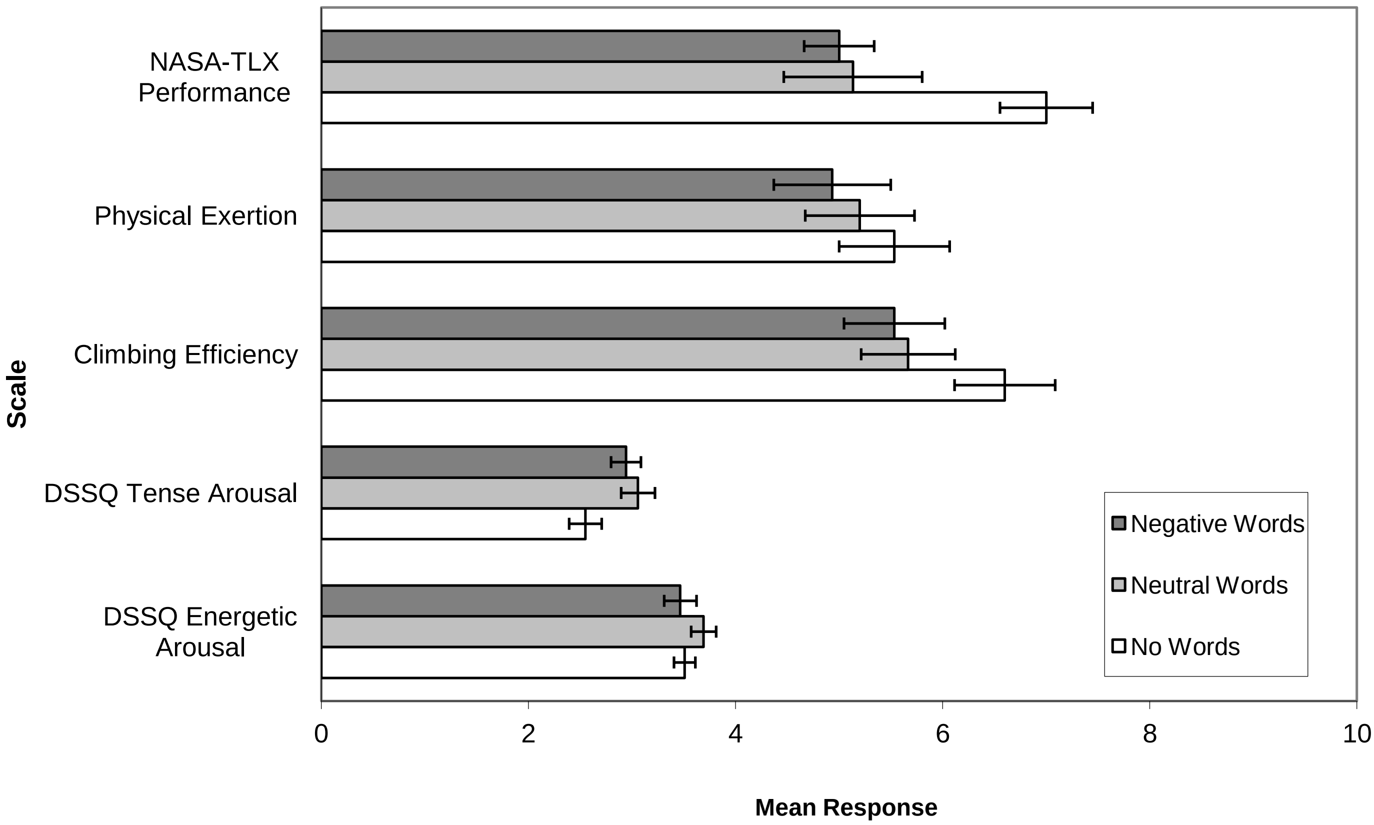

Figure 4. Participants' mean responses on self-report across the three climbing conditions.

