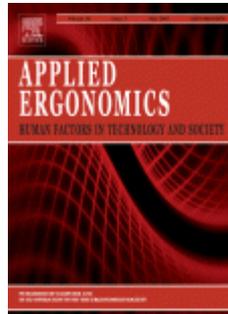# Applied Ergonomics - rok 2010, ročník 41

Číslo 2 (March 2010)

SPECIAL SECTION: Behavioural Effects and Drive-Vehicle-Environment Modelling in Modern Automotive Systems

P.C. Cacciabue, O. Carsten, F. Tango. *AE special issue on "driver modelling in automotive systems".* Pages 177-178.

- ▪ bez abstraktu a klíčových slov

Frank Lai, Magnus Hjälmdahl, Kathryn Chorlton, Mats Wiklund. *The long-term effect of intelligent speed adaptation on driver behaviour.* Pages 179-186.

This paper investigates the impact of prolonged experience with an Intelligent Speed Adaptation (ISA) system on driver behaviour. ISA refers to a driver support system which brings speed limit information into the vehicle. Drivers' interaction with the ISA system was explored by means of data collected from long-term field trials carried out in the UK and Sweden. Results indicated that participants' overriding behaviour increased in line with system exposure. However, there was no strong evidence supporting a generalised turning point of behavioural changes (e.g. 3000 km, 4000 km, or 5000 km accumulated experience) at which the upward trend plateaued. Driver characteristics were found to be influential on the pattern of overriding the ISA system with respect to subjective measures (intention to speed) as well as objective measures (observed speeding behaviour). Driving environment also demonstrated an impact on participants' overriding behaviour. Implications for driver behavioural changes in the presence of a generic ADAS are discussed.

- ▪ **Keywords:** Intelligent Speed Adaptation; Intention to speed; Road environment; Driver characteristics

Pietro Carlo Cacciabue, Oliver Carsten. *A simple model of driver behaviour to sustain design and safety assessment of automated systems in automotive environments.* Pages 187-197.

This paper proposes a structure for an "active" model of driver that enables to predict behaviour and performances in dynamic changing traffic conditions, with potential application both offline and online. A simple prototype of the system has been realised in software, and has been compared against observed data in a rudimentary validation. The comparison reveals that the software's outputs accord reasonably with the observed

values, not only in terms of central tendency but also in terms of capability to predict the between-driver variability. The next step is to create a system capable of identifying driver characteristics and state from observed data. However, further research is needed in order to expand the model in several dimensions, primarily to represent more complex scenarios in the presence of advanced automation technologies.

- **Keywords:** Automotive transport; Modelling driver behaviour; Design of human-machine systems

M. Casucci, M. Marchitto, P.C. Cacciabue. *A numerical tool for reproducing driver behaviour : experiments and predictive simulations*. Pages 198-210.

This paper presents the simulation tool called SDDRIVE (Simple Simulation of Driver performance), which is the numerical computerised implementation of the theoretical architecture describing Driver–Vehicle–Environment (DVE) interactions, contained in Cacciabue and Carsten [Cacciabue, P.C., Carsten, O. A simple model of driver behaviour to sustain design and safety assessment of automated systems in automotive environments, 2010]. Following a brief description of the basic algorithms that simulate the performance of drivers, the paper presents and discusses a set of experiments carried out in a Virtual Reality full scale simulator for validating the simulation. Then the predictive potentiality of the tool is shown by discussing two case studies of DVE interactions, performed in the presence of different driver attitudes in similar traffic conditions.

- **Keywords:** Automotive domain; Field studies; Modelling driver behaviour; Simulation of Driver–Vehicle–Environment

Fabio Tango, Luca Minin, Francesco Tesauri, Roberto Montanari. *Field tests and machine learning approaches for refining algorithms and correlations of driver's model parameters*. Pages 211-224.

This paper describes the field tests on a driving simulator carried out to validate the algorithms and the correlations of dynamic parameters, specifically driving task demand and drivers' distraction, able to predict drivers' intentions. These parameters belong to the driver's model developed by AIDE (Adaptive Integrated Driver-vehicle InterfacE) European Integrated Project. Drivers' behavioural data have been collected from the simulator tests to model and validate these parameters using machine learning techniques, specifically the adaptive neuro fuzzy inference systems (ANFIS) and the artificial neural network (ANN). Two models of task demand and distraction have been developed, one for each adopted technique. The paper provides an overview of the driver's model, the description of the task demand and distraction modelling and the tests conducted for the validation of these parameters. A test comparing predicted and expected outcomes of the modelled parameters for each machine learning technique has been carried out: for distraction, in particular, promising results (low prediction errors) have been obtained by adopting an artificial neural network.

