# MAN-MACHINE COMMUNICATION EFFICIENCY

BY

DARRYL M. JOOST

AGRICULTURAL ENGINEERING DEPARTMENT

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Approved by:

Stephen W. Searcy

Dr. Stephen W. Searcy

## ABSTRACT

A computer model was developed to simulate the steering and gear shifting functions of a tractor. The model was used to test the use of audio and visual operator feedback methods used in machine monitors. Five operators were tested and the audio method was found to have a consistently faster rate of response time for an average operator shift over the visual method. The audio feedback method is recommended to increase monitor effectiveness, operator efficiency, and machine efficiency.

## ACKNOWLEDGEMENTS

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# TABLE OF CONTENTS

# LIST OF FIGURES

# MAN-MACHINE COMMUNICATION EFFICIENCY

## INTRODUCTION

Agricultural machinery today is larger and more complex than in the past. Manufacturers are continually adding more monitoring devices to tractors and equipment that measure machine functions and conditions. Currently, there are several systems being developed that monitor tractor performance. The monitors figure the most efficient throttle and gear ratio combination to maximize fuel efficiency. These systems concentrate on the determination of the feedback information rather than how to best provide that information. More research is needed on communication of information from the monitor to the operator.

Currently, analog gauges and lights are used extensively to relay feedback to the operator. In some instances, buzzers and horns are used to warn the operator of severe conditions. The operator must notice the gauges and lights to react to any needed changes. If the operator does not look at the gauges or lights they can not help him. With the increased use of machine monitors, there needs to be an improved method of man-machine communication.

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*Conforms to the American Society of Agricultural Engineers stylesheet.

One possible improvement in communication efficiency could be the increased use of an audio feedback method for the operator. To determine the level of efficiency, there needs to be tests performed to compare audio and visual feedback methods. This paper is documentation for a project to compare audio and visual feedback methods. The specific objectives of this project were:

1. Develop a computer program to simulate operating conditions of a machine in conjunction with two operator feedback methods.
2. Compare the results obtained from operator tests of the visual and audio feedback methods.

## LITERATURE REVIEW

There are many monitors on the market today that are capable of doing several different jobs. These jobs range from counting plant populations to controlling spray applications. There are also many monitors being developed by researchers in several universities.

Currently, Dickey-john Corporation has several monitors on the market. The Dickey-john Tractor Performance Monitor II monitors ground speed and can calculate the wheel slip of the tractor. Other monitors put out by the company include a planter monitor and a sprayer monitor. These monitors use some type of digital display, lights, or gauges to give the operator feedback from the monitor (Dickey-john, 1980).

Another company that manufacturers monitors is Hiniker Corporation. This company makes a type of sprayer monitor and acre counter (Hiniker, 1985).

John Deere, a major agricultural equipment manufacturer, uses a combination of analog gauges, warning lights, and an audible horn signal in their tractors to warn the operator of an abnormal water temperature, oil pressure, or filter pressure (John Deere, 1983).

Agricultural engineers at the Kansas State University have developed a microcomputer based gear-selection aid monitor. The device monitors several tractor operating conditions and determines the optimum throttle and transmission setting. The settings are displayed using a digital feedback method. Preliminary results indicate fuel savings of 12.5% when the monitor was used (Schrock, 1985).

Another tractor performance monitor is being developed and tested at Texas A&M University. This microcomputer controlled monitor uses a combination of a visual LCD display and an audio message generated through speech synthesis that specifically tells the operator what gear and throttle setting to use in order to maximize fuel efficiency (Grogan et al., 1984).

Becker et al. (1983) have developed a test procedure to test the concept of the psychological speed-load stress.

According to the speed-load theory, there is a direct linear relationship between number and rate of stimuli received and the number of response errors made. Tractor operators are given visual and auditory signals during a run on a test course. The number of signals and the operator responses are recorded and this data is analyzed to find an optimum number of signals an operator can comprehend without making too many errors. There has not been enough tests run to get meaningful results yet.