4.4 Discussion

The results of this experiment support the findings of Experiment 1, with climbing performance and free recall memory performance decreasing in the dual-task conditions, relative to the single-task conditions. Participants were both significantly more efficient and climbed significantly more distance in the climbing-only condition, compared with the two dual-task conditions, supporting both Hypotheses 1 and 2. In Experiment 1, no significant difference was found in the total climbing distances between the dual-task and climbing-only conditions. However, as this experiment contained an additional climbing condition, and participants were thus climbing for a longer period of time, it is believed that the costs of climbing inefficiently were greater, contributing to a significant difference in total average climbing distance being found. Participants also recalled significantly fewer words in the dual-task conditions, compared with the memory-only seated conditions, supporting Hypothesis 5. The decrease in the number of words recalled across the dual-task conditions was again particularly large. The percentage decrease in words recalled in the dual-task conditions, relative to the memory-only conditions, was 43%, effectively replicating the percentage decrease in word recall found in Experiment 1.

Not only was there a difference found in climbing performance between the climbing-only condition and dual-task conditions, but a significant difference in climbing performance was found between the two dual-task conditions. Participants were both significantly more efficient and climbed significantly more distance in the neutral word dual-task condition than the negative word dual-task condition, supporting both Hypothesis 3 and 4. This indicates that the negative stimuli caused greater disruption to participants' ability to climb than the neutral stimuli. This result provides further evidence of the effect of emotion on motor action. Whilst emotional stimuli have been demonstrated to affect specific motor actions, such as hand coordination or pinch-grip force (Chen & Bargh, 1999; Coombes et al. 2005, 2008), this result suggests that emotional stimuli also affect motor control on more complex physical activities.

The decreased climbing efficiency and lower average total distance climbed in the negative word dual-task condition present a similar pattern of results as the decreased efficiency and longer climbing times of novice climbers who were experiencing increased levels of anxiety as a result of performing a climb at height (Pijpers et al., 2003, 2005, 2006). This similar pattern of results suggests that altering the emotional content of a secondary task can affect climbing performance in a manner similar to altering the physical nature of the climbing task. A possible explanation for this is that the processing of emotion consumes some of the cognitive resources required for motor planning, or that it alters the climber's focus of attention. One other possible explanation is that the negative emotional content resulted in a type of 'postural freezing' that produced a more conservative climbing style.

The subtle nature of changes to motor behaviour, as a result of the negative emotional stimuli, is evidenced in the self-report data. Participants recognised that their climbing performance suffered as a result of the dual-task, with lower mean NASA-TLX Performance scale and Climbing Efficiency scale ratings for the two dual-tasks, relative to the mean ratings in the climbing-only condition. Participants also reported elevated levels of stress following the dual-tasks, with higher Tense Arousal present in the dual-task conditions, relative to the climbing-only condition. No significant differences were found in ratings across the Physical Exertion or Energetic Arousal scales. Whilst participants appeared to recognise the costs to climbing performance as a result of the dual-task, they did not appear to recognise the additional impairment caused by the negatively valenced words. No significant differences were found in the mean ratings of the self-report measures of performance between the two dual-task conditions, even though climbing efficiency and distance climbed were lower in the negative word dual-task. Neither was there any significant difference in reported levels of Energetic Arousal or Tense Arousal. This suggests that people may not be conscious to the effects that emotional stimuli have on their motor behaviour.

5. General Discussion

Experiment 1 demonstrated the performance costs associated with a dual climbing and memory task. Both climbing efficiency and free recall memory performance were significantly lower in the dual-task condition, relative to the single-task conditions. These dual-task performance costs were replicated in Experiment 2. However, unlike Experiment 1, free recall memory performance, climbing efficiency, and climbing distance were all significantly lower across the dual-task conditions, relative to the single-task conditions in Experiment 2. Climbing efficiency and climbing distance were also found to be significantly lower in the negative word dual-task condition, relative to the neutral word dual task condition in Experiment 2. The findings from these two experiments present a number of potential applications, particularly for search and rescue and fire services, but also other fields including military and law enforcement.