- **Keywords:** Behavioural model; Machine learning; Cognitive architecture; Distraction; Driver-vehicle-environment frame work; Simulation; Neural networks; Fuzzy logic

Angelos Amditis, Katia Pagle, Somya Joshi, Evangelos Bekiaris. *Driver–Vehicle–Environment monitoring for on-board driver support systems : lessons learned from design and implementation*. Pages 225-235.

This paper is presenting the efforts to implement in real time and for on-board applications a set of Driver–Vehicle–Environment (DVE) monitoring modules based on the theoretical work done in DVE modelling within the EC 6th FW co funded AIDE Integrated Project. First the need for such an implementation will be discussed. Then the basic DVE modelling principles will be introduced and analysed. Based on that and on the overview of the theoretical work performed around the DVE modelling, the real time DVE monitoring modules developed in this project will be presented and analysed. To do this the DVE parameters needed to allow the required functionalities will be discussed and analysed. Special attention will be given to the use cases and scenarios of use for the real time DVE modules. This allows the reader to understand the functionalities that these modules enable in tomorrow's vehicles that will integrate a large degree of automation supported by advanced integrated and adaptive human machine interfaces (HMIs). The paper will also present examples of the functional and technical tests and validation results for some of the DVE modules. The paper will conclude with a discussion around the lessons learned about the design and implementation of such systems. This will include also the next steps and open issues for research in order for these systems to become standard modules in tomorrow's vehicles.

- **Keywords:** Driver support systems; Validation; Driver–Vehicle–Environment monitoring

REGULAR PAPERS

Jun-Ming Lu, Mao-Jiun J. Wang, Régis Mollard. *The effect of arm posture on the scan-derived measurements*. Pages 236-241.

Among various three-dimensional (3D) scanning anthropometric surveys, the inconsistent arm postures for scanning may lead to incompatible measurement results. Therefore, this study aims to investigate the effect of arm posture on the scan-derived measurements. The two arm postures in concern are the one with palms facing inward and the one with palms facing backward. The experimental results reveal that the two postures do not differ from each other in obtaining the scan-derived measurements for most body dimensions except for those related to the upper torso. Besides, the scan-derived measurements can be more precise between the two postures than the manual measurements. Further, it was found that being scanned with palms facing backward can contribute to the smaller difference between the scan-derived measurements and the manual measurements and the better image quality. Overall, the arm posture with palms facing backward is considered as the preferred posture for 3D whole body scanning.

- **Keywords:** Three-dimensional (3D) body scanner; Anthropometric data; Arm posture

V.V. Khanzode, J. Maiti, P.K. Ray, V.K. Tewari. *Injury severity assessment for underground coalmine workers*. Pages 242-250.

An injury severity model is proposed for assessment of injury incidents in industrial settings. A classification scheme for injury incidents considering interactions is also developed. The injury severity model considers injury potential in the form of unsafe conditions and analyzes its transfer to actual injury of varying severity. A case study was conducted in an underground coalmine of eastern India. An observed reduction in risk realization is explained through the model. Presence of interactions is found to be the most significant incident attribute of injury occurrences. The classification scheme and the results obtained from this study will help in improving accident/injury investigation reporting and devising preventive measures for reducing injury severity.

- **Keywords:** Injury potential; Incident classification; Injury severity mode; Incident attributes; Ridit analysis

F. Michael Williams-Bell, Geoff Boisseau, John McGill, Andrew Kostiuk, Richard L. Hughson. *Air management and physiological responses during simulated firefighting tasks in a high-rise structure*. Pages 251-259.

Air consumption, oxygen uptake (VO_2), carbon dioxide output (VCO_2) and respiratory exchange ratio ($RER = VCO_2/VO_2$) were measured directly from the self-contained breathing apparatus (SCBA) as 36 professional firefighters (three women) completed scenarios of high-rise stair climbing and fifth floor search and rescue. During stair climbing VO_2 was $75 \pm 8\%$ VO_{2max} (mean $\pm$ SD), $RER = 1.10 \pm 0.10$, and heart rate $= 91 \pm 3\%$ maximum (based on maximum treadmill data). Firefighters stopped climbing on consuming 55% of the air cylinder then descended. In the fifth floor search and rescue VO_2 was slightly lower than stair climbing but RER remained elevated (1.13 ± 0.12) reflecting high anaerobic metabolism. The first low air alarm sounded, indicating 25% of the air remaining in a "30-min cylinder", during the stair climb at 8 min with 19 of 36 sounding before 12 min. Aggressive air management strategies are required for safety in high-rise firefighting.

