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The Impact of Shift Length on Processor Operator Fatigue

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Summary

A study was undertaken to determine the impact of a range of alternative work schedules on processor operators using extended shifts, in terms of mental and subjective fatigue, stress level, physical workload and muscular discomfort. Three operators worked through a range of alternative work schedules dependent on their operational circumstances. All operators showed signs of increased subjective fatigue, body part discomfort and mental fatigue as the day progressed. Once alternative schedules incorporating more frequent breaks were introduced, muscular discomfort as well as subjective and mental fatigue ratings decreased. However, operator stress levels appeared to fluctuate throughout the day. If processor operators are expected to maintain a high degree of performance throughout the entire working day, then the effective use of rest breaks is essential.

Recommendations

- Limit processor operator shift length to a maximum of 4 hours continuous machine operation.
- One 40 minute rest break be taken for every 3 - 4 hours continuous machine operation.
- Processor operators physically get off the machine for 5 minutes in every hour of operation.
- The working day be broken up every 3 - 4 hours by rest, meal or maintenance breaks or the inclusion of job rotation and/or enlargement.
- Extended shift schedules be designed to incorporate a minimum of two processor operators per complete working day.

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Introduction

In order to obtain maximum machine utilisation and maintain a profitable operation, many mechanised harvesting systems are operating extended work shifts for the harvester/processor machines. This usually results in the machine working either a double shift (2 x 12 hours) or extended standard shift (1 x 12 - 14 hours) system. As a result, machine operators may be working 10 to 14 hour days operating these machines. The mental, physical and financial implications of continually running such systems are well documented in terms of operator mental fatigue, with implications on both the operator's physical wellbeing and the operations financial viability (Axelsson and Ponten, 1990; Hansson, 1990; Inoue, 1996; Sondell, 1987; Tyson,1997).

The continual use of poorly designed extended shifts have been clearly linked to increased levels of mental fatigue, physical discomfort and injury. This results in poor overall operator performance and lower value recovery worldwide, (Stone, 1987) Canada, (Tyson, 1997) America, (Axelsson and Ponten, 1990; Hansson, 1990; Sondell, 1987) Sweden, (Inoue, 1996) Japan and (Attebrant, 1995; Attebrant et al., 1997) Finland. The principle link between extended shift operations and poor value recovery is the operator's natural tendency to develop symptoms of mental fatigue.

Processor operators delimb full stems, and in many cases, also have to process these stems into logs. The processing function, more commonly known as logmaking, requires constant attention and intense mental effort (Stone, 1987). Key elements of this logmaking process are visual feature recognition (knot size, draw-wood, out-of-round), the ability to select the correct grade in terms of log specifications and market demand. These functions must be carried out within the time pressures typical of high producing harvesting operations. Consequently, the operator places considerable pressure upon their central nervous system in terms of the ability to process rapidly presented information whilst drawing upon their memory and information processing capability.

Extended shift lengths negatively impact upon this whole process by exposing the operator to extended periods of high mental demands, with little chance for either rest and/or recuperation. Such demanding work conditions provide the perfect conditions for developing high levels of mental fatigue. Mental fatigue impacts significantly on the operator's ability to accurately detect stem features, increases error rates, slows reaction time, decreases concentration levels, increases boredom levels and increases negative mood states (Krueger, 1991).

A side effect of this increase in mental demand is the increase in muscular tension within specific muscle groups within the body. Unlike motor-manual logmakers, processor operators do not have the chance to stretch out tense muscle groups by physically moving around the skid. Muscular discomfort arises as the operator is exposed to excessive periods of sitting, excessive work intensity during work in fixed, ergonomically inappropriate positions and repetitive, short-cycled movement patterns (Hansson, 1990).

Work undertaken by Byers (1997) revealed that New Zealand harvester and processor operators frequently worked extended shifts on the machine (8 - 12 hours/day), took minimal rest breaks, worked extended working weeks (4 - 6.5 days/week) and had limited recuperation time (1 - 1.5 days/week). These findings clearly revealed a lack of understanding by the forest industry of the benefits associated with correctly designed extended work shifts. Understandably, many of these factors were occurring due to intense financial pressures. However, ignoring the lessons learnt by similar overseas operations will in the long run only cause greater social and financial hardship for those concerned.

Study Objective

To determine the impact of a range of rest break schedules on processor operators using extended shifts, in terms of mental fatigue, stress levels, physical workload and muscular discomfort.

Methodology

Operators

Three single grip harvester/processor operators working in clearfell harvesting operations took part in the study.

Critical Flicker Fusion Frequency

Central nervous system function was assessed by measuring Critical Flicker Fusion Frequency (CFFF). This was the frequency at which a rapid flickering light was perceived as being continuous. CFFF reflects an individual's ability to process rapidly presented information and is correlated with memory and information processing ability. Increased fatigue is associated with a reduction in CFFF. Six alternative ascending and descending measurements were taken. The highest and lowest values were rejected and the mean CFFF calculated for the four remaining observations (Legg et al., 1991)

Subjective Mood

Subjective mood state was measured at one hour intervals throughout the working day using six point self rating scales taken from the Profile of Mood States questionnaire which inquired about an individual's current feelings. Six scales were used, with extremes: Not at all fatigued/Extremely fatigued, Fresh/Weary, Relaxed/Tense, Strong/Weak, Vigorous/Exhausted and Wide Awake/Sleepy (Kirk et al., 1996).

Body Part Discomfort

Body part discomfort was determined at one-hour intervals throughout the working day according to a method modified from Corlett and Bishop (1976). The subject was shown the body part diagram and asked if they currently felt any discomfort in any of the body part segments shown in the diagram. If the operator stated that they did have some discomfort, they were then asked to identify which segment was experiencing discomfort and to give the discomfort a severity rating. The severity rating consisted of a four-point scale with the anchors zero (minimal discomfort) and four (unbearable discomfort).

