Picking Goods Assisted by Head-mounted Augmented Reality Systems in Warehouses

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Abstract

Background: *There are several systems for workers in order to optimize the picking processes in handling goods. Aim of the study was to compare physiological strain and performance of a prototype vision system (VS) to a voice system (VC).* ***Methods:*** *20 male subjects performed a cycle ergometry to determine exercise performance. Heart rate (HR) recordings, number of steps, gas exchange measures and bipolar surface electro-myography recordings were obtained.* ***Results:*** *Shift HR 106.6 ± 12.6 bpm (59.7 ± 5.9 %* HR_{max}*) and oxygen consumption during selected phases of work 1.178 ± 0.189* $l.min^{-1}$ *(39.9 ± 3.3 %* VO_{2max}*) for VS differed significantly compared to 99.7 ± 9.6 bpm (55.9 ± 5.7 %* HR_{max}*) and 1.011 ± 0.139* $l.min^{-1}$ *(33.5 ± 5.5 %* VO_{2max}*) for VC.* ***Conclusion:*** *Subjects picked a higher number of pieces applying VC although lower physiological responses compared to VS indicating the need for further improvements of the system.*

Key Words: augmented reality system, lactate turn point, physiological strain, heart rate, oxygen consumption

1. *Introduction*

The aim of modern logistics companies is to provide picking systems efficient and economical, to handle goods in order picking. Usually workers pick up items out of selected batches in warehouses by paper lists. Picking operations are subject to continuous improvements, as more and more goods must be loaded on even smaller spaces. The diversity of products is increasing, while the number of single orders is decreasing [1]. This requires supportive systems for the workers, in order to optimize the working process.

Usually flexibility and techniques of the workers are very important to handle this number of enquiries. A completely computerized technique was shown as an inefficient method. For example, fully-automated techniques are not able to handle unexpected situations such as fallen pallets or misplaced bar-codes. For these problems the programming effort would be too high. In these unexpected situations well-trained workers are more efficient [1]. Additionally, the order situation varies according to season and requirements including large fluctuations of workers. Thus, systems are needed, which allow workers to quickly get used to changing situations and to support them in an efficient way. In order to avoid errors the system development should also take the level of workers strain into account. This requires systems to support workers with just the right information at the right time. There are several different picking systems currently available. The most popular, but somehow outdated form to execute the orders is using a paper list. A more recent and commonly used technique is the voice system which was also used in this study [1]. The voice system gives the workers all instructions through a computer's speech output and is controlled by voice recognition. The quality of an order picking system is determined in according to time and error rate. Vision- and voice systems have a lower order picking time compared to a conventional paper list [1]. Additionally the error rate is about 0,08 % with a voice system compared to 0,35 % with a paper list [2].

However most of the modern picking systems like voice-, light- and point-systems also have disadvantages like a higher error rate [3]. For example the artificial speech of the voice system is difficult to understand in noisy environments. Furthermore, a monotone voice can be very unpleasant for the worker during a whole shift day. To further improve the order picking logistics companies always launch new systems or optimize existing systems. These new systems need to combine the real world with additional information, the augmented reality. Usually the augmented reality systems use head-mounted displays (HMDs) such as the so called vision system. Comparable to the entertainment industry HMDs and vision systems are used in many areas like medicine, such as documentation in forensic medicine [4], or different surgery methods [5]. The augmented systems were shown to be a benefit for blind individuals to help them to achieve a better quality of life [6]. Unfortunately, augmented systems are not yet fully developed and have some deficits in certain areas like shown by Schega et al. [7]. These authors compared three types of HMDs [look around (LA); optical see-through (OSTs) with organic light emitting diodes and virtual retinal display], in which basic visual functions were negatively affected by LA. The LA system could be an alternative to OSTs systems if temporal disturbances on the medium can be reduced. For complex working conditions with many different visual stimuli the OSTs systems seems to be more practicable. In addition to increased productivity but to avoid overloads, physiologically acceptable strain of workers is important to consider [8-10], as well as long working hours [11-13].

Similar to voice systems, vision systems may have some advantages in warehouses compared to paper lists. Alt et al. [14] in Schwerdtfeger et al. [3], compared subjects performing with a paper list and a vision system. These authors suggested that subjects performed up to 26% faster with the vision system. In this study a one-eye prototype HMD was applied in an order picking situation. This real time one-eye display allows workers to see augmented information additional to the reality. The workers are navigated through this system and can visually confirm the code of the goods and also confirm the task by a coded button.