5.1 Practical Applications

The results of the two experiments demonstrate the difficulty of performing a dual climbing and memory task. Yet this type of dual-task is not uncommon in settings such as search and rescue. For example, an urban search and rescue worker may need to climb through a collapsed building in order to search for survivors. During such an operation, a rescuer is likely to be in remote communication with other members of the rescue team. Based on the findings from these experiments, it could be expected that receiving auditory information during climbing, or other similar manner of physical movement, will impair a rescuer's performance. This type of dual-task is likely to affect a rescuer's physical performance, with a potential decrease in movement efficiency. Such a decrease in efficiency could lead to greater physical fatigue, especially as operations may require the worker to be active for long periods of time. If a rescuer is fatigued then they will be slower in reaching a target destination. Given that some situations may present only a small window of opportunity in which a successful rescue can take place, any delays may have a significant impact on the outcome of an operation. A decrease in efficiency of movement, coupled with an increase in physical fatigue, may also increase the likelihood of a slip occurring. Given the hazardous environments emergency response workers may be operating in, any slip could potentially endanger the worker.

Climbing whilst receiving information via remote communication may not just hinder a rescuer's physical performance, but also their cognitive performance. In both experiments word recall was close to 50% lower in the dual-task conditions. This represents a very large drop in the amount of communicated information able to be recalled whilst climbing. Such a large loss of auditory information in field settings, such as search and rescue operations, would be particularly significant. Given the importance of the information communicated in such field settings, greater priority is likely to be given to recall than was given by participants in the experiments. However, if greater priority is given to recalling information, this will likely cause even greater impairment to physical performance. Whilst the amount of auditory information lost during climbing in settings such as search and rescue operations may not be as high as 50%, even a small amount of information loss could have a significant impact. Due to the constructive nature of human memory, rescuers may be susceptible to experiencing memory distortions, or confabulation, during an operation (Schacter, 1995; McClelland, 1995). As some information communicated during movement is likely to be forgotten, a person's memory system may construct false memories in place of the lost information. For example, during a rescue a fire-fighter may incorrectly believe he or she was told that occupants were believed to be on the third floor of a burning apartment complex, when in fact he or she was told it was the fourth floor. Given the potentially large costs associated with such a mistake during a rescue operation, loss of information could have disastrous consequences.

One way to potentially reduce the problems associated with climbing and remote communication in emergency response operations would be through a communication management suite called Multi-Modal Communication (MMC; Finomore, Popik, Castle, & Dallman, 2010). MMC allows an operator to replay the last 10 seconds of dialogue, allowing them to repeat any information they may have missed. More importantly, MMC incorporates automatic speech recognition technology that can capture voice communication and display it in text form. Rather than having to attend to radio communication, as well as having to later recall this information, MMC would allow a rescuer to focus on the physical task at hand by maintaining a record of any communication. MMC technology could be incorporated into a smartphone, providing a light, portable device that a rescuer could easily check if they needed to clarify any information. Given the increased availability of smartphones, MMC would be made easily accessible to all members of an emergency response organisation, both professionals and volunteers. This is important given the number of volunteers involved in organisations such as Land Search and Rescue New Zealand and New Zealand Fire Service.

Whilst technology such as MMC could have great benefit to emergency response organisations, the results of the experiments raise doubts about incorporating the use of other aids, such as video eyewear technology. Video eyewear technology has become commercially available and this does present potential applications for emergency response work. For example, a fire-fighter could have a small video display mounted as part of his/her breathing apparatus. This would allow video or images, such as building floor plans, to be sent to the fire-fighter to help them navigate through their environment. This would be particularly useful in situations where visibility was low, such as in thick smoke. Whilst video eyewear technology presents benefits to rescuers in such situations, it may also have some costs for performance. In particular, the results from this study would suggest that such technology would significantly impair physical performance. As climbing performance was shown to be impaired by a secondary auditory task, then it could be expected that even greater impairment would occur if the secondary task involves visual processing, as this would provide greater competition for the visual and cognitive resources used for climbing (see multiple resource theory; Wickens, 2008).