Working Heart Rate (HR_W)

Measurements of the operator's working heart rate were taken every two hours for a period of 60 minutes using a Polar Vantage NV heart rate monitor set at a 1-minute heart rate interval (Kirk et al., 1996).

Stress Levels

Operator stress levels were determined at 1 hour intervals through the working day using intra-heart beat variability monitored by a Polar Vantage NV heart rate monitor set to record the intra-heart beat interval.

Work Schedules

A range of different work schedules were applied to each operator depending on what situations best suited their particular operation. The standard work/rest schedule that was normally used by the operator was first monitored, followed by the theoretical optimal work/rest schedule. Finally, an operational schedule which was designed by the prime contractor, operator and the researcher, and which could be effectively used in a production situation, was applied and monitored.

A range of alternative shift designs were used including:

- 3 x 20 minute breaks spread evenly throughout the work day
- 2 x 30 minute breaks (1 @ 10 am another @ 1pm)
- 2 x 30 minute breaks (1 @ 10 am another @ 1pm) plus 15 minutes manual logmaking on the skid every 1.5 hours of machine operation.
- 1 x 40 minute break @ 11am
- 1 x 40 minute break @ 10am followed by 2 hours of skidder driving
- 2 x 40 minute breaks @ 10 am and 1pm

Results and Discussion

Operators

The operators had an average of 3.5 years experience operating these particular machines and processor heads.

Critical Flicker Fusion Frequency (CFFF)

The degree of mental fatigue, as measured by the CFFF device (Figure 1), was variable across alternative work/rest schedules. Schedules which provided the operator with two or more substantial rest breaks spread evenly throughout the working day, appeared to provide the best degree of recovery from mental burn-out. A single shorter break, or breaks combined with job rotation, did improve the situation compared to "no-break" schedule, but the degree of recovery was short lived and fatigue rates noticeably increased in the afternoon in comparison to the multi-break and/or job rotation schedules.

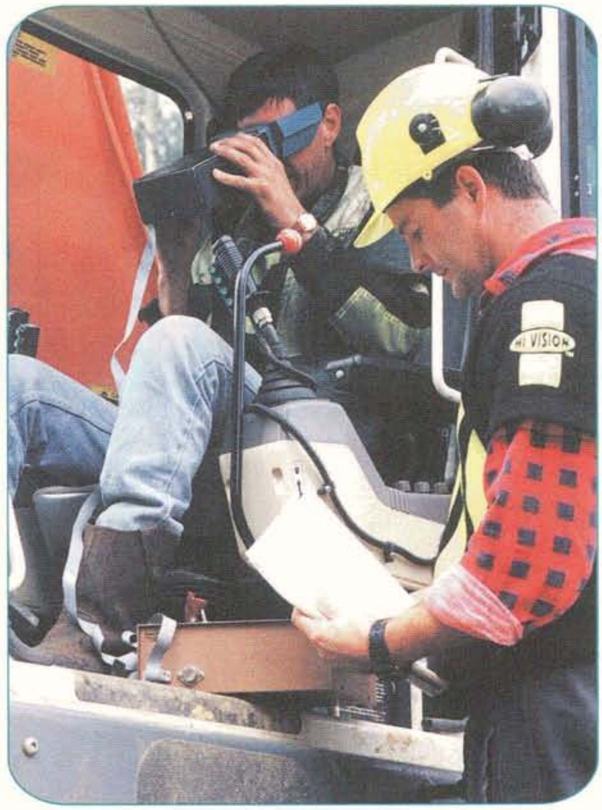

Figure 1- Operator undertaking the CFFF test

It appears that the ability to fully relax the mind away from the mental pressures of the job has the greatest long-term recuperative effect in terms of recovering from the effects of mental fatigue. Time involved with other tasks such as quality control or driving another piece of machinery appears to prevent the mind fully recovering, as such work still requires the operator to constantly concentrate on the job at hand and demands the use of an already fatigued central nervous system. Schedules that used two or three rest breaks spread evenly throughout the day appeared to reduce the degree of mental fatigue experienced by operators in the latter part of the day.