- **Keywords:** Self-contained breathing apparatus; Firefighter; Oxygen uptake

Zulquernain Mallick. *Optimization of the operating parameters of a grass trimming machine*. Pages 260-265.

Hand–arm vibration syndrome (HAVS) is very common among the workers operating power tools and doing similar nature of work for long hours. Grass trimming is one of the operations that involves use of vibrating cutter, and results in hand–arm vibration among workers. In this study, the influence of several operating parameters (length of nylon cutting thread, engine speed and handle material) is investigated in terms of HAV. Data are analyzed via orthogonal array, main effect, signal-to-noise (S/N) ratio, and analysis of variance to determine the appropriate operating parameter levels to minimize HAV. Operating parameters under investigation are found to be influential in controlling HAV generation during grass trimming operation. Experiments are carried out for measuring hand–arm vibration using tri-axial accelerometer conforming the effectiveness of this approach. Results show that 100 mm length of nylon thread, 3000 ± 400 rpm of engine speed and ABS handle material combination results in minimum HAV (HARM) of magnitude 2.76 m/s^2. Through this study not only the optimal operating parameter levels for GTM are obtained, but also the main process parameters that affect the HAV are determined. The optimum HAV obtained through appropriate level selection of operating parameters, significantly reduces the occurrence of HAVS among the grass trimmers.

- **Keywords:** Grass trimming machine; Hand–arm vibration (HAV); Operation parameters; Signal-to-noise (S/N) ratio; Analysis of variance (ANOVA)

Janan Al-Awar Smither, Robert S. Kennedy. *A portable device for the assessment of dynamic visual acuity*. Pages 266-273.

Dynamic visual acuity (DVA) thresholds are among the few visual functions predictive of automobile crashes. DVA is also sensitive to alcohol and aging. However, measuring DVA is awkward because there is no standardized, efficient, flexible apparatus for DVA assessment. In this project, we developed a prototype of an automated, portable DVA system using a low-energy laser, and we compared this laser DVA with the traditional device in two within-subjects, repeated measures designs. The two studies included 48 participants (22 males and 26 females with an average age of 18.33 years). The most important findings were that: (1) retest reliabilities of the two DVA devices were comparable and higher with the laser; (2) average correlations between the two devices were $r = 0.62$ ($p < 0.01$) and $r = 0.65$ ($p < 0.01$) for the two designs respectively; and (3) after correction for reliability attenuation these improved to $r = 0.92$ and $r = 0.78$.

These findings indicate that a flexible DVA laser device can be developed to measure the same construct as the more traditional bulky DVA device.

Ali Aybek, H. Atil Kamer, Selçuk Arslan. *Personal noise exposures of operators of agricultural tractors*. Pages 274-281.

Approximately one million agricultural tractors are used in Turkey for crop production and about one-third of the population lives in rural areas. The objectives of this study were to determine sound pressure levels, A-weighted sound pressure levels, and the permissible exposure time for tractors without cabins, field-installed cabins, and original cabins at ear level of agricultural tractor operators for following machines: plows, cultivators, top soil cultivators, rotary tillers, tool combinations (harrow + roller), mechanical drills, pneumatic drills, chemical applicators, fertilizer applicators, drum mowers, balers, and forage harvesters. Variance analyses showed that type of operation, type of cabins, and operation × cabin interactions were statistically significant ($P < 0.01$) both for sound pressure levels and equivalent (A-weighted) sound pressure levels. The use of original cabins had a greater effect in decreasing average sound pressures and resulted in more efficient noise insulation, especially at higher center frequencies compared to field-installed cabins whereas field-installed cabins proved to be more favorable compared to tractors without cabins. Sound pressure levels at 4000 Hz center frequency was reduced 2–13 dB and 4–18 dB by using a field-installed cabin and an original cabin, respectively. The measured A-weighted equivalent sound pressure levels were compared to the threshold limit level, and was concluded that depending on the cabin types used, the operators could usually work from 4 to 6 h a day without suffering from noise induced inconveniences while 2–3 h is permissible for plowing and forage harvesting on tractors without cabins. Due to timeliness considerations in agricultural machine operations, a farmer would not be willing to interrupt the operation based on permissible exposure time set by the standards. Based on the findings of this study, particularly an original cabin is recommended to reduce machine-induced noise below the danger limit during agricultural machine operations. Personal protection devices should be used when tractors are operated without cabins, which could reduce A-weighted equivalent sound pressure levels by 10–45 dB(A).

