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Automatic guidance systems in agricultural machinery as a tool for drivers' mental strain and workload relief

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Absatract

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This article evaluates agricultural operator´s stress, mental strain and generally fighting with driving difficulties during operating agricultural machinery sets by means of a heart rate indicator. Different drivers driving different tractors with implements were chosen and evaluated during different field jobs, namely soil tillage and sowing. Machinery position on the field was precisely monitored by a GPS receiver and the heart beat rate was observed by means of a chest belt special device with a heart rate sensor. The output data from the sensors were monitored during conventional manual steering of the tractor-implement set and also when using the complete automatic guidance steering without any driver´s intervention to steering wheel – all by using the DGPS guidance signal. The data were further processed with a special software for the heart rate sensor and detailed statistical evaluation was performed. All described trials were measured at different farms in the Czech Republic. The final outcomes from the experiment showed a statistically significant difference between two experimental variants and confirm our hypothesis that the guidance systems bring a great benefit for drivers concerning mental strain and relief of their workload.

Key words: navigation in agriculture; heart rate sensor; driver's stress; driver's workload

Guidance systems in agricultural machinery have become a necessary part of modern farming. Formerly, the use of guidance systems was limited only to military use; however over the last 15 years these systems have very quickly spread to the civilian use – in the transport industry, tourism, geodesy and also in agriculture. Navigation of machinery sets in fields, and therefore the precise establishment of adjacent passes without a manual control, allows the drivers to use unconventional organization of machinery passes in the field and allows the use of new management of tillage systems – controlled traffic farming (CTF). These systems also bring relief for drivers' mental strain and stress when driving farm machines.

Every driver of a mobile vehicle or operator of any kind of machine is exposed to a certain psychological stress – mental load. This phenomenon is caused by the combination of various factors referred to as stressors. These may be due to physical causes (e.g. noise, high temperatures, discomfort, poor ergonomic conditions inside the cab of a vehicle, etc.), as well as social-work reasons (e.g. high requirements of the employer, shift work, feelings of isolation, overtime requirements, compliance with certain deadlines or targets, responsibility for transferred persons and goods when talking about professional drivers). Finally, the stressors can have origins in the personality of the driver (e.g. im-

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pulsivity, stress tolerance, adaptability, etc.). This phenomenon has been studied especially on drivers in road transportation under real traffic conditions, where the number of stressors is very high (Švancara 2003).

According to the classification of stressors, it is possible to distinguish three main forms of mental strain and drivers workload: strain resulting from sensory perception which comes from the activity of the sense organs and their corresponding structures of the central nervous system; mental workload, resulting from requests for information processing which place demands on the psychological processes such as attention, memory, imagination, thinking and decision making; finally it is the emotional strain which follows from the situations and requirements instigating affective response. The last cited emotional strain is possible to see in particular on drivers in road traffic (James, Nahl 2002). Dey and Mann (2010) published their research concerning the mental strain of drivers who operated agricultural sprayers with navigation system using LED light bars. Eye movements and heart rate of the drivers were monitored during their job. The measurements were supplemented with a questionnaire, where the drivers answered questions concerning their personal thoughts about prevailing factors of mental strain and workload.

Batte and Ehsani (2005) evaluated the economic benefits of the navigation system for sprayers' utilization and as additional measurements, they carried out also evaluation of operators´ mental strain during their spray job when using navigation system.

The aim of the present research focused on the evaluation of the mental strain and workload of agricultural machinery operators was to evaluate the benefits of navigation systems used in agriculture, which are reflected by reduction of stress and mental strain of the drivers.

MATERIAL AND METHODS

The heart rate monitoring method was chosen for our measurements. The agriculture machinery drivers were observed concerning their mental strain during work. The measurements were carried out in different agricultural enterprises in the Czech Republic. All the experimental data were gained during soil preparation and sowing field. Drivers' heart rate was monitored during soil tillage for the same tractor and for the same driver during the same field job (soil tillage) in the same field when the machinery guidance system was used and without the use of any navigation when the machine was operated fully manually. Each experimental variant was measured for 30 to 45 minutes. In practice, one driver on the same field performed a 30–45 min soil tillage job with the navigation system engaged – it means with the automatic establishment of adjacent passes; afterwards he performed another 30–45 min soil tillage job without navigation only with manual tractor control and establishing passes visually, according to the experience and the estimation for pass-to-pass connection. This procedure with alternating machinery guidance and work without the navigation was performed in total three times for one driver.