The aim of our study was to compare an OST-prototype vision system, a picking system with an augmented reality approach, to a conventional voice system during a typical order picking activity in terms of physiological impacts on the workers.

2. Materials and Methods

The study group included 24 volunteers. For statistical reasons only 20 male subjects, who performed the complete ten hours of occupational work, were taken into consideration. Drop out reasons were shorter working time and errors on the technical systems. The 20 male subjects (mean age 29.9 ± 4.5 years) had a mean height of 1.83 ± 0.06 m, mean weight of 83.7 ± 15.7 kg with a mean BMI of 24.9 ± 3.8. The study was carried out to test a new HMD prototype augmented system for order picking (vision) and to compare it with an existing voice system (Vocollect, Intermec-Honeywell). The volunteers worked for two days each with a different system in a randomized order.

At the first day half of the participants worked with the new vision system and the others worked with the voice system. At the second day they changed the systems. The subjects were no professional workers and therefore they had a one-week induction phase with both systems. The study participants had to have no history of significant musculoskeletal, neurological, metabolic or cardiopulmonary pathology and no physical illness during the last three months. Ophtamologic tests were done by all participants before, during and after the shift (data not shown). These criteria were controlled by the leading Physician of the study. The study was approved by the local medical university ethics committee. The authors declare that there is no conflict of interest regarding the publication of this paper.

To determine maximal aerobic power output (P_{max}) all subjects completed a maximal incremental cycle ergometer test until voluntary exhaustion after medical examination and a resting ECG. The cycle ergometer test was carried out on an electronically braked, computer controlled ergometer (Monark 839E, Monark Exercise AB, Sweden). The starting exercise workload was 40 Watt (W) and work load was increased by 20 W every minute. This procedure is the recommended protocol of the American College of Sports Medicine (ACSM) [15], and the Austrian Society of Cardiology [16], to determine P_{max} among young and healthy people. The subjects were verbally encouraged to continue the test until they could no longer maintain the given crank frequency of 70 rpm. A 12-lead ECG (Custo Cardio 200 BT) was recorded and supervised by a Physician, which also measured the blood pressure every second load step. The heart rate (HR) was measured continuously during the test and during five minutes of recovery. 20 µl blood samples from an ear lobe were taken after every workload step and during recovery. The blood lactate concentration (La) was determined encymatically (Biosen S-Line; Diagnostic GmbH, Germany). After calibrating the equipment to measure gas-exchange variables according to the manufactures guidelines before each test, oxygen uptake (VO_2) and carbon dioxide output (CO_2) were measured continuously using a breath by breath ergospirometric system (Metamax 3B, Cortex Biophysik, Germany). The average of the highest five consecutive breaths attained in the last minute of exercise was defined as maximal oxygen uptake (VO_{2max}). The first (LTP_1) and second lactate turn point (LTP_2) were assessed by means of computer-aided linear regression breakpoint analysis [17]. LTP_1 was defined as the first increase in blood lactate concentration (La) above baseline and LTP_2 was defined as the second increase in blood lactate concentration between LTP_1 and lactate at P_{max} (Figure 1).

The voice system (*Vocollect, Intermec- Honeywell*; Voice Software: Voice Client; Management Software: Voice Console; Process Software: Voice Applications or Tasks; Operating System: Windows CE 6; Processor: OMAP @ 500MHz; Memory 256MB RAM, 512MB Flash; Bluetooth: Version 2.1; Radio: 802.11a/b/g or 822.11b/g; Serial Ports: One; Drop Tested: Four drops from 5 feet on six surfaces (24 drops). Two drops from six feet on six surfaces (twelve drops); Battery: 4400mAh; Headsets: Complete SR Series, SRX, and SL-14; Peripherals: Scanners Mobile Printers Displays) is a head-mounted system, where the workers receive orders through a voice system and a wired headset connected to a pocket-PC. The voice system specifies the number of the storage compartment and the number of goods the worker has to identify and to pick. If the worker arrives at the storage compartment he has to confirm it by a voice code through the headset. After loading the number of goods he confirms it again with a voice code and he receives the next order. The weight of the headset is about 150g, the weight of the whole system with the battery is 340g.