The findings from Experiment 2 regarding the influence of affect on motor action also have applications for organisations involved in emergency response operations. Participants' climbing efficiency and climbing distance were lower in the negative word dual-task condition than in the neutral word dual-task condition, demonstrating that negative emotional content can impair physical performance. This is significant, given that emergency response workers are frequently exposed to situations of negative emotional content. It is important that emergency response workers are aware that emotion can impair their performance. However, the results of Experiment 2 also demonstrate that people may not be consciously aware of the effects that emotion can have on their motor behaviour, as no significant difference was found in the levels of self-reported measures of performance between the dual-task conditions. If a person is not aware of the impact of negative emotional content on their movement, they may fail to make appropriate adjustments, potentially increasing the likelihood of error. It is therefore important that members of organisations involved in emergency response are made aware of the effects of emotion on performance. This could be done through the use of training and development programmes run by emergency-response organisations. These organisations may benefit from incorporating emotional stimuli into training scenarios, thereby plausibly imitating the impact of emotional stimuli on emergency-response workers. The use of such training programmes requires further research.

5.2 Limitations and Future Research

This research was not without its limitations. The sample sizes in both Experiment 1 and Experiment 2 were small, due to the difficulty in finding high-skilled climbers who were willing to participate. Whilst significant results were found in both experiments, future research may wish to endeavour to use larger samples.

Due to the need for a consistent measure of climbing distance, only the horizontal distance climbed by participants was measured. However, as participants moved a small distance vertically across the duration of the climbs, this may have affected the total distance climbed. Any similar future research may wish to account for both horizontal and vertical distance climbed.

The words used for the memory tasks in Experiment 1 were controlled for across a number of variables to ensure that the words used in each list were equally memorable. However, the words used in Experiment 2 were selected based on valence, and therefore were not controlled for across the same parameters used in Experiment 1, such as meaningfulness. This meant that the neutral words could have been easier to remember than the negative words, or vice versa. However, no significant difference was found in the number of words recalled within the two memory-only conditions or within the two dual-task conditions.

The self-report measures of climbing efficiency and physical exertion following climbing were created for the purpose of Experiment 2. These two measures were reviewed by a subject matter expert. However, no other testing on the measures was conducted prior to their use. This raises concerns regarding the reliability of the measures. However, a similar pattern of responding was found between the climbing efficiency measure and the NASA-TLX performance measure. No significant differences were found in reported levels of physical exertion across the three climbing studies. This suggests that it may not have been a sensitive enough measure of physical exhaustion following climbing.

Given the relative lack of research on human factors issues involved in fields such as civilian search and rescue, future research into this area is recommended. One particular area of research that should be further explored is the effect of emotion on motor behaviour. Experiment 2 demonstrated the effects that negative emotional stimuli have on climbing performance. However, there has been very little other research investigating the effects of emotion on other types of physical performance. Participants' reported performance ratings following the dual-task conditions in Experiment 2 suggested that they were not consciously aware of the effects that negative emotional content had on their climbing performance. However, future research should also ask participants whether they believe that emotional stimuli will affect their performance prior to the task. Future research may also wish to examine the effects of emotion on cognitive performance relating to areas of search and rescue and other emergency response fields, such as decision making and vigilance. Finally, given the technological advancements being made that could potentially aid emergency response workers, such as MMC and video eyewear technology, future research may also wish to examine any human factors associated with incorporating these aids into operations.

5.3 Concluding Statement

Climbing is a demanding activity, both physically and mentally. This was illustrated across the two experiments by introducing a secondary memory task to a traverse climb, resulting in significant climbing performance and free recall memory performance impairments. These impairments occurred even though participants were skilled climbers. Participants' climbing performance was also more greatly impaired when the secondary memory task required memorising negatively valenced words, expanding on the previous findings on the relationship between emotion and motor behaviour. As has been described, the findings from the two experiments present a number of possible applications for fields such as search and rescue and fire-fighting. Whilst there are obvious differences between performing rescue operations in the field, and performing climbing tasks in a laboratory setting, it is hoped that some of the general findings of these two experiments will be recognised by emergency response organisations and ultimately incorporated into the training and management of their workers.