## DEVELOPMENT OF COMPUTER SIMULATOR

The simulator was designed to keep the operator busy with the steering function, yet have a second function that the operator would need to notice and perform. The second function was designed to simulate a monitor. This monitor would detect changes in operation that would warrant a response from the operator. In the visual feedback test the second function indicated the most efficient gear ratio to be in by an arrow next to a transmission indicator box. In the audio feedback method, the change was indicated by beeps made by the computer. The operator would need to match his transmission gear to the gear that was indicated to be most efficient.

The computer model was written in the BASIC computer language. A computer simulation was used to test the audio and visual communication methods because of time, equipment, and monetary limitations.

The program was written to run on a Texas Instruments Professional Computer with graphics capability. Kaminaka (1983) found that a computer graphics simulation to test motion contollers is superior to a pure mathematical approach. A graphical simulation is more real and more flexible than the mathematical simulation.

Two conditions of operation were simulated with the program, steering and transmission gear-ratio selection. The tractor functions were controlled using random number generation. The operator used four keys on the computer keyboard to input responses to the tractor movements.

The steering function of the simulator consisted of a rectangular box situated horizontally on the computer screen with a target within the box. The target moved constantly to the left or right depending on random numbers. The operator controlled an arrow beneath the box. The operator's duty was to keep the arrow and the target lined up vertically as closely as possible (Figure 1). The operator controlled his steering arrow with a left arrow key and a right arrow key. The program also kept track of the operator error by taking the vertical distances that the operator was different from the steering target and totaling the differences up throughout the testing. This scoring of operator steering performance was done to insure that the operator kept reasonable control of the steering function.