This prototype of a HMD vision system (*KiSoft Vision, KNAPP*; Wearable PC-Operation System: Windows 7 Embeded; RAM: 2 GByte; Harddrive: 4 GByte NAND; Network: 802.11 a/b/g/n IEEE, wireless adapter; Display: SVGA 800x600; Field of view: 32°; Eye-motion box: 10x10mm; Eye relief: up to 23mm; Video-signal: LVDS; Camera: uEye XS, 800x480; Frames per second: 30; Sensor: 8 mega-pixel CMOS, autofocus; picture stabilization: automatically; EMV-compliance: CE-class B, FCC-class B; Battery: Ni2020A2 lithium-ion; capacity: Ni2020A24 / XE24: 7.2Ah) provides the worker all the information needed for his work task (storage space, articles, quantity of goods) through a data glass. The aim of this augmented system is to guide workers through the warehouse. The HMD is connected with a computer together with a battery which is worn in a back vest. The position of the worker and his line of sight can be determined by a tracking system. In addition to static text information virtual objects like arrows for navigation or a colored outline of the current storage compartment are shown in the data glass display. All storage compartments have an optical code so that the worker can confirm the ordered goods before he loads them.

By finishing the job the worker has to visually confirm it with an entrained code looking at a specific code card. The weight of the headset is about 420g, the weight of the whole system with the battery and the vest is about 2700g.

HR recordings were obtained for a complete ten-hour work shift by means of a portable HR monitor (Polar S810; Polar Electro, Finland) storing the HR every 5 seconds. Gas exchange measures were determined by means of breath by breath gas exchange analysis during 25 minutes of representative periods of work with a portable system (MetaMax 3B, Cortex Biophysik, and Germany). Before testing of the devices a calibration was performed according to the instructions of the manufacturer. The triple-V turbine was calibrated using a 3.0-litre syringe. Heart rate during 25 minutes of gas exchange measurement was determined to obtain comparisons with the mean heart rate during the complete ten hours of shift work. The total energy consumption during the working time was calculated by indirect calorimetry using oxygen uptake measures during a representative work period.
Total energy expenditure 10h [kcal] = oxygen consumption [l] x caloric equivalent at an respiratory exchange ratio during work x 600 [min]

Since the oxygen uptake is closely related to the heart rate during these 25 minutes, a correction was done by the average heart rate from the ten hours working time, when necessary. Work-related energy expenditure was calculated from the total energy expenditure minus the basal metabolic rate (BMR), which was calculated as shown previously [18].

BMR (men) = 10 x weight (kg) + 6.25 x height (cm) – 5 x age (years) + 5

BMR (women) = 10 x weight (kg) + 6.25 x height (cm) – 5 x age (years) – 161

Work energy expenditure (EEw) [kcal] = Energy expenditure (EE) - BMR

Surface electro-myography (SEMG)-recordings were performed, using a bipolar SEMG which was carried out to identify possible fatigue processes during the entire duration of the work activity. Measurements were performed four times every 160 minutes with a portable SEMG device (Duch led device "TeleMyo 2400 T G2" *Noraxon*). The data were processed with the software "MyoResearch XP masts Edition", where the raw signals were processed to the root-mean-square (RMS), representing the amplitude within the used time frame. Evaluation of the data was processed by means of "Microsoft Office Excel 2007" and "Winstat” (Kalmia Corp., USA).

All measurements and calculations were carried out according to recommended standards [19]. SEMG-recordings were done for the right neck muscles [Mm. cervicis (CERV)] and forearm muscles [M. flexor carpi ulnaris (FCU), M. extensor carpi radialis (ECR)]. Every subject was investigated four times during ten hours of working time with standardized weights (4.2 kg dumbbell forearm muscles, 1 kg weight neck muscles). For the measurement of the forearm muscles subjects performed static holding of weights in a standardized angular positions of 45 degrees between the upper and lower arm. For five seconds per measurement the subjects had to hold a weight dumbbell in the right hand in a seated position, for the measurement of the neck muscles they had to lie in a head-down position, leaving the head over the lounger in a free position. Then the subjects had to keep up the one kg weight statically on the back of the head, holding the head parallel to the floor for five seconds.
Step counts were obtained for a complete work shift by means of a portable pedometer (Omron HJ-720IT-E2, Omron Healthcare UK). The pedometer provides continuous step-count feedback and allows the user to review step-count history for the previous day. The walking distance was determined by measured step length before starting work. The step-count data were uploaded via a USB cable to a computer and evaluation of data was done by means of standard statistic software (Winstat, Kalmia Corp., USA).