6. References

Azevedo, T. M., Volchan, E., Imbiriba, L. A., Rodrigues, E. C., Oliveira, J. M., Oliveira, L. F., Lutterbach, L. G., & Vargas, C. D. (2005). A freezing-like posture to pictures of mutilation. *Psychophysiology*, *42*, 255-260.

Beilock S. L., Carr T. H., MacMahon C, Starkes J. L. (2002a). When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied, 8*, 6–16.

Beilock, S. L., Wierenga, S. A., & Carr, T. H. (2002b). Expertise, attention, and memory in sensorimotor skill execution: Impact of novel task constraints on dual-task performance and episodic memory. *The Quarterly Journal of Experimental Psychology*, *55A*, 1211-1240.

Bourdin, C., Teasdale, N., & Nougier, V. (1998). Attentional demands and the organization of reaching movements in rock climbing. *Research Quarterly for Exercise and Sport, 69*, 406-410.

Brent, S., Draper, N., Hodgson, C., & Blackwell, G. (2009). Development of a performance assessment tool for rock climbers. *European Journal of Sport Science, 9*, 159-167.

Brisswalter, J., Collardeau, M., & René, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports Medicine, 32*, 555-566.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, *25*, 225-236.

Coombes, S. A., Gamble, K. M., Cauraugh, J. H., & Janelle, C. M. (2008). Emotional states alter force control during a feedback occluded motor task. *Emotion*, *8*, 104–113.

Coombes, S. A., Janelle, C. M., & Duley, A. R. (2005). Emotion and motor control: Movement attributes following affective picture processing. *Journal of Motor Behavior*, *37*, 425–436.

Darlington, R. B., & Carlson, P. M. (1987). *Behavioral Statistics*. New York, The Free Press.

Draper, N., Canalejo, J., Fryer, S., Dickson, T., Winter, D., Ellis, G., Hamlin, M., Shearman, J., & North, C. (2011a) Reporting climbing grades and grouping categories for rock climbing. *Isokinetics and Exercise Science, 19*, 273-280.

Draper, N., Dickson, T., Blackwell, G., Priestley, S., Fryer, S., Marshall, H., Shearman, J., Hamlin, M., Winter, D., Ellis, G. (2011b). Sport-specific power assessment for rock climbing. *Journal of Sports Medicine and Physical Fitness, 51,* 417-425.

Draper, N., Jones, G. A., Fryer, S., Hodgson, C., & Blackwell, G. (2008). Effect of an on-sight lead on the physiological and psychological responses to rock climbing. *Journal of Sports Science and Medicine, 7*, 492-498.

Draper, N., Jones, G. A., Fryer, S., Hodgson, C., & Blackwell, G. (2010). Physiological and psychological responses to lead and top rope climbing for intermediate rock climbers. *European Journal of Sport Science*, *10*, 13-20.

Eccles, D. W., Ward, P., Woodman, T., Janelle, C. M., Le Scanff, C., Ehrlinger, J., Castanier, C., & Coombes, S. A. (2011). Where's the emotion? How sport psychology can inform research on emotion in human factors. *Human Factors, 53*, 180-202.

Eysenck, M. W. & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion*, *6*, 409-434.

Facchinetti, L. D., Imbiriba, L. A., Azevedo, T. M., Vargas, C. D., & Volchan, E. (2006). Posutral modulation induced by pictures depicting prosocial or dangerous contexts. *Neuroscience Letters*, *410*, 52-56.

Field, A. (2000). *Discovering Statistics Using SPSS for Windows: Advanced Techniques for Beginners*. London: Sage Publications.

Finomore, V., Popik, D., Castle, C., & Dallman, R. (2010). Effects of a network-centric multi-modal communication tool on a communication monitoring task. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 54,* 2125-2129.

Gage, W. H., Sleik, R. J., Polych, M. A., McKenzie, N. C., Brown, L. A. (2003). The allocation of attention during locomotion is altered by anxiety. *Experimental Brain Research, 150*, 385–394.

Gaines, S. D., & Rice, W. R. (1990). Analysis of biological data when there are ordered expectations. *American Naturalist, 135*, 310-317.