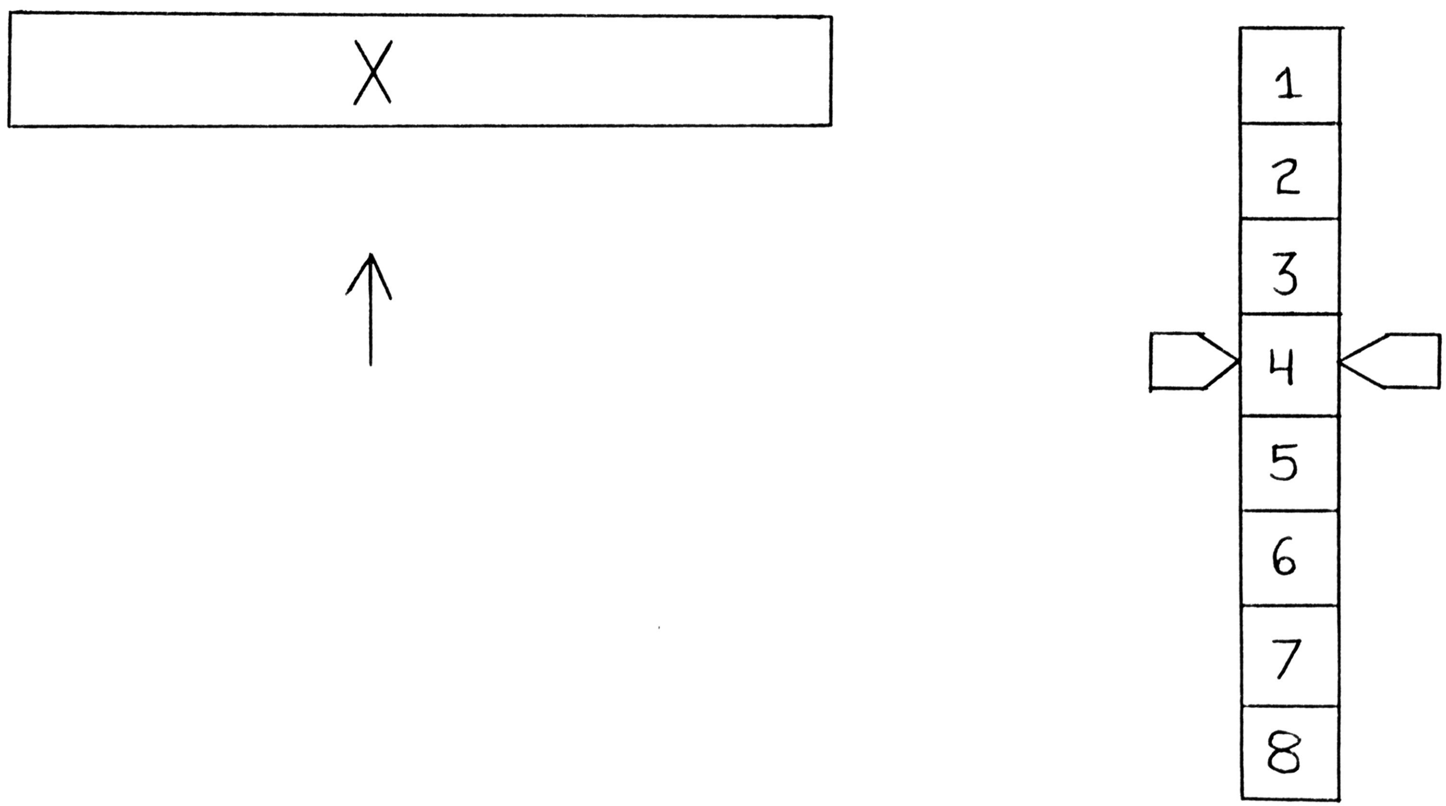


FIGURE 1. Illustration of computer screen

The second and most important function was the transmission gear selector function, also shown in Figure 1. The gear selector function consisted of a rectangular box situated vertically along the right side of the computer screen. The large box was divided into eight smaller boxes with the numbers one through eight in them. A large arrow located on the right-hand side of the selector box indicated which gear the operator had chosen to shift into. This large arrow was controlled by the operator with the use of an up-arrow key and a down-arrow key located on the computer keyboard. For the visual response test, there was a large arrow on the left-hand side of the selector box. This arrow moved up or down to a different gear according to random numbers. The operator's duty was to match his arrow to the same gear as the computer-controlled arrow. He was supposed to do this as fast as he noticed the indication to change.

The audio-response test was exactly the same except for the left-hand arrow on the gear selector box. The audio method used a warning beep of a certain octave and another beep of either a higher or lower octave depending on the indication to shift up or down. The warning beep was used to get the operator's attention and also to serve as a reference sound for the second beep.

Both the audio and visual methods are scored within the program by the number of seconds from change indication to actual operator gear change.

The scoring is done automatically by the program and the data is saved on a disk during the operator's test. Later, the data is analyzed through graphs or tables.

The logic of the program is outlined in the flowchart in Figure 2. After initialization, the program enters a loop where the operator can enter a steering or gear change if indicated. If a steering change is indicated, the operator presses one of his steering arrows. The operator's steering arrow then moves in the proper direction and the difference between the arrow and the target is calculated. This difference is then added to a total steering difference. The program then goes back to check for more operator inputs. If a gear change is indicated and the operator presses his gear change arrows, the program proceeds into the gear change sequence. The operator's gear indicator arrow moves and a response time difference is calculated. This individual difference is added to a total time difference and both differences are stored on the disk. The program then goes back to check for more operator inputs.

The next step is the random selection of the desired transmission gear. The program was designed to indicate a gear change on the average of once every two minutes.