For the purposes of driver's heart rate monitoring two measuring kits of sport tester Polar RSX800CX (G) (Polar Electro Oy, Kempele, Finland) were used (Fig. 1). The Polar RSX800CX kit consisted of digital watches, chest belt with a heart rate sensor connected to the watches via Bluetooth linkage. GPS receiver was also a part of this professional measuring kit and thus it was possible to determine the immediate position of the person and consequently the whole tractor-implement set. The data about the driver's immediate position and his heart rate were stored into the watches memory each second. It enabled to save data finally to the PC and to do the statistical analysis.

The experiments were carried out with randomly chosen drivers of different age who had experience and were fully acquainted with the tractor navigation system and its functions. This requirement was important, because the use of tractor navigation system for a driver not accustomed to this system can act as a disturbing stress factor.

Fig 1. Sport tester Polar RS800CX G

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For the statistical evaluation, the software Statistica 12 (Statsoft, USA) was used.

RESULTS AND DISCUSSION

The fields chosen for the above described measurements were of larger size (20 ha and more) and were regular in shape, in order to ensure sufficiently long machinery passes with no need for frequent turns on headlands or field corners and also with no obstacles such as electricity poles.

Before a start of each measurement it was necessary to fasten the chest band with the heart rate sensor on the driver's body – his chest. Polar digital watches and their GPS module were turned on and linked together. The following data were written down before each driver's experiment start:

– Driver's name, field name, experiment date, field job monitored, variant WITHOUT the guidance system utilization, start time, duration of the variant (30–45 min);
– Driver's name, field name, experiment date, field job monitored, variant WITH the guidance system utilization, start time, duration of the variant (30–45 min).

This was the experimental set-up and its sequence was repeated 3 times.

Processing of the measured values was performed by means of a specialized communication software for Polar watches, where it was possible to demonstrate all the outcomes clearly in a graphic form and further sort, evaluate and analyse the measured values (Fig. 2). This software provides browsing through the measurement calendar and all the data, from which it is possible to pick up and see each field job and variant recorded into the watches in the chronological order.

It is very easy to identify the field job, time, position and the person who carried out the field op-