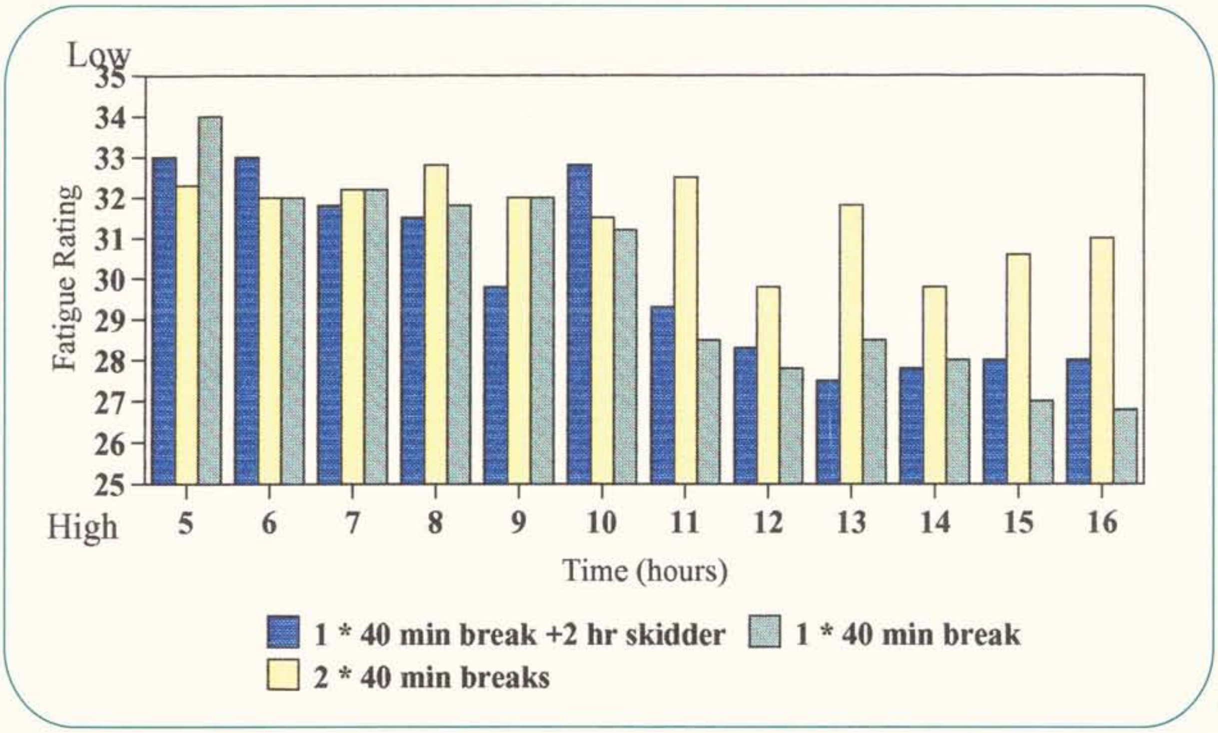

Figure 2 - Critical Flicker Fusion Frequency (CFFF) Mental Fatigue Ratings

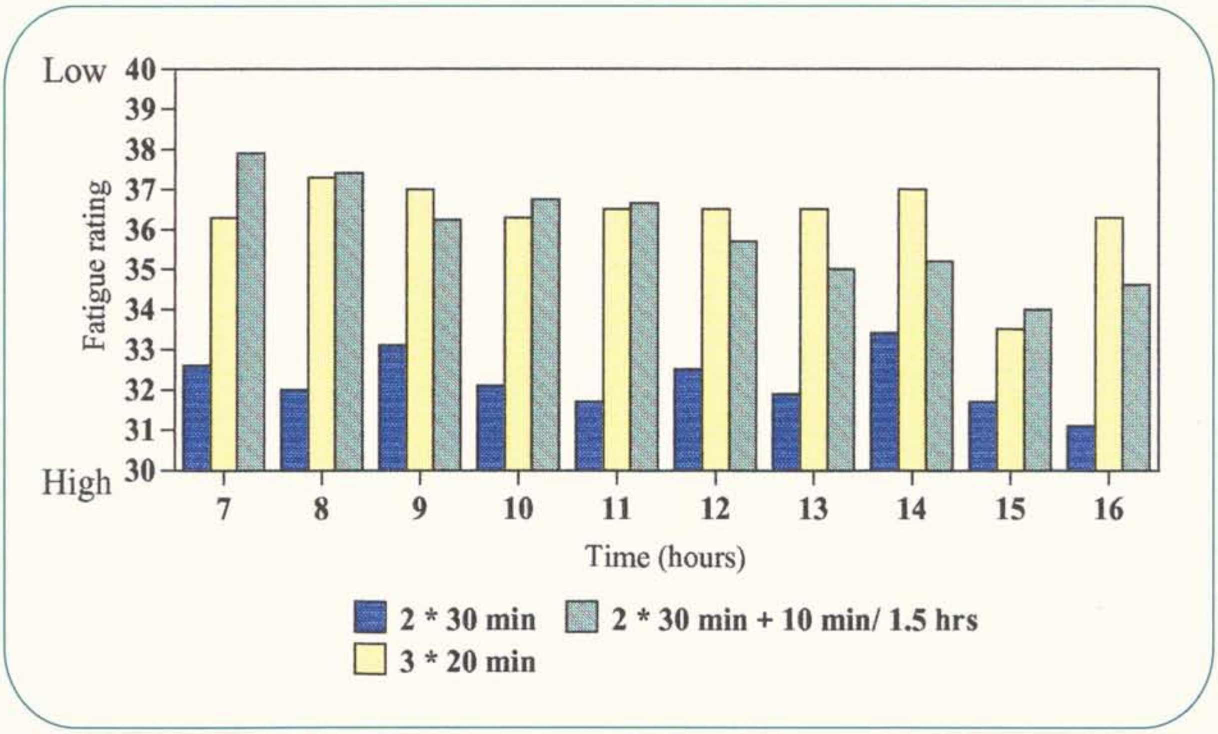

Figure 3 - Critical Flicker Fusion Frequency (CFFF) Mental Fatigue Ratings

Such findings are important to processor operators as they are expected to maintain high levels of concentration for extended periods over the entire working day, in order to maintain high quality standards. The effective use of breaks to separate the working day into shorter work periods enables the operator to reduce the negative impacts of mental fatigue and burn-out in terms of slowing down the onset of poor defect recognition, increased error rates, poor decision making and slow reaction time. If the operator is expected to maintain a high degree of processing quality throughout the entire working day, then the effective use of rest breaks is essential.

These findings are neither surprising or new, as many previous researchers have found the effective use of rest breaks to shorten the length of continuous work for processor operators can dramatically improve the operator's performance and productivity (Axelsson and Ponten, 1990; Hansson, 1990; Inoue, 1996; Sondell, 1987; Tyson, 1997). All of these researchers stated that the main cause of many processor operator injuries are directly related to excessive periods of sitting, excessive work intensity during work in fixed, ergonomically inappropriate positions, and repetitive, short-cycled movement patterns. The design and length of work shifts, as well as job rotation, were the two alternatives seen as offering the best solution to these problems.

Subjective Mood Ratings

Operators' subjective mood ratings showed a steady negative increase in the subjective fatigue rating as the day progressed (Figure 4). The use of alternative schedules did reduce the magnitude of the fatigue rating, but did not eliminate it altogether.