Giesbrecht, F. G. & Gumpertz, M. L. (2011). *Planning, Construction, and Statistical Analysis of Comparative Experiments*. Hoboken: John Wiley & Sons.

Giles, L. V., Rhodes, E. C., & Taunton, J. E. (2006). The physiology of rock climbing. *Sports Medicine, 36,* 529-545.

Grant, S., Hasler, T., Davies, C., Aitchison, T. C., Wilson. J., & Whittaker, A. (2001) A comparison of the anthropometric, strength, endurance, and flexibility characteristics of female elite and recreational climbers and non-climbers. *Journal of Sports Science, 19*, 499–505.

Hardy, L. & Hutchinson, A. (2007). Effects of performance anxiety on effort and performance in rock climbing: A test of processing efficiency theory. *Anxiety, Stress and Coping, 20*, 147-161.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. Hancock & N. Meshkati (Eds.), *Human mental workload* (pp. 139-183). Amsterdam: North-Holland.

Hays, W. L. (1994). *Statistics* (5th Ed). Fort Worth: Harcourt Brace.

Helton, W. S., Dember, W. N., Warms, J. S., & Matthews, G. (2000). Optimism, pessimism, and false failure feedback: Effects on vigilance performance. *Current Psychology, 18*, 311–325.

Helton, W. S., & Russell, P. N. (2011). The effects of arousing negative and neutral picture stimuli on target detection in a vigilance task. *Human Factors, 53,* 132-141.

Helton, W. S. & Warm, J. S. (2008). Signal salience and the mindlessness theory of vigilance. *Acta Psychologica, 129,* 18-25.

Hillman, C. H., Rosengren, K. S., & Smith, D. P. (2004). Emotion and motivated behavior: postural adjustments to affective picture viewing. *Biological Psychology, 66,* 51-62.

Hodgson, C. I., Draper, N., McMorris, T., Jones, G., Fryer, S., & Coleman, I. (2009). Perceived anxiety and plasma cortisol concentrations following rock climbing with differing safety rope protocols. *British Journal of Sports Medicine, 43,* 531-535.

Horslen, B. C., & Carpenter, M. G. (2011). Arousal, valence and their relative effects on postural control. *Experimental Brain Research, 215,* 27-34.

Lazarus, R. S. (2000). How emotions influence performance in competitive sports. *Sport Psychologist*, *14*, 229–252.

Lewis, B., & Linder, D. (1997). Thinking about choking? Attentional processes and paradoxical performance. *Personality & Social Psychology Bulletin, 23,* 937-944.

Lindenberger, U., Marsiske, M., & Baltes, P. B. (2000). Memorizing while walking: increase in dual-task costs from young adulthood to old age. *Psychology and Aging, 15,* 417-436.

Matthews, G., Campbell, S. E., Falconer, S., Joyner, L. A., Huggins, J., Gilliand, K., Grier, R., & Warm, J. S. (2002). Fundamental dimensions of subjective state in performance settings: Task engagement, distress, and worry. *Emotion*, *2*, 315–340.

Matthews, G., Joyner, L., Gilliland, K., Huggins, J., & Falconer, S. (1999). Validation of a comprehensive stress state questionnaire: Towards a state big three? In I. Merville, I. J. Deary, F. DeFruyt, & F. Ostendorf (Eds.). *Personality psychology in Europe* (Vol. 7, pp. 335–350). Tilburg: Tilburg University Press.

McClelland, J. L. (1995). Constructive memory and memory distortions: A parallel-distributed processing approach. In D. Schacter (Ed.), *Memory Distortion: How Minds, Brains, and Societies Reconstruct the Past* (pp. 69-90). London: London University Press.

Morrison, A. B. & Schöffl, V. R. (2007). Physiological responses to rock climbing in young climbers. *British Journal of Sports Medicine, 41*, 852-861.

Nieuwenhuys, A., Pijpers, J. R., Oudejans, R. R. D., & Bakker, F. C. (2008). The influence of anxiety on visual attention in climbing. *Journal of Sport & Exercise Psychology, 30,* 171-185.

Paivio, A., Yuille. J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*, *76*, 21-25.