Joo-Young Lee, Eric A. Stone, Hitoshi Wakabayashi, Yutaka Tochihara. *Issues in combining the categorical and visual analog scale for the assessment of perceived thermal sensation : methodological and conceptual considerations*. Pages 282-290.

Typically, the scales for the measurement of thermal sensation have been formatted as categorical scales (CS). Emerging is the use of CS combined with visual analog scale (VAS) for the measurement of thermal sensation to improve the sensitivity of scales. However, reports are rare comparing the typical CS, standard VAS, and combined CS with VAS. Methodological and conceptual issues are arising with the combining of scales, but there are insufficient reports about the advantages and limitations of different scales. The present study compared 9-points categorical scale (9pts CS), VAS, and CS combined with VAS (graphic CS) through a questionnaire survey (n = 988) and a controlled experiment during exercise (17 male subjects). Our results showed that graphic CS was more closely related to indoor air temperature for resting residents rather than VAS or 9pts CS. Around thermal neutral zone indoor environments, sensitivity to discriminate thermal sensation was the greatest for graphic CS. In particular, questionnaire responses to VAS showed a remarkable clustering around the thermal neutral zone. For dynamic exercising subjects, mean skin temperature was more closely related to graphic CS than 9pts CS. Our results indicated that graphic CS seemed to be more valid and sensitive

than 9pts CS or VAS for the measurement of thermal sensation, but there are many issues to be considered when combining CS and VAS from the methodological and conceptual view points: definitions of terms, verbalizing with descriptors, number of category, scoring length, unipolar/bipolar construction, language translation, central terms, both anchor terms, orientation, color, etc. The above methodological and conceptual issues were discussed.

- **Keywords:** Thermal sensation; Categorical scale (CS); Visual analog scale (VAS); Graphic categorical scale (graphic CS)

Misty A. Blue, Celestine Ntuen, Tomasz Letowski. *Speech intelligibility measured with shortened versions of Callsign Acquisition Test (CAT)*. Pages 291-294.

The Callsign Acquisition Test (CAT) is a new speech intelligibility test developed by the Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL-HRED). CAT uses the phonetic alphabet and digit stimuli combined together to form 126 test items. **Objective:** The purpose of this study was to assess the reliability of data collected with shorter versions of CAT. **Design:** A total of 5 shorter versions of the original list (CAT-120, CAT-60, CAT-40, CAT-30, and CAT-24) were formed and evaluated using 19 participants. Each of the subsets of CAT was presented in pink noise at signal-to-noise ratios (SNRs) of −6 dB and −9 dB. **Results:** Results showed that shortened CAT lists have the capability of providing the same predictive power as the full CAT with good test–retest reliability. **Conclusions:** Under the experimental conditions of this study, any of the shorter versions of the CAT can be utilized in place of the full version to reduce testing times with no effect on predictive power.

- **Keywords:** Callsign Acquisition Test (CAT); Speech intelligibility testing; Predictive power

Svend Erik Mathiassen, Victor Paquet. *The ability of limited exposure sampling to detect effects of interventions that reduce the occurrence of pronounced trunk inclination*. Pages 295-304.

Ergonomics interventions often focus on reducing exposure in those parts of the job having the highest exposure levels, while leaving other parts unattended. A successful intervention will thus change the form of the job exposure distribution. This disqualifies standard methods for assessing the ability of various exposure measurement strategies to correctly detect an intervention's effect on the overall job exposure of an individual worker, in particular for the safety or ergonomics practitioner who with limited resources can only collect a few measurements. This study used a non-parametric simulation procedure to evaluate the relationship between the number of measurements collected during a self-paced manufacturing job undergoing ergonomics interventions of varying effectiveness, and the probability of correctly determining whether and to which extent the interventions reduced the overall occurrence of pronounced trunk inclination, defined as an inclination of at least 20°. Sixteen video-recordings taken at random times on multiple days for each of three workers were used to estimate the time distribution of each worker's exposure to pronounced trunk inclination. Nine hypothetical ergonomics intervention scenarios were simulated, in which the occurrence of pronounced trunk inclination in the upper 1/8, 1/4, and 1/2 of the job exposure distribution was reduced by 10%, 30% and 50%. Ten exposure measurement strategies were explored, collecting from one to ten pre- and post-intervention exposure samples from an individual worker. For each worker, intervention scenario and sampling strategy, data were bootstrapped from the measured (pre-intervention) and simulated (post-intervention) exposure distributions to generate empirical distributions of the estimated intervention effect. Results showed that for the one to three intervention scenarios that had the greatest effect on the overall occurrence of trunk inclination in the job, one to four pre- and post-