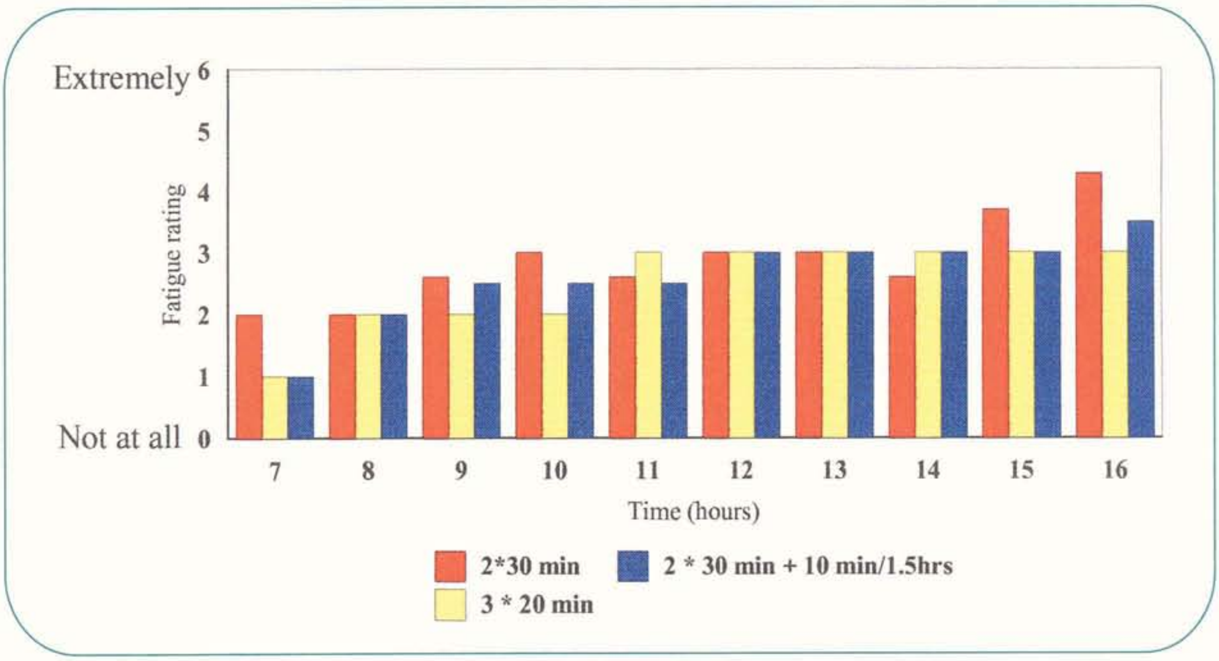

Figure 4 - Operator subjective fatigue rating

The use of rest breaks to break the day into shorter work periods appears to have decreased the impact of fatigue in the latter part of the day. This is largely due to an increase in the ability to take a break away from the mental demands of the job, as well as increasing the degree of task variety in the working day. Added to the mental benefits are the physical benefits of being able to physically move around and stretch out tense muscle groups and enable the body to re-supply these areas with fresh supplies of food and oxygen.

Previous researchers have shown that job enlargement, shorter work periods and job rotation, are all effective ways to mitigate the impacts of fatigue on operator performance. Although the total work time may be reduced if more frequent break schedules are adopted, the use of shorter work periods in most cases actually increase rather than decrease overall productivity. The reason being that the operators are able to apply a greater degree of effort and vigilance to task during these shorter work periods. Therefore the use of several operators within one crew has the benefit of obtaining optimal performance from each operator before substituting them for the next and allowing the first operator time to recover. The alternative is to maintain one operator who

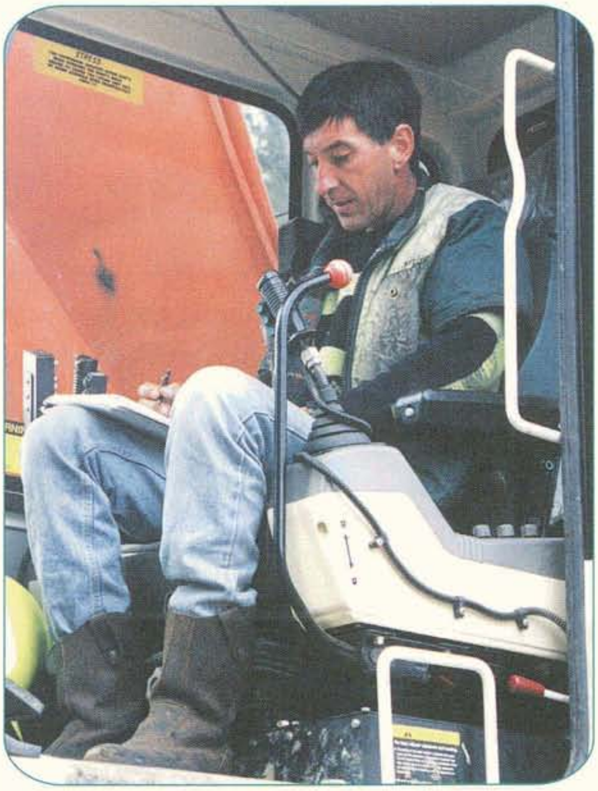

Figure 5 - Operator completing subjective mood state questionnaire

has a good morning run, but then gradually fades away as the day progresses.

The best analogy is the running of a relay where you either use four sprinters to cover 400 metres running at top speed for 100 metres each, or you use one runner who, to ensure they will make the finishing line, runs at a slower pace. The only way the lone runner will ever keep up with the performance of the sprinters is to run as fast as they can for the entire race. The result is that they will never beat the relay team and will in most cases physically injure themselves in the process.

More detailed analysis of the fatigue rating showed an overall trend for increasing levels of weariness as the day progressed (Figure 6). Alternative schedules which increased the frequency and duration of breaks reduced the magnitude of these trends by increasing time for recuperation and task variability (Figure 6).