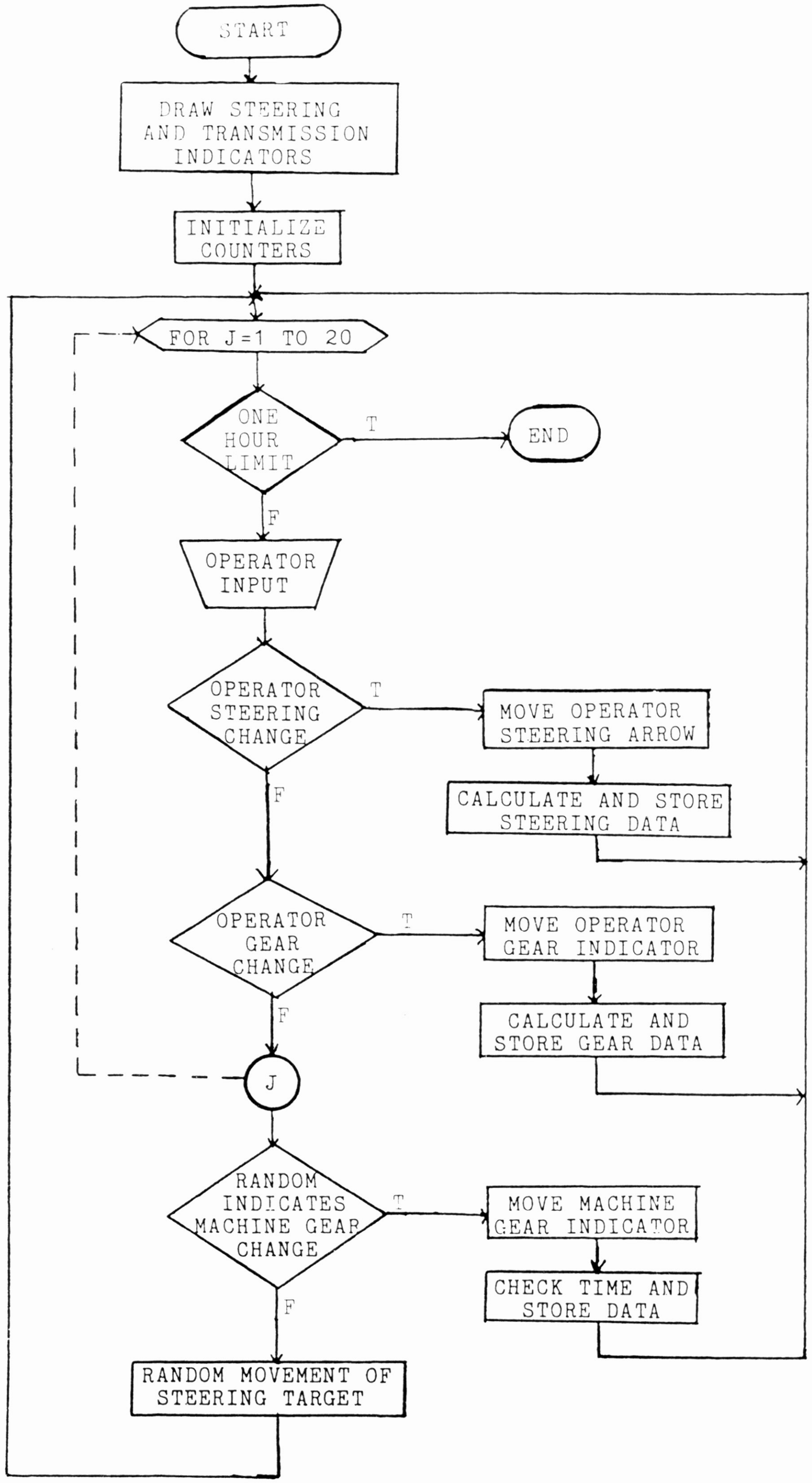


FIGURE 2. Simulation Flowchart

If the random numbers indicate a gear change, the program goes to the machine gear change sequence and the gear indicator moves up or down. Or, in the case of the audio test, the computer beeps. The time is recorded to be compared with the operator's gear change later in the program to get a gear change response time. The program then loops to accept more operator input.

The last step of the program is to change the steering target location. The steering target will move either left of right depending on the random numbers. The program then loops back to accept any operator inputs.

The program automatically stops after one hour. An hour limit was used because of the lack of time to test operators. This time factor was made more realistic to a full day's work by having the steering and gear change more often than in an actual tractor. This caused the boredom and fatigue factor which is prevalent in tractor operation.

## METHOD OF TESTING

Five operators were used to test the feedback methods. Each operator ran each program for one hour. Two of the operators had experience in tractor operation. Three of the operators had no experience in tractor operation. Before each test, instructions were given to the operator on how the program worked and what to do.

The operator was allowed five minutes of practice to get familiar to the simulator. Three of the operators ran the test on different days. Two of the operators ran the audio test right after the visual test.