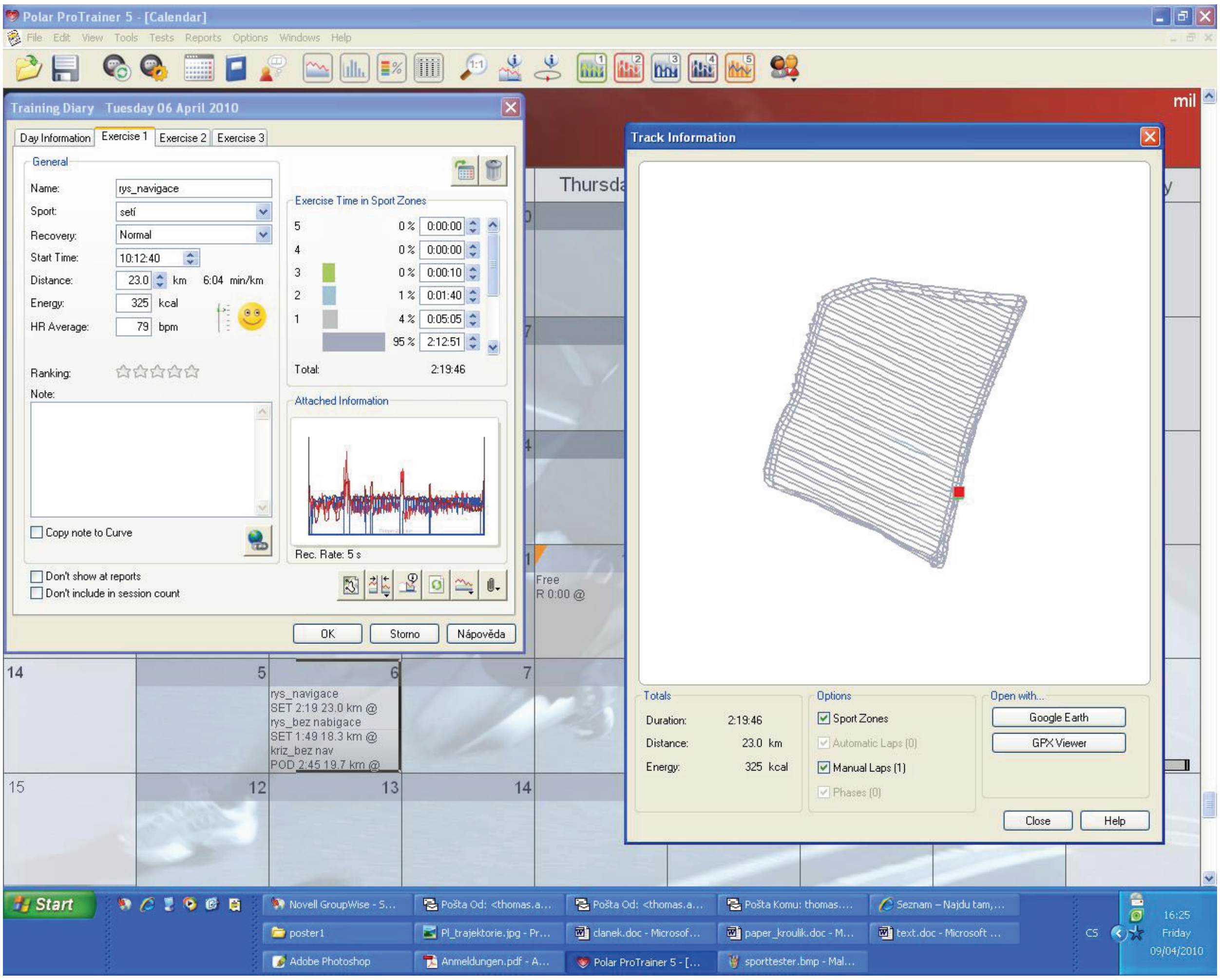

Fig. 2A. Overview of the main page of the Polar processing software

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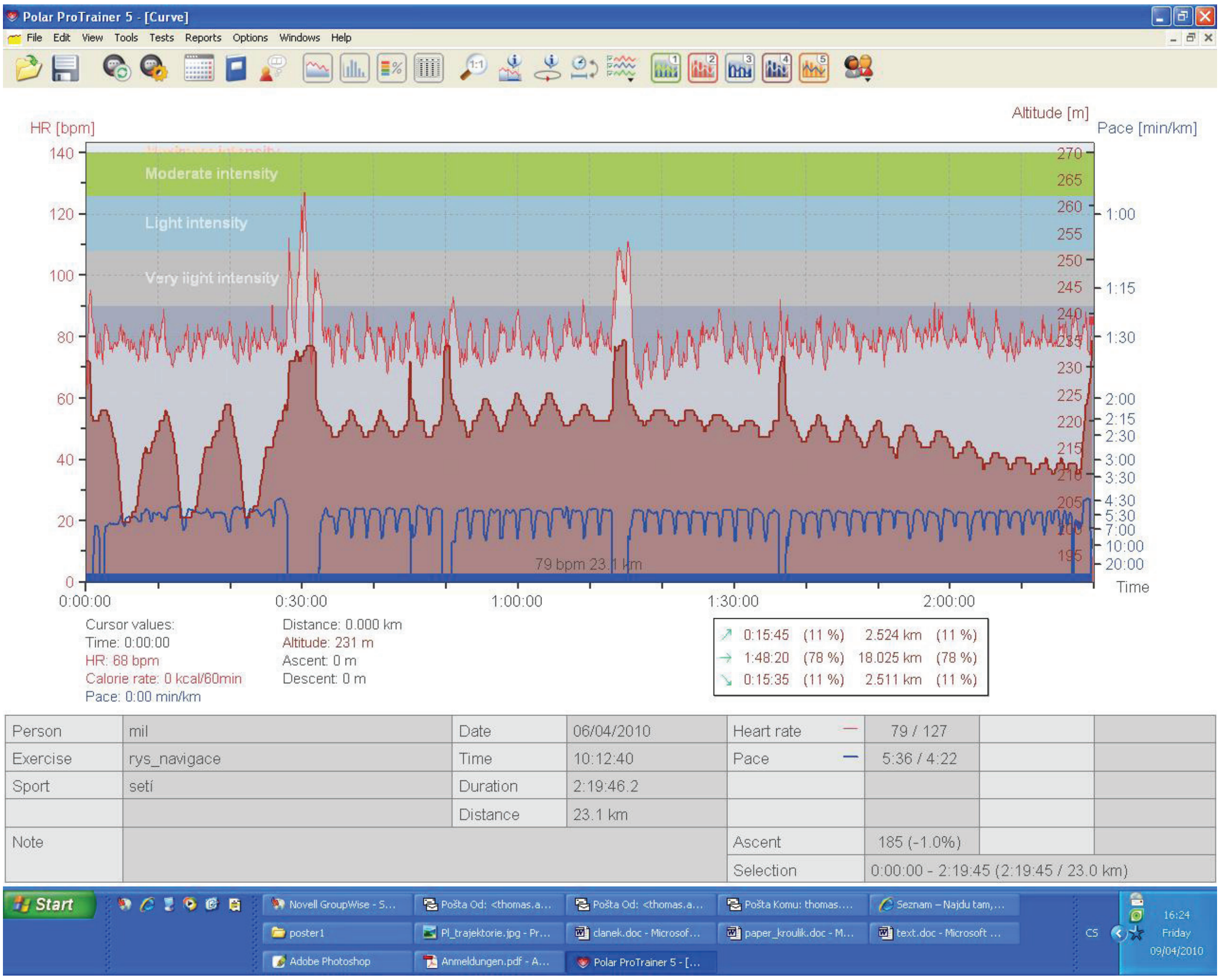