The statistical analysis and processing of the data was performed with the software Winstat Statistics Version 3.1 (Winstat, Kalmia Corp., USA). All data are presented as means and standard deviation (SD). The data were controlled for normal distribution by the Kolomogorov-Smirnov test. Differences between groups were calculated by a dependent t-test where appropriate and a level of 5 % ($p<0.05$) was considered significant.

Significant differences between the two order-picking systems are identified subsequently with an asterisk (*). Relationships between variables were determined using linear regression and the Pearson correlation coefficient.

3. Results

Subjects had a maximal power output (P_{max}) of 236.4 ± 26.6 watts, a VO_{2max} of 2.975 ± 0.367 $l.min^{-1}$ and reached a HR_{max} of 178.9 ± 10.7 $b.min^{-1}$ in the incremental cycle ergometer test. The maximum reached power (P_{max}) corresponded to a performance of 103.8 ± 12.1 % of the standard performance according to guidelines [20]. All subjects had normal blood pressure and ECG readings (data not shown). Maximal and submaximal values (LTP_1 and LTP_2) are presented in table 1.Work related measurements are presented in table 2. Subjects walked between 9477 ± 2254 steps/ 6.85 km (VS) and 10448 ± 3014 steps/ 7.72 km (VC). Significant differences were found between the two systems for steps ($p<0.05$) and distance (km) ($p<0.05$) during the ten hours working time. Although subjects walked significantly shorter distances using the vision system, they had a significantly higher heart rate (table 2) compared to the voice system. Additionally, the relative strain indicated by % of HR_{max} from the cycle test was significantly different between the systems.

The HR_{10h} corresponded to 88.6% (vision) and 82.9 % (voice) of the heart rate at the first lactate turn point (figure 1). HR_{max} during the work shift ($p<0.05$), mean oxygen consumption ($p<0.05$), the relative strain as percent of the maximum oxygen uptake ($p<0.05$), the working energy expenditure ($p<0.05$), the total energy consumption during work ($p<0.05$) and the pieces of goods picked ($p<0.05$) were significantly different between the systems (table 2). Subjects handled 1141.7 goods (7767.2 kg) with the voice system compared to 1066.3 goods (7529.2 kg) with the vision system. No significant correlation between pieces of goods and HR_{10h}, $VO_{2\ 10h}$, $HR_{max\ 10h}$ and EE_W were found for both systems. In the first hours of work with the voice system the forearm muscles showed a non-significant increase of the SEMG-amplitude in the ECR- and FCU-measurements. SEMG-amplitude of CERV-measurement significantly decreased from the start during the whole work period and stayed below baseline during the rest of the work period (figure 2). Similar to the voice system the SEMG- amplitude in the ECR- and FCU- measurements of the forearm muscles with the vision system showed a non-significant increase. Contrary to the voice system SEMG-amplitude of the CERV-measurement showed a non-significant increase compared to baseline values and decreased significantly down to baseline at the end of the work shift (figure 3). No significant differences were found between the voice and vision system for ECR- and FCU-measurements however both systems significantly differed at the second, third and fourth CERV-measurement.

4. Discussion

The main result of the study was that the two systems differed statistically significant in all measures, except the weight of the handled goods and the SEMG-measurements. Thus with a higher weight handled compared to the vision system the workers picked up more goods with the voice system. All the physiological parameters measured were significantly lower with the voice system compared to the vision system although a lower number of goods were handled with the vision system. Mean shift heart rate (HR_{10h}), relative oxygen uptake as well as the energy consumption were significantly different between the two systems; however there was no significant relationship of goods handled. Different strain levels for vision and voice were suggested to be caused by the unusual work using the vision system and not lack of training before the start of the shift, because subjects had a training phase of one week before the start of the study.

A possible reason could be a higher degree of attention with the new vision system. Additionally, learning effects could be an important factor, which has been shown in earlier studies [3]. Learning effects and long term adjustments were not the aim of this study but further studies should focus on explaining possible differences applying a vision system. The different strain levels for vision and voice can be shown by relating HR_{10h} to the mean weight of handled goods. The subjects needed 14.2 beats per ton to handle the goods with the vision system compared to 12.8 beats per ton with the voice system indicating a lower strain with the voice system. Mustonen et al. [21], showed that HMD´s could reduce walking performance (speed and number of steps) and change a person´s general performance such as the ability to guide and control gait. These authors suggested that both visual and motor aspects of walking negatively affected cognitive tasks.