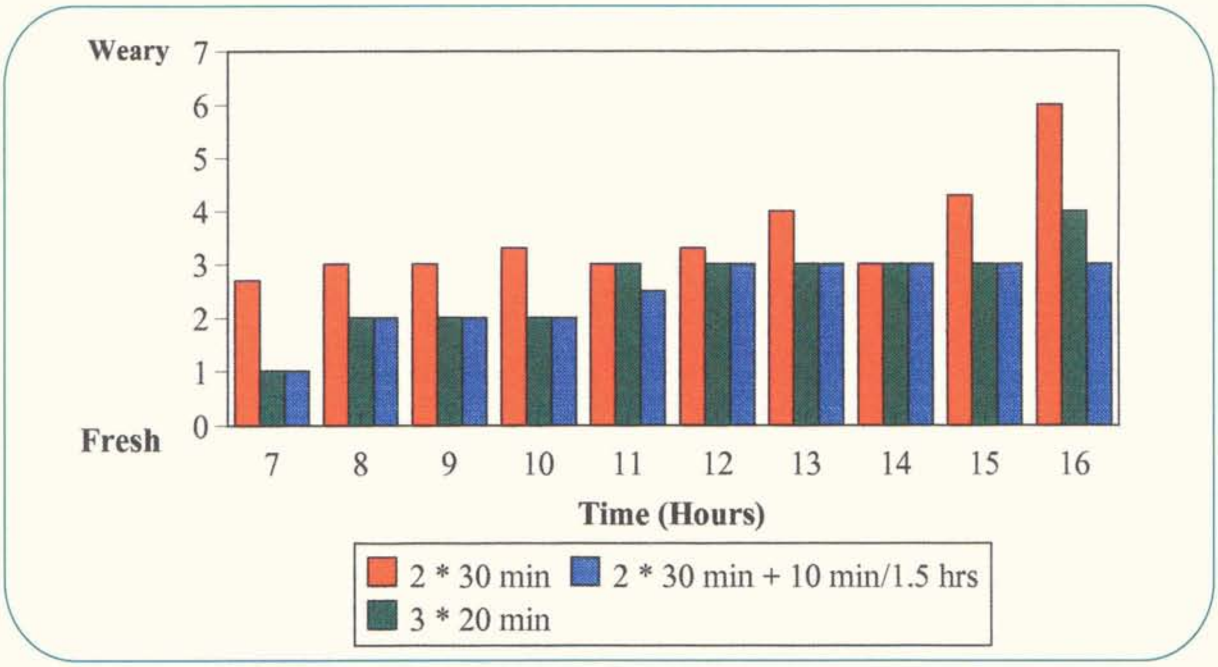

Figure 6 - Operator subjective mood state (Weary/Fresh)

(NB: Standard operation in this case was 2 x 30 minute breaks)

The same trend was seen for levels of sleepiness (Figure 7), with increased ratings of sleepiness as the day progressed. These ratings were also lowered once the frequency and duration of breaks was increased.

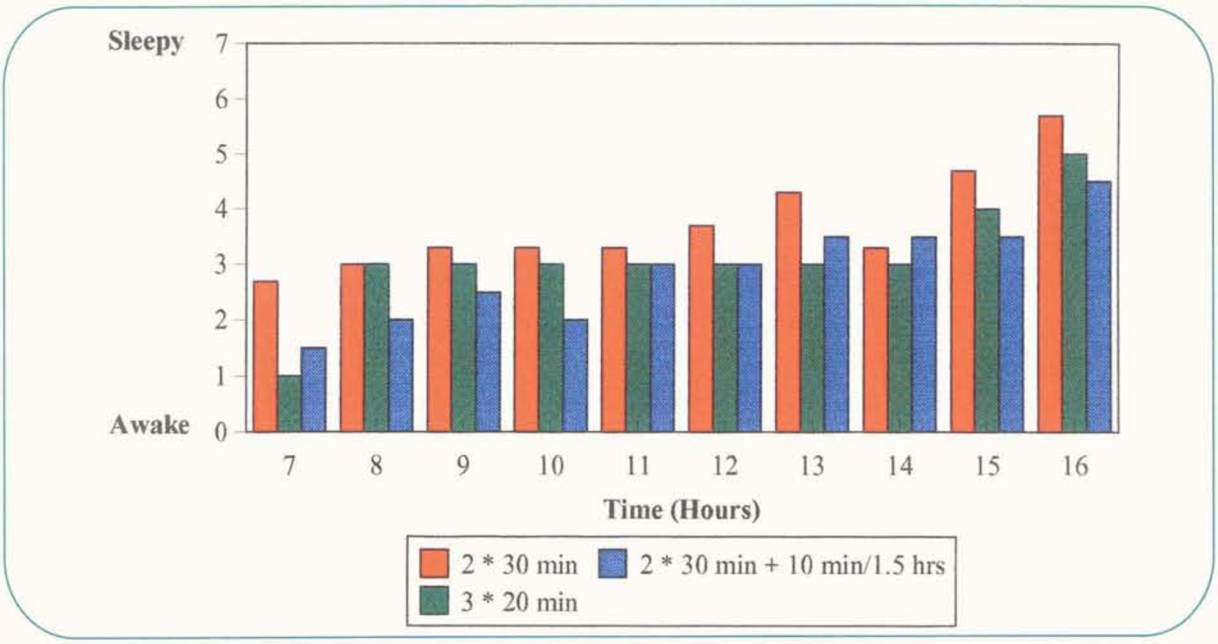

Figure 7- Operator subjective mood state (Sleepy/Awake)

(NB: Standard operation in this case was 2 x 30 minute breaks)

This is compounded by reduced total sleep time, as many operators start work at 5am having left home approximately 30 to 60 minutes earlier. Consequently, the reduced total sleep time has most effect on the Rapid Eye Movements (REM) phase of sleep, as REM sleep dominates the end of a person's sleep cycle. Shorten your total sleep time and it's the REM phase that pays the price. REM sleep focuses primarily on mental recovery. A reduction in REM cycle sleep manifests itself as reductions in vigilance, alertness and reaction time.

