A STUDY IN A FOREST MACHINE SIMULATOR ON THE EFFECTS OF A SEMI-AUTOMATIC FORWARDER CRANE ON OPERATOR WORKLOAD AND PERFORMANCE.

Martin Englund, Helena Andersson, Hans Richter, Dmitry Domkin, Mikael Forsman
Skogforsk, Uppsala, Sweden - Martin.Englund@skogforsk.se

In the virtual environment of a human-in-the-loop forest machine simulator, Skogforsk has developed a semi-automatic forwarder crane. When loading, the operator manually controls the grabbing of logs on the ground. Then, by command of the operator, the crane automatically moves the logs to the load area. Once there, the operator again takes over and manually adjusts the crane tip and grapple before releasing the logs. At another command, the grapple automatically returns to a predetermined position on the chosen side of the machine. Use of the semi-automatic crane resulted in roughly half the time spent actively using the joysticks, compared to when using the conventional crane. Eleven professional forwarder operators were studied while using the semi-automatic crane as well as a conventional, manually controlled crane in the machine simulator. The operators spent the first half of the day practicing the operation of the forwarder in the simulator, the use of the automation and the performance of the task.

Physiological measurements indicating mental and physical workload were recorded while performing a loading task. Sensors for measurement of muscle activation (EMG) were placed on both forearms, as a measure of physical load resulting from joystick use. EMG was also recorded from the trapezius as a measure of overall load. A NIRS (Near-InfraRed Spectroscopy) sensor was placed on the forehead to measure the blood flow and oxygenation in the brain in an area controlling willful effort. Additionally, the operators gave subjective accounts on the use of the crane and performance of the task.

Table 1. Time to complete task relative to Manual condition (Manual = 100)

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median</td>
<td>106</td>
</tr>
<tr>
<td>Mean</td>
<td>113</td>
</tr>
</tbody>
</table>

Four of the operators performed the task faster with the use of automation seven performed slower.

Table 2. Mean muscle activation relative to Manual condition (Manual = 100)

<table>
<thead>
<tr>
<th></th>
<th>Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left lower arm</td>
<td>79</td>
</tr>
<tr>
<td>Right lower arm</td>
<td>106</td>
</tr>
<tr>
<td>Left trapezius</td>
<td>73</td>
</tr>
<tr>
<td>Right trapezius</td>
<td>80</td>
</tr>
</tbody>
</table>
Muscle activation was lower for trapezius on both sides and for the left arm (Table 2). The right arm unexpectedly showed slightly higher activation. The reasons behind the differences will be further investigated by analysis of joystick use and muscle activation per work phase.

**Table 3.** Mean deltaT2O2Hb

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Auto</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.65</td>
<td>2.00</td>
<td></td>
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The NIRS measurements indicated a higher mental effort when performing the task with a conventional, manual crane compared to the semi-automatic.

In the subjective accounts of mental exhaustion directly after the task performance, on a Borg rating of perceived exertion scale, nine of the operators rated lower exhaustion from performing the task with automation, one rated lowest exhaustion with the manually operated crane and one operator rated them the same.