Pijpers, J. R., Oudejans, R. R. D., & Bakker, F. C. (2005). Anxiety-induced changes in movement behavior during the execution of a complex whole-body task. *The Quarterly Journal of Experimental Psychology, 58A,* 421–445.

Pijpers, J. R., Oudejans, R. R. D., Bakker, F. C., & Beek, P. J. (2006). The role of anxiety in perceiving and realizing affordances. *Ecological Psychology, 18,* 131–161.

Pijpers, J. R., Oudejans, R. R .D., Holsheimer, F., & Bakker, F. C. (2003). Anxiety–performance relationships in climbing: A process-oriented approach. *Psychology of Sport and Exercise*, *4*, 283–304.

Rogosa, D. (1995). Myths and methods: Myths about longitudinal research plus supplemental questions. In J. M. Gottman (Ed.), *The Analysis of Change* (pp. 3–66). Mahwah: Erlbaum.

Schacter, D. L. (1995). Memory distortion: History and current status. In D. Schacter (Ed.), *Memory Distortion: How Minds, Brains, and Societies Reconstruct the Past* (pp. 1-43). London: London University Press.

Schimmack, U. (2005). Attentional interference effects of emotional pictures: Threat, negativity, or arousal? *Emotion*, *5*, 55-66.

Shumway-Cook A., Woollacott, M., Kerns, K. A., Baldwin, M. (1997). The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *Journal of Gerontology: Medical Sciences*, *52A*, 232–240.

Sheel, A. W. (2004). Physiology of sport rock climbing. *British Journal of Sports Medicine, 38*, 355-359.

Siu, K. C., Catena, R. D., Chou, L. S., Donkelaar, P., Woollacott, M. H. (2008). Effects of a secondary task on obstacle avoidance in healthy young adults. *Experimental Brain Research*, *184*, 115–120.

Sparrow, W. A., Bradshaw, E. J., Lamoureux, E., Tirosh, O. (2002). Ageing effects on the attention demands of walking. *Human Movement Science, 21*, 961–972.

Stevenson, R. A., Mikels, J. A., & James, T. W. (2007a). Characterization of the affective norms for English words by discrete emotional categories. *Behavior Research Methods*, *39*, 1020-1024.

Stevenson, R. A., Mikels, J. A., & James, T. W. (2007b). Stevenson-BRM-2007. Retrieved 11 May, 2011 from Springerlink: www.springerlink.com.

Stins, J. F., & Beek, P. J. (2007). Effects of affective picture viewing on postural control. *BMC Neuroscience*, *8*, 83.

Szalma, J. L., Hancock, P. A., Dember, W. N., & Warm, J. S. (2006). Training for vigilance: The effect of knowledge of results format and dispositional optimism and pessimism on performance and stress. *British Journal of Psychology*, *97*, 115–135.

Watts, P. B. (2004) Physiology of difficult rock climbing. *European Journal of Applied Physiology, 91*, 361-372.

Wickens, C. D. (2008). Multiple resources and mental workload. *Human Factors, 50*, 449–455.

Yogev-Seligmann, G., Rotem-Galili, Y., Mirelman, A., Dickstein, R., Giladi, N., & Hausdorff, J. M. (2010). How does explicit prioritization alter walking during dual-task performance? Effects of age and sex on gait speed and variability. *Physical Therapy*, *90*, 177–186.

Appendix A

POST-QUESTIONNAIRE

General Instructions. This questionnaire is concerned with your feelings and thoughts during the task. Please answer **every** question, even if you find it difficult. Answer, as honestly as you can, what is true of **you**. Your answers will be kept entirely confidential. You should try and work quite quickly. The first answer you think of is usually the best.

Please indicate how well each word describes how you felt **DURING THE TASK** (circle the answer from 1 to 5).