Body Part Discomfort (BPD)

All operators who participated in this study reported some form of body part discomfort, over the course of the study. Slight discomfort in the hands, wrist and neck, plus moderate discomfort in the buttocks were the most frequently recorded areas. The level of discomfort increased in both severity and frequency as the day progressed. The most pronounced reduction in operator BPD recorded during the study, is shown in Figure 8.

The BPD findings are not unexpected, and have been clearly identified in previous overseas research. Sondell's (1987) work with Swedish machine operators found very similar BPD ratings as found in this present study. Axelsson and Ponten's (1990) survey of 1,174 machine operators also found a significantly high degree of BPD in operators and named the affliction "overload syndrome" which was characterised by operators reporting complaints and injuries to the neck, arms and spine. Byers (1997) survey of harvester operators also found that 43% of those surveyed reported some form of BPD.

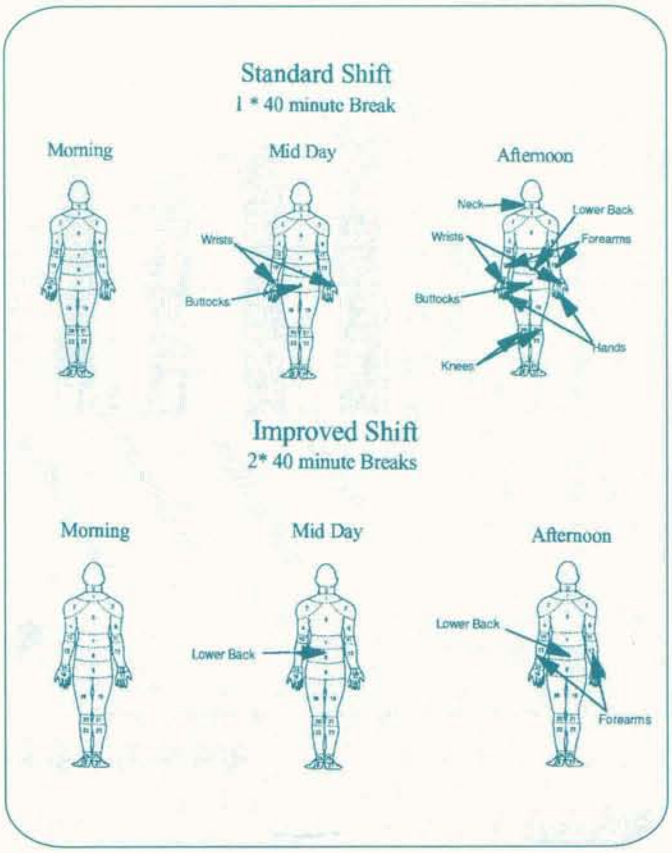

Figure 8 - Body Part Discomfort Ratings (BPD)

The use of alternative work/rest schedules in the current study reduced, but did not completely remove, the degree of BDP recorded by the operators. The best example of this is shown in Figure 8 where the operator included one extra 40 minute rest break in the afternoon run.

The reduced incidence of BPD in the improved shift schedules was primarily due to operators spending less time sitting on the processing machine operating the controls for extended periods of time. More time was spent physically moving around either during their break, or while undertaking alternative tasks such quality control or maintenance.

Allowing the operator to get off the machine and move around, enabled the body to flush out waste products, stretch and increase the flow of blood and oxygen to tense overworked muscle groups. By using different muscle groups to those used when operating the processor, the body was able to rest the overworked muscle groups to enable them to recover for the next work shift.

The use of short frequent breaks combined with some form of physical activity or stretching programme is a frequently used method by many industries to help reduce and /or prevent injury resulting from jobs that require one-sided, repetitive, short-cycle working movements with arms and hands (Byers and Skerten, 1997; Tyson, 1997).

Working Heart Rate

The working heart rate of the machine operators fell within the light workload category (Åstrand and Rodahl,1986), with a mean heart rate of 83 ± 7 beats per minute (bt.min^{-1}) (Figure 9). Relative physical strain, shown as % heart rate range (%HRR), was low at 18%. The internationally accepted level for most industries for sustained continuous physical work is 40% HRR (Åstrand and Rodahl, 1986).

The recording of low levels of physical strain in this study mirrors those of other researchers who also found that machine operators tended to record low levels of physical, but high levels of mental strain (Inoue, 1996; Attebrant et al., 1997). A comparison of processor operator workload against a range of other forest industry tasks is shown in Figure 9.