Our subjects covered more steps and distance with the voice system, but also handled a higher number of goods. We suggest that a longer training time for the vision system might be needed to reach a similar or even better working performance. Additionally, the higher number of steps may be explained by a faster handling process with the voice system. The workers number of steps is at the upper range of the health related recommendation even within their ten hours shift [22-23]. These counts of steps have been found to be effective in improving health outcomes such as blood pressure and body mass index (BMI) [24]. Thus, handling goods is a highly demanding job with high energy expenditure during the working time [20, 25, 26].

Nine subjects (30%) were above common limits of heavy work like an energy expenditure during the working time (EEw) of 2145 ± 342 (voice system) and 2538 ± 468 (vision system) [20, 25, 26], which indicates that the workers may have a higher age-related risks for job-related musculoskeletal and cardiovascular disease health problems [27-29]. An additional factor may be the fitness status of the workers as it was shown recently by Wultsch et al. [25]. The data showed that employees with a high fitness level (high P_{max}, P_{LTP1}, P_{LTP2}, and VO_{2max}) had a lower $HF_{\%}$ HF_{max} during the shift work. Therefore the implementation of new systems like HMD´s should aim to reduce strain with the same output. An additional concern is the higher extra weight of the vision system. The overall weight of 2700g was significantly higher compared to the voice system. Even the weight of the headset was higher compared to the voice headset. To capture the code of the goods with the optical vision system, the subjects often had to turn the head and keep the head in a stable position. These procedures needed more attention and time, so to compensate the lost time they had to work faster, which might explain the higher overall intensity during picking the goods. The surface electromyography method is a widely accepted method to evaluate neuromuscular fatigue [34-36]. The SEMG-response of the arm muscles was similar comparing the two systems although the subjects handled more goods and processed more weight with the voice system indicating a normal strain without fatigue to the arm muscles. Our results of SEMG changes of the forearm muscles during a shift were comparable to studies for workers that mainly use the arms [34-35]. Although not statistically different at the first control measurement, a slight decrease of the SEMG of the forearm - muscles was visible for the voice system, which could be a possible warm up effect [37].

Surprisingly with a higher number of goods and weights the SEMG amplitude decreased after 160 minutes of working time maybe with a more economic work style with the voice system. Only three subjects showed a significant increase of the SEMG amplitude of the neck muscles with the vision system (figure 3) although the remaining subjects were similar to the voice system and no significant decrease of the heart rate during work was found for this phase, indicating a similar overall strain. The higher weight of the vision system and a higher stress for the neck muscles is suggested to be the reason for this SEMG response, as shown in other studies [30-32], although only three subjects (15 %) responded differently in our study. With the vision system the subjects often must turn the head and hold it statically so that the optical system can capture the code of the goods. Thus, the neck muscles could have a higher stress-level than with the voice system. External influences may affect the results of the SEMG measurements as reported in other studies [38-40], but these influences should have been minimized with the high number of subjects and SEMG-measurements.

The SEMG amplitude of the neck muscles during standardized tests showed significant differences between the systems indicating an extra load by the vision system but not in all subjects. Therefore weights of HMD systems need to be reduced to comparable levels of the voice system or even lower. Different studies showed that an increased head-mounted mass, for example night vision equipment by helicopter pilots, may increase overall neck activity [30-31]. Developments like counterweights may decrease metabolic and hemodynamic responses of neck muscles which could reduce neck pain [32]. Schega et al. [7], showed that the different augmented reality systems have limitations by various external influences. These authors suggested that some modifications for HMD systems improve efficiency and economy. Additionally, the error rate of vision and voice systems are significant lower to a conventional paper list [2], but the differences in error rate between vision and voice system was not investigated in our study, but should be done in further studies. Chen et al. [33], suggested that auditory temporal information is processed relatively automatically, whereas visual temporal information processing requires controlled attention, which may explain the slower working performance during a ten hour shift with the vision system compared to the voice system. To make precise statements about the value of HMDs, further studies with a longer training phase and lighter equipment are necessary.

5. Limits of the study

A longer crossover trial with professional workers in order picking is necessary to determine small differences between systems. Thus, different HMD systems should be compared to each other for a longer period of time in order to prove learning effects. A one-week adjustment period for both systems for people who have never run this activity may be too short. Regarding the SEMG measurements, a higher number of measurements have to be carried out directly during shift work to obtain a more detailed profile.