Not at all = 1 A little bit = 2 Somewhat = 3 Very much = 4 Extremely = 5

1. Energetic	1	2	3	4	5
2. Relaxed	1	2	3	4	5
3. Alert	1	2	3	4	5
4. Nervous	1	2	3	4	5
5. Passive	1	2	3	4	5
6. Tense	1	2	3	4	5
7. Jittery	1	2	3	4	5
8. Sluggish	1	2	3	4	5
9. Composed	1	2	3	4	5
10. Restful	1	2	3	4	5
11. Vigorous	1	2	3	4	5
12. Anxious	1	2	3	4	5
13. Unenterprising	1	2	3	4	5
14. Calm	1	2	3	4	5
15. Active	1	2	3	4	5
16. Tired	1	2	3	4	5

Please indicate roughly how often you had each thought **DURING THE TASK.**

Never = 1 Once = 2 A few times = 3 Often = 4 Very often = 5

17.	I thought about how I should work more carefully.	1	2	3	4	5
18.	I thought about how much time I had left.	1	2	3	4	5
19.	I thought about how others have done on this task.	1	2	3	4	5
20.	I thought about the difficulty of the problems.	1	2	3	4	5
21.	I thought about my level of ability.	1	2	3	4	5
22.	I thought about the purpose of the experiment.	1	2	3	4	5
23.	I thought about how I would feel if I were told how I performed.	1	2	3	4	5
24.	I thought about how often I get confused.	1	2	3	4	5
25.	I thought about members of my family.	1	2	3	4	5
26.	I thought about something that made me feel guilty.	1	2	3	4	5
27.	I thought about personal worries.	1	2	3	4	5
28.	I thought about something that made me feel angry.	1	2	3	4	5
29.	I thought about something that happened earlier today.	1	2	3	4	5
30.	I thought about something that happened in the recent past (last few days, but not today).	1	2	3	4	5
31.	I thought about something that happened in the distant past	1	2	3	4	5
32.	I thought about something that might happen in the future.	1	2	3	4	5

Appendix B

NASA Task Load Index

Mental Demand **How mentally demanding was the task?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Physical Demand **How physically demanding was the task?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Temporal Demand **How hurried or rushed was the pace of the task?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Performance **How successful were you in accomplishing what you were asked to do?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Effort **How hard did you have to work to accomplish your level of performance?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Frustration **How insecure, discouraged, irritated, stressed, and annoyed were you?**

1	2	3	4	5	6	7	8	9	10
Very Low									Very High

Appendix C

Physical Exertion and Climbing Efficiency Scales

Physical Exertion **How "pumped" are your arms following the climb?**

1	2	3	4	5	6	7	8	9	10
Not At All									Extremely

Climbing Efficiency **How efficiently do you feel you climbed?**

1	2	3	4	5	6	7	8	9	10
Not At All Efficiently									Extremely Efficiently

Appendix D

Word List 1	Word List 2	Word List 3
ankle	piston	lemon
saloon	butcher	hamlet
icebox	fiord	shotgun
slipper	typhoon	abode
infant	nectar	poster
mucus	harness	cigar
pudding	reptile	painter
hostage	lobster	steamer
banner	rattle	sunset
bullet	bandit	costume
sulphur	pepper	bagpipe
doorman	morgue	banker
locker	trumpet	spinach
piano	singer	hairpin
sunburn	blister	beggar
missile	jelly	skillet
thicket	salad	invoice
monarch	settler	robber
cowhide	sultan	kettle
leopard	fabric	glacier

Appendix E

Negative List 1	Negative List 2
suicide	torture
malaria	panic
gun	abuse
poison	assault
hurricane	shark
death	massacre
failure	avalanche
rape	robber
abduction	cancer
fear	demon
murderer	crisis
war	devil
tumor	surgery
terrorist	killer
tornado	horror
bomb	hell
prison	weapon
danger	intruder
nightmare	scorpion
trauma	evil

Appendix F

Neutral List 1	Neutral List 2
Item	Hammer
Hand	Bowl
Chin	Phase
Context	Theory
Patent	Lamp
Paper	Sphere
Iron	Barrel
Trunk	Elevator
Appliance	Board
Machine	Part
Taxi	Circle
Corner	Building
Thermometer	Stool
Egg	Industry
Door	Arm
Spray	Lantern
Cord	Metal
Corridor	Hawk
Stove	Curtains
Column	Passage