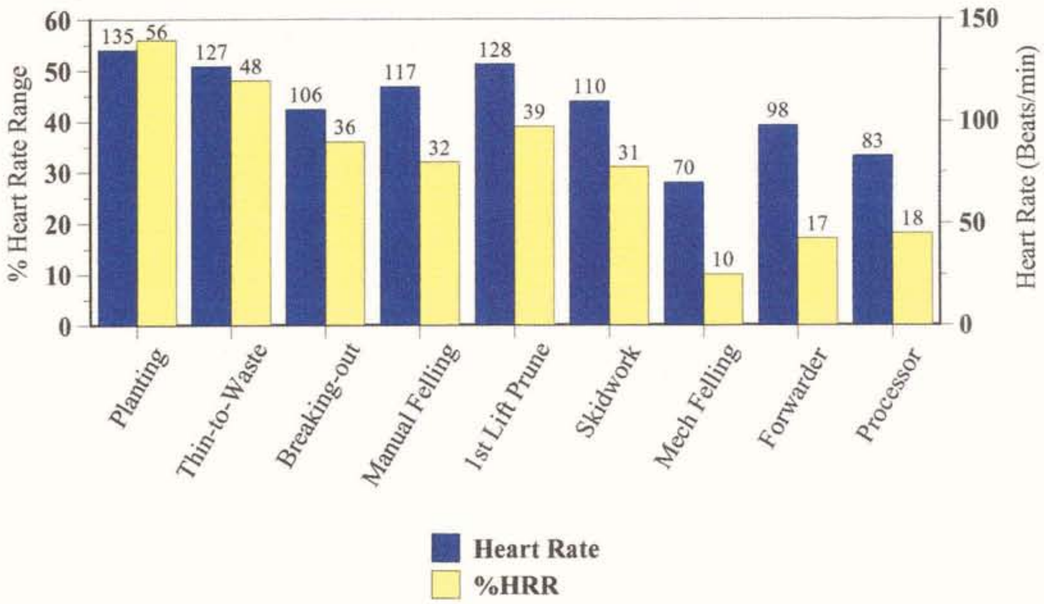

Figure 9 - Physiological workload of various forest tasks

Stress

Stress levels varied considerably between operators and time of day. There appeared to be little cumulative trend during the day, with degrees of both high to low stress being recorded at the end of each working day. Fluctuations in stress levels could occur very quickly and within one 40 minute recording period, an operator could experience the entire range of high and low stress levels.

Alternative shift schedules appeared to have little effect on the overall stress level of the operator. The only impact being a reduction in total exposure to stress when shift lengths were reduced. However, as soon as the operator resumed work, they quickly returned to their earlier stress response state.

It appears that operating a processor is associated with a set degree of stress, simply by being part of the larger harvesting operation, as all operators studied worked hot deck operations. The only time that operators experienced noticeably lower stress levels were when the operators worked on their own, usually during the early morning run (5am - 7am) before the main crew arrived. This was especially noticeable if the crew's loader did the early morning load-outs from another skid separate to the one being used by the processor. Once the remainder of the crew arrived and more people and machines began operating on the skid, stress levels rapidly began to fluctuate, due to an increase in man and machine interference.

Examples of heart rate recordings showing both high and low stress states are shown in Figures 10 and 11.

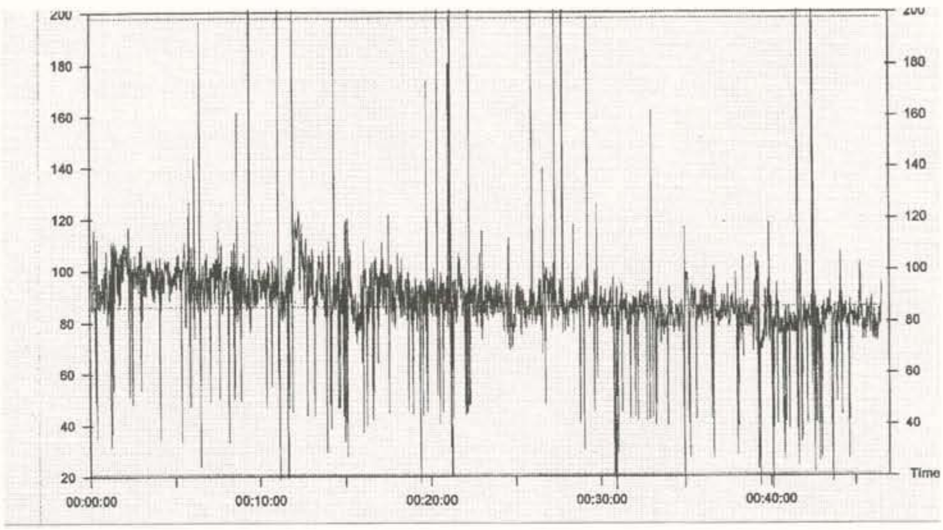

Figure 10 - Example of a low stress state recording (high variability)

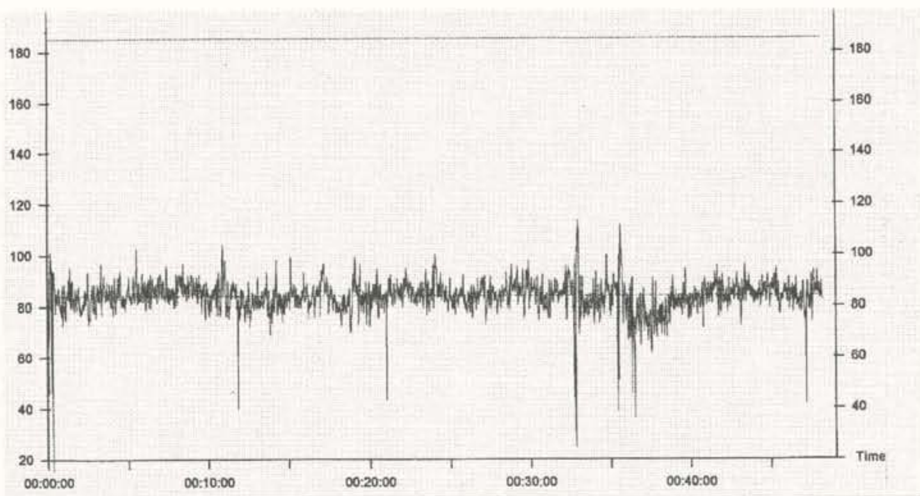

Figure 11 - Example of a high stress state recording (low variability)

Work Schedules

Most operators were originally working a range of standard shift lengths, ranging from 5 hours to 13 hours duration before having a break. Most common shifts involved a continuous shift length of 4 - 5 hours followed by a break ranging from 30 - 40 minutes followed by a further 4 - 5 hour shift.

A common misconception amongst both operators and contractors is that operational efficiency will always be increased through the running of extended shifts. In reality, the opposite is often found to occur if inappropriately designed schedules are used. This is a result of the simple fact that as mental fatigue and muscular discomfort levels increase, the operator compensates by doing one of two things:

(1) If the job being undertaken is primarily a production-based operation, they will reduce time spent on the quality aspect of the operation in order to maintain production levels. That is, quality tends to suffer in favour of quantity.