6. Conclusion

To summarize the subjects picked up fewer goods with a significantly higher physiological strain using a new prototype vision system. A higher degree of attention with the new vision system, a short training phase and higher weight may explain these differences. Nevertheless, new systems like the HMDs should reduce strain with the same output and therefore development should focus on the weight of systems in order to minimize the risk of neck pain as reported in previous studies [31-32].

7. References

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Table 1. Results from incremental cycle ergometer exercise. [P_{max}= maximal power output; VO_{2max}= maximal oxygen consumption; HR_{max}= maximal heart rate; La_{max}= maximal lactate concentration; RER_{max}= maximal respiratory exchange ratio; LTP_1= first lactate turn point; LTP_2= second lactate turn point; %= percentage of maximal values from incremental cycle ergometer exercise]

		Mean	SD
LTP_1	P_{LTP1} (watts)	101,7	16,4
	$\%P_{LTP1}$ (watts)	42,9	4,3
	$VO_{2\ LTP1}$ ($l.min^{-1}$)	1,557	0,23
	$\%VO_{2\ LTP1}$ ($l.min^{-1}$)	52,4	4,8
	HR_{LTP1} (bpm)	120,6	10,4
	$\%HR_{LTP1}$ (bpm)	67,4	4,1
LTP_2	P_{LTP2} (watts)	172	22,4
	$\%P_{LTP2}$ (watts)	72,3	3,5
	$VO_{2\ LTP2}$ ($l.min^{-1}$)	2,307	0,305
	$\%VO_{2\ LTP2}$ ($l.min^{-1}$)	77,6	4,1
	HR_{LTP2} (bpm)	152,2	11,4
	$\%HR_{LTP2}$ (bpm)	85,1	3,3
max	P_{max} (watts)	236,4	26,6
	VO_{2max} ($l.min^{-1}$)	2,975	0,367
	HR_{max} (min^{-1})	178,9	10,7
	La_{max} ($mmol.l^{-1}$)	8,8	1,49
	RER_{max}	1,28	0,07

Table 2. Comparison of the results between Vision and Voice system (significant differences ($p<0.05$) are characterized with *****)

	Vision		**Voice**	
	mean	SD	mean	SD
Steps	9477*	2254	10448	3014
km	6.85*	1.92	7.72	2.52
HR mean (30min)	110.7*	15	101.8	12.8
% HR_{max}	61.8*	7.0	56.5	5.9
HR 10h	106.6*	12.6	99.7	9.6
% HR_{max}	59.7*	6,7	55.9	5.7
% HR LTP_1	88.6*	9.5	82.9	7.4
HR_{max} 10h	155.6*	13.6	146.9	11.1
VO_2 mean	1.178*	0.189	1.011	0.139
% $VO_{2\ max}$ Ergo	39.9*	6.3	33.5	5.5
% $VO_{2\ LTP1}$	76.4*	11.0	64.5	9.0
EE_{tot}	3303*	507	2936	399
EE_W	2538*	468	2145	342
Number of goods handled per subject	1066.3*	198.76	1141.7	222.3
Weight per subject	7529.6	1567.4	7767.2	1454.3