Fig. 2B. Overview of the data protocol about one measurement in a particular field

eration. Short, clear and well-arranged protocol is saved into the PC for each field. This software allows saving the data very simply as a text file, and so it is possible to analyse the data about the immediate location of the machine and heart rate record in more detail by means of any different statistical software.

Program ArcGIS was used for further evaluation of the measured data. GPS coordinates of the operator's position, and therefore the position of the whole machinery tractor-tool set, allowed us to distinguish between passes on headlands and working passes through the field during the measurements. For the purposes of our measurements, the headland was defined as a strip of land around each field 24 m in width (Fig. 3). Subsequently, it was possible to process our measured values for the working passes while driving between the headlands for both variants – driving without the navigation and driving with the navigation. It was also possible to evaluate the measurements during headland turns again while driving without the navigation and with the navigation in the same way.

The results of our measurements are shown in this paper on two examples from the statistical evaluation. The presented results of measure-

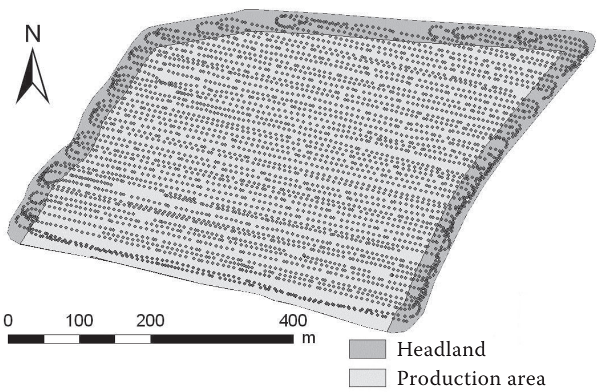

Fig. 3. Measured values from a GPS receiver made by ArcGIS software – trajectories of the tractor-implement set during a field operation

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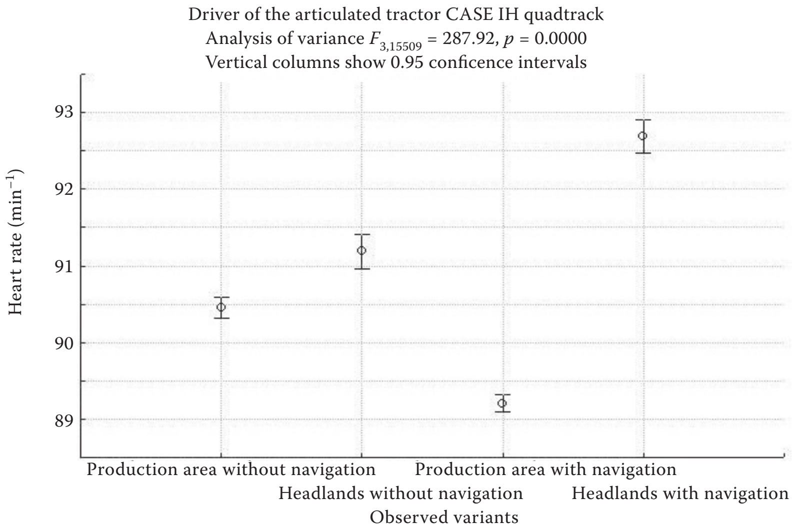

Fig. 4. Average values of the heart rate measured on the CASE IH articulated tractor driver – comparison between four specific places observed in the field

ments, described in more detail, were obtained during basic soil tillage. In the first case, the quad-track articulated tractor CASE IH (CNH Industrial N.V., USA) was observed doing this field job. The second case was a tiller with tracked tractor Caterpillar Challenger.

Fig. 4 shows a graph with the heart rate values of the driver of the quad-track CASE IH tractor. There are obvious differences between the values of the driver´s heart rate when using the navigation system and without the use of navigation. A significant increase of the driver's heart rate is noticeable when turning on the field headlands.