(2) If quality takes precedence over quantity, increased mental fatigue means that the operator must now utilise a greater proportion of their mental capacity to perform the same task as before. Therefore in order to perform the same task to the same quality level, more time per task is required (i.e. productivity decreases). In extreme cases, both of these scenarios occur as the operator's mental capacity decreases to such a level that both quality and quantity functions fail and the operation suffers both reduced productivity and reduced quality.

Work undertaken by Tyson (1997) that showed when an operation went from running two extended continuous shifts, to one incorporating more frequent shorter shifts with regular breaks, productivity increased from 44 trees/hour to 66 trees/hour and accuracy increased to 96%. (Figure 12).

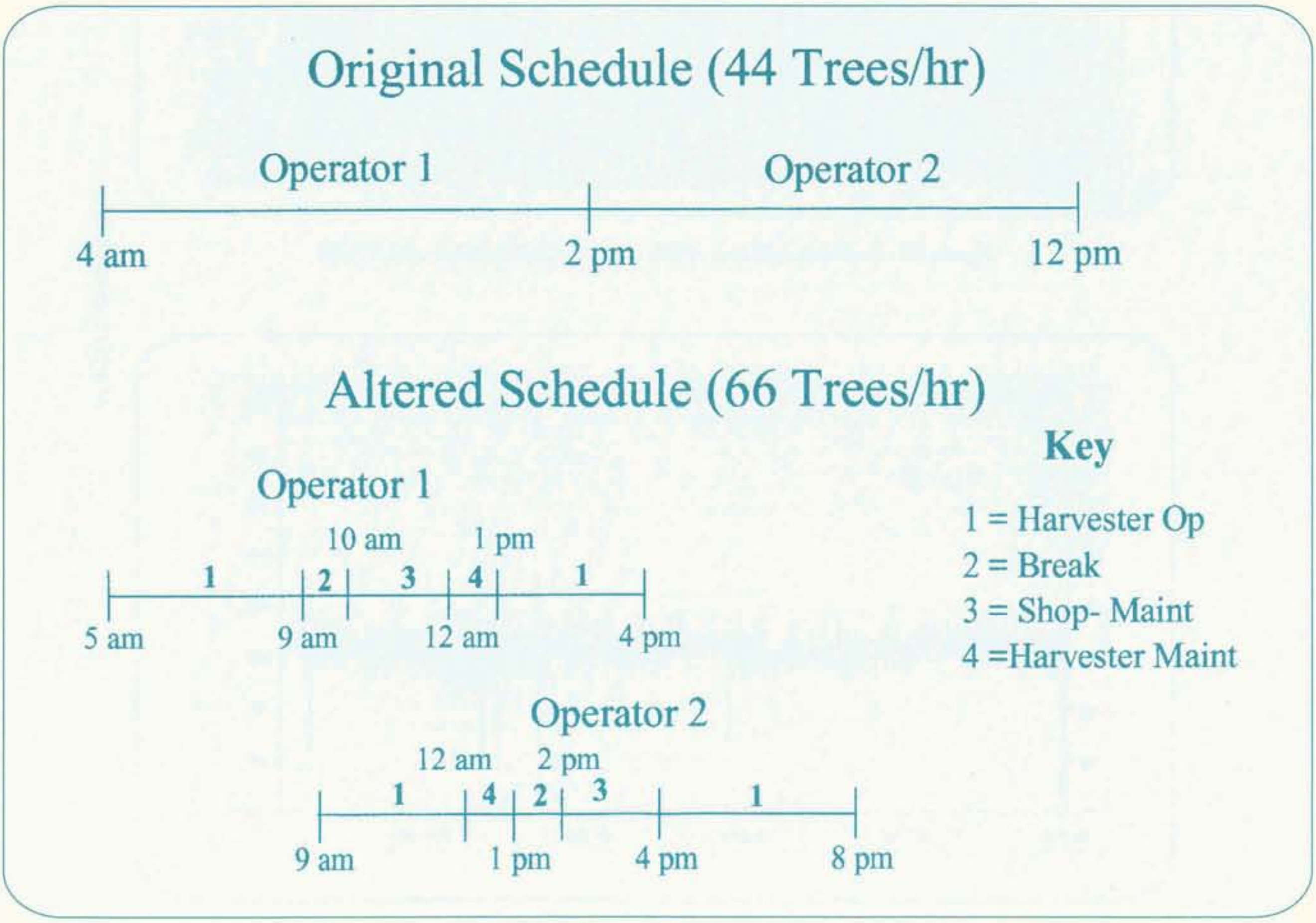

Figure 12 - Alternative schedule design

The study showed that 75% of an operator's daily production was produced during the first five hours of the shift. Therefore operating for a further five hours only produced 25% of the daily production. As a consequence of this finding, shift length for processing was restricted to a maximum of four continuous hours. A structured break system was implemented to provide both regular rest breaks and job variety for the operators, and maintenance time for the machines. Such rest break structures have been widely advocated in both New Zealand, European and Scandinavian mechanised harvesting operations (Gellerstedt, 1997).

Conclusion

It was evident that the standard work/rest schedules traditionally applied by many motor-manual forest workers in New Zealand do not suit machine operators, particularly processor operators. The physical workload of processor operators is light, with most operators working at only 18% of their heart rate range (%HRR). Consequently, the requirement for physical recovery is relatively low. The mental demand of the processor operators were high, and suited a work schedule that contained shorter but more frequent breaks. All of the operators showed a marked improvement in body part discomfort and fatigue ratings when more frequent breaks were taken. Breaks could take the form of alternative jobs such as quality control or driving the skidder, or preferably, a complete rest break where operators could fully relax and refresh both their body and mind. All work schedules which contained variety and/or variability during the standard work day achieved a high degree of success in terms of improved/sustained operator performance, when compared to more standard work schedules where the operators spend extended periods of time operating one machine.

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