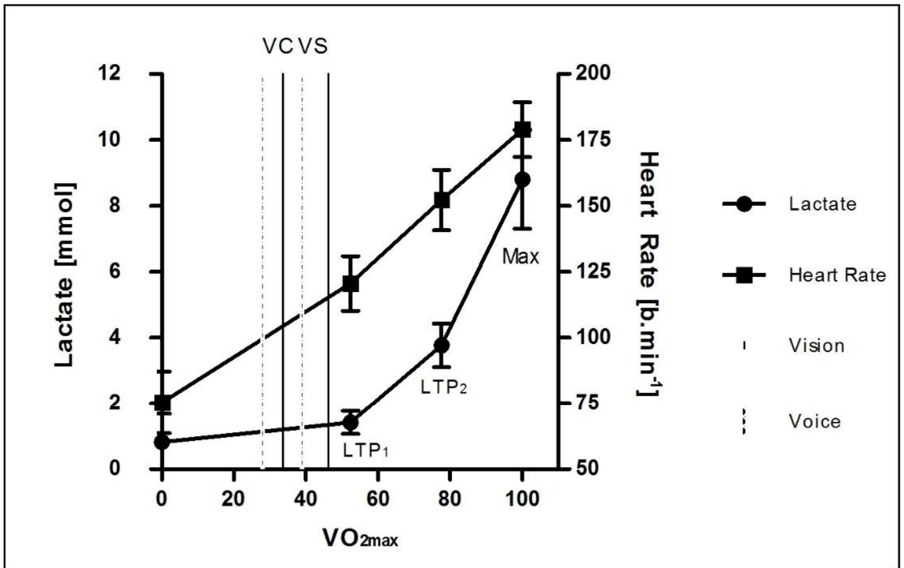

Figure 1. Incremental cycle ergometer test. Marked area showes the mean strain during shift work with the vision (VS) and the voice (VC) system. LTP_1= (first lactate turn point), LTP_2 =second lactate turn point (15), Max= maximum workload.

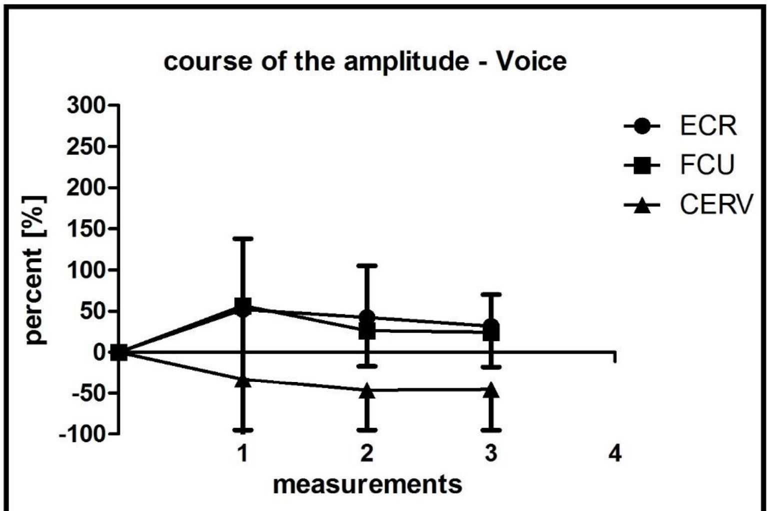

Figure 2. Increase/decrease in the amplitude in percent (Voice), [ECR= M. extensor carpi radialis, FCU= M. flexor carpi ulnaris, CERV= Mm. cervicis]

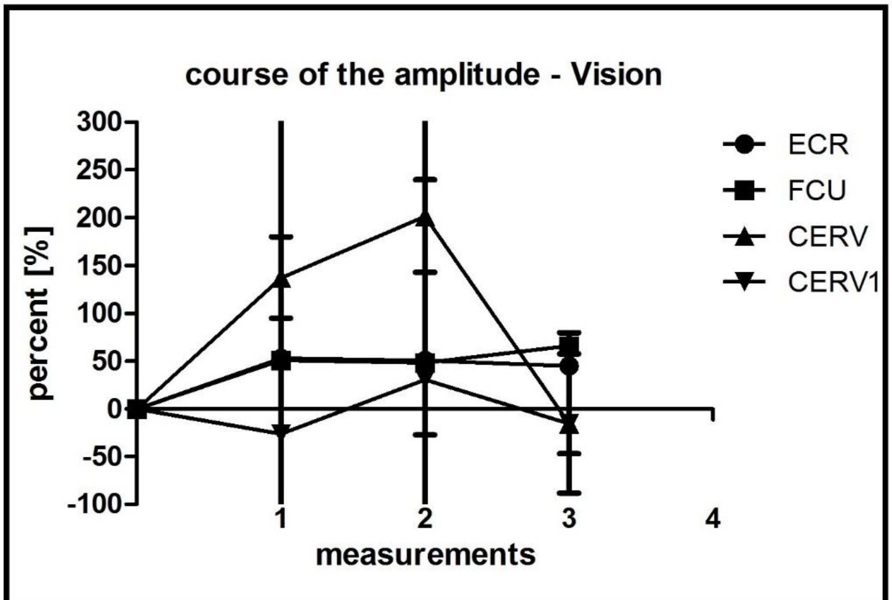

Figure 3. Increase/decrease in the amplitude in percent (Vision), [ECR=M. extensor carpi radialis, FCU=M. flexor carpi ulnaris, CERV=Mm. cervicis, CERV1= Mm. cervicis without 3 subjects]