## RESULTS AND DISCUSSION

The data collected on the disk during an operator test was later printed out into a table form. From this data, graphs could be plotted showing the total gear difference over the hour. In Figure 3, the total gear differences for both feedback methods are shown over the hour for one of the experienced operators. The large, sudden increases in slope indicate where the operator failed to notice a desired shift and change his gear accordingly. The visual method resulted in larger sudden increases and overall a higher total difference. This difference indicates that it took longer for the operator to notice the visual method than the audio method. Figure 4 shows the total gear differences for both feedback methods over the hour for an inexperienced operator. Again, the same results of an overall higher response time for the visual method indicates that the audio method was more noticeable.

Even though the average response time overall for all the operators differed by only about one second, the large response differences are the important factors.

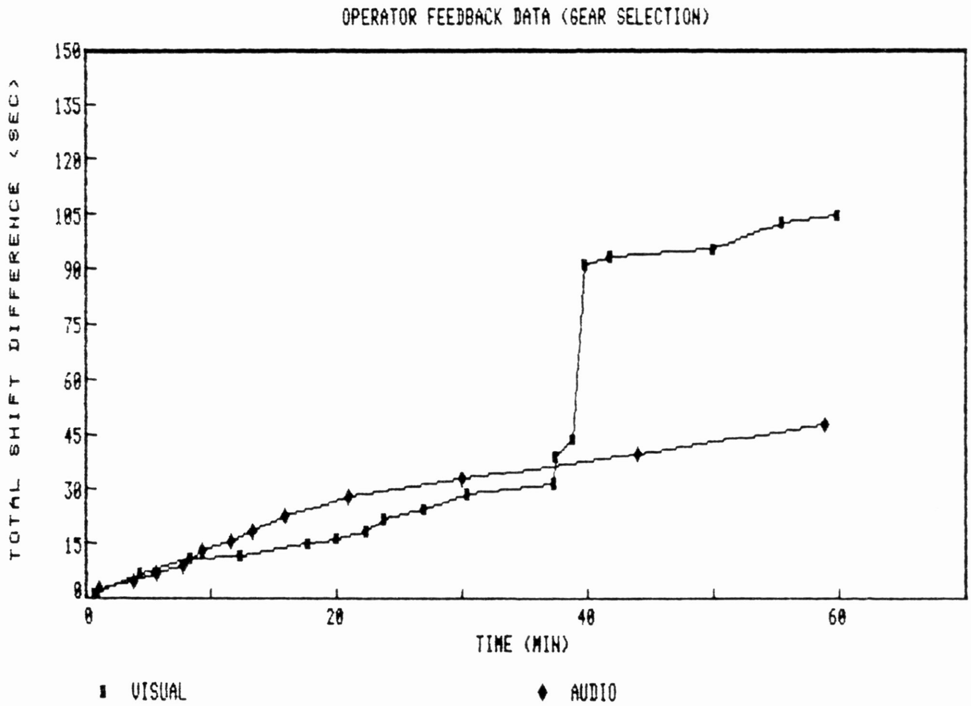


FIGURE 3. Experienced Operator Data

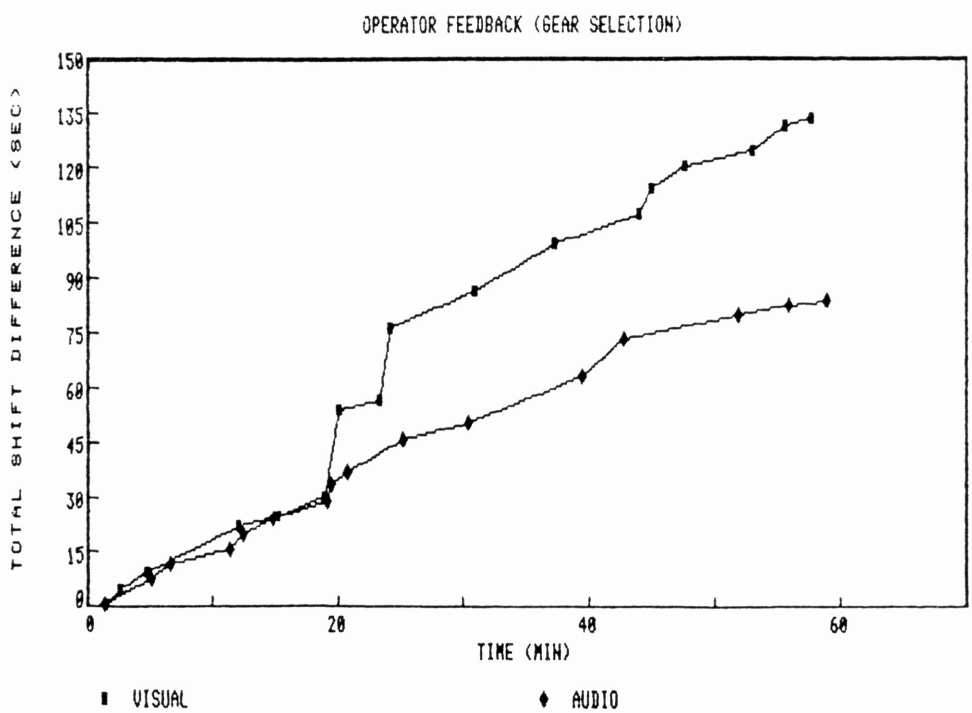


FIGURE 4. Inexperienced Operator Data

In actual operating conditions the response times will probably be much higher due to more variables associated with actual operating conditions. These longer periods of time can mean wasted fuel while the tractor is in the improper gear. It could also mean wrong plant populations in the case of a planter monitor. It could also mean increased repair bills if an engine malfunction is not noticed in time.

Table 1 shows all of the data collected for each operator. The important results shown here is that the average shift response time is almost twice as high for the visual method (2.16 seconds) compared to the audio method (1.20 seconds). Also, the range of operator responses to shifts is much higher for the visual method than for the audio method. Each operator experienced a higher total shift difference for the visual method over the audio method. It was predicted that the total steering difference would also be lower for the audio method. However, this was not true for every operator.