When comparing the average values it is possible to see a decrease of heart rate values by 1.4% when using the navigation compared to driving without the navigation of the tractor. By comparison of the driver's heart rate values recorded in the working area and on the headlands when the navigation system was engaged (real turns of the tractor on headlands were always performed manually), it is possible to present an increase in the measured heart rate values on headlands by 3.9%. During field jobs with manual tractor steering, this increase in heart rate on headlands was only 0.9%. However, an overall decrease in the heart rate was observed when using the navigation system during field jobs. Therefore, it is possible to deduce that there is a significant relief for the driver; when the driver performed back-turns on headlands his mental strain was higher, which corresponded with his heart rate increase.

As demonstrated in Table 1, statistically significant differences in drivers' heart were proved at a significance level α = 0.05.

In the second case, the driver of the tracked tractor Caterpillar Challenger was monitored. The graph in

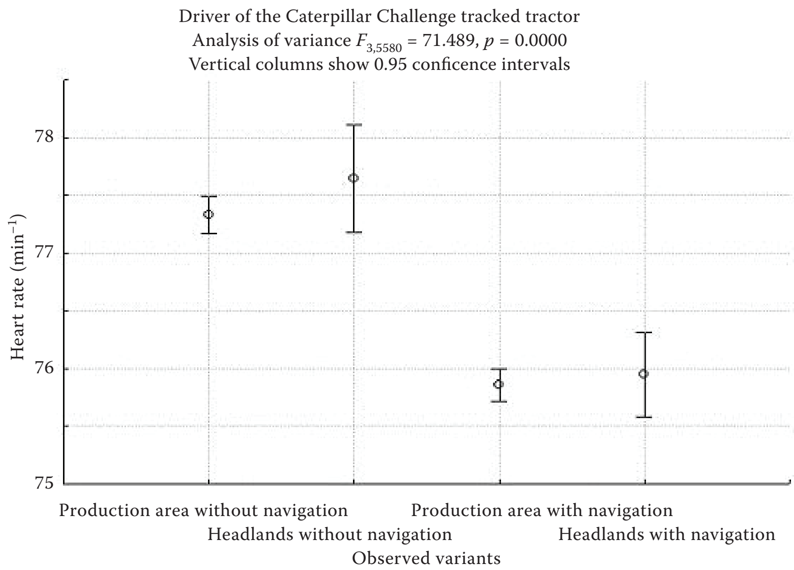

Fig. 5. Average values of the heart rate measured on the Caterpillar Challenger-tracked tractor driver – comparison between four specific places observed in the field

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Table 1. Statistical analysis of variance – testing of statistical significance of differences within the different types of tractors

Variants observed	Heart rate (average values) (min^{-1})	
	articulated tractor CASE IH	tracked tractor Challenger
Production area WITHOUT navigation usage	90.4^{a}	77.3^{a}
Headland WITHOUT navigation usage	91.2^{b}	77.6^{a}
Production area WITH navigation use	89.2^{c}	75.8^{b}
Headland WITH navigation usage	92.7^{d}	75.9^{b}

different indexes determine statistically significant differences at significance level α = 0.05

Fig. 5 also highlights differences in the drivers' heart rate in different navigation regimes. The graphical representation of statistically processed measured data allow us to identify only two groups of heart rate values – driving without the navigation system and using the navigation without any statistical difference between the filed production area and headlands. When using navigation system of the tractor, the heart rate values were measured by about 2% lower in the production area compared to manual steering. As Table 1 demonstrates, the differences were also statistically significant.

Using the navigation system for automatic steering in both tractors during their field operations thus contributed to reduction in the drivers' mental strain. The "headland" heart rate of both drivers always increased. However, as shown by the results, the statistically significant increase in drivers' heart rate on headlands was observed only when driving the articulated quad-track tractor CASE IH.

Operating the tracked tractor Caterpillar Challenger represents a different type of steering wheel movement when the steering wheel is being turned not around, but only by a certain angle less than 180° to perform greater turns.

Further reduction in drivers´ mental strain on field headlands would be possible by using the new navigation systems that are able to steer and turn the tractor automatically by themselves.

CONCLUSION

Statistically significant differences in drivers´ heart rate were measured and evaluated during different field jobs with different tractors with navigation system switched on and switched off. Navigation system and automatic steering was taken as a device for possible drivers' stress and mental strain reduction. The experimental measurements revealed a correlation between drivers' heart rate and drivers' workload, mental strain and generally their attention during tractor-implement set operation in a field in agriculture.

The following outcomes can be derived from the above described experiments. When steering a tractor with activated navigation system, the drivers' heart rate was on average by more than 2% lower than when steering a tractor fully manually without the navigation system engaged. These results indicate that the use of navigation systems in the agricultural machinery in the field can reduce the mental strain and workload of the operator.

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