## SUMMARY AND CONCLUSIONS

A computer model was developed to simulate the steering and gear indicator functions of a tractor. Two methods of operator feedback were tested, the visual and audio methods. Five operators tested both methods.

The visual method consistently took longer for the operator to notice than the audio method.

Table 1. Results of all operator tests.

| OPERATOR | AUDIO DATA | | | | | VISUAL DATA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NUMBER OF OPERATOR SHIFTS | RANGE OF OPERATOR RESPONSE TO SHIFTS (SEC) | AVERAGE SHIFT RESPONSE TIME (SEC) | TOTAL SHIFT DIF. (SEC) | TOTAL OPERATOR STEERING DIFFERENCE (PIXELS) | NUMBER OF OPERATOR SHIFTS | RANGE OF OPERATOR RESPONSE TO SHIFT (SEC) | AVERAGE SHIFT RESPONSE TIME (SEC) | TOTAL SHIFT DIF. (SEC) | TOTAL OPERATOR STEERING DIFFERENCE (PIXELS) |
| 1 (I) | 70 | 0-6 | 1.2 | 85 | 29,041 | 67 | 0-24 | 2 | 134 | 24,108 |
| 2 (I) | 47 | 0-7 | 1.6 | 75 | 43,790 | 53 | 1-16 | 1.9 | 101 | 32,289 |
| 3 (I) | 35 | 0-3 | 0.8 | 28 | 59,002 | 28 | 0-4 | 1.4 | 39 | 55,213 |
| 4 (E) | 48 | 0-3 | 1.0 | 49 | 33,800 | 32 | 1-48 | 3.3 | 105 | 45,771 |
| 5 (E) | 46 | 0-6 | 1.3 | 61 | 26,805 | 43 | 1-34 | 2.3 | 97 | 43,940 |
| | | AVERAGE | 1.2 | | | | AVERAGE | 2.16 | | |

The difference was usually present because of several large individual differences.

The use of an audio feedback method in monitors or a combination of audio and visual feedback methods could result in significant fuel savings if used in conjunction with a tractor performance monitor. The efficiency of other types of monitors could also be increased if they took advantage of some type of audible warning device.

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