intervention measurements, depending on worker, were sufficient to reach an 80% probability of detecting that the intervention did, indeed, have an effect. However, even for the intervention scenario that had the greatest effect on job exposure, seven or more samples were needed for two of the three workers to obtain a probability larger than 50% of estimating the magnitude of the intervention effect to within ±50% of its true size. For almost all interventions affecting 1/8 or 1/4 of the job, limited exposure sampling led to low probabilities of detecting any intervention effect, let alone its correct size.

- **Keywords:** Intervention effectiveness; Exposure measurement; Bootstrapping

Jennifer A. Hess, Laurel D. Kincl, Kermit Davis. *The impact of drywall handling tools on the low back*. Pages 305-312.

Carpenters and other construction workers who install drywall have high rates of strains and sprains to the low back and shoulder. Drywall is heavy and awkward to handle resulting in increased risk of injury. The purpose of this study was to evaluate several low-cost coupling tools that have the potential to reduce awkward postures in drywall installers. Five coupling tools were evaluated using the Lumbar Motion Monitor that measures trunk kinematics and predicts probability of low back disorder group membership risk (LBD risk). Workers answered surveys about their comfort while using each tool. The results indicate that use of the 2-person manual lift and the J-handle provide the best reduction in awkward postures, motions, low back sagittal moment, and LBD risk. The two-person manual lift appears to be the safest method of lifting and moving drywall, though using the two-person J-handle also significantly reduces injury risk. Given that carpenters are skeptical about using equipment that can get in the way or get lost, a practical recommendation is promotion of two-person manual lifting. For single-person lifts, the Old Man tool is a viable option to decrease risk of MSDs.

- **Keywords:** Low back disorders; Ergonomics; Biomechanics; Construction; Drywall; Musculoskeletal disorders

Chih-Long Lin, Ming-Shan Chen, Yu-Li Wei, Mao-Jiun J. Wang. *The evaluation of force exertions and muscle activities when operating a manual guided vehicle*. Pages 313-318.

A manual guided vehicle (MGV) is used to handle heavy materials in thin film transistor-liquid crystal display (TFT-LCD) manufacturing clean rooms. This study focuses on evaluating the force exertions and muscle activities in MGV operations. The independent variables include gender, force direction, handle height, load handled and wheel diameter of the MGV. The results show the force direction, handle height and load handling effects are significant in most measures except for F_{ending} (the peak force required to stop the MGV) and the EMG of the anterior deltoid. The wheel diameter had a significant effect on $F_{initial}$ (the peak force required to move the MGV) and F_{ending} responses. Gender did not significantly effect any measures. Moreover, the pushing and pulling force is less at 115 cm handle height than at 101.5 cm and 88 cm handle heights. Using 15.3 cm (6 inch) diameter wheels requires less force than 20.3 cm (8 inch) diameter wheels because the two front wheels are fixed and the two rear wheels are rotatable. The design implications are discussed.

- **Keywords:** Manual guided vehicle (MGV); Pushing and pulling force exertion; EMG

L.K. Jensen, S. Rytter, J.P. Bonde. *Exposure assessment of kneeling work activities among floor layers*. Pages 319-325.

The objective of this study was to quantify the proportion of kneeling work activities among floor layers and to assess external knee joint forces in five different kneeling work positions. Thirty-three floor layers were videotaped discontinuously and four floor layers were videotaped continuously for a whole working day. External knee forces were measured in five different kneeling work positions in ten floor layers using Computer Dynography. The study showed that floor layers spent a high percentage of time in knee-straining work positions. Kneeling work tasks, particularly gluing and crawling caused high external knee forces ranging from 0.3 Newton (SD 0.2) times body weight when floor layers were kneeling back on the heels, to 3.5 Newton (SD 0.3) times body weight in the crawling work position. The study highlights the need for prevention by minimizing the amount of kneeling work positions among floor layers.

- **Keywords:** Exposure; Kneeling; Floor layers

Christian Larivière, Guy Tremblay, Sylvie Nadeau, Lotfi Harrabi, Patricia Dolez, Toan Vu-Khanh, Jaime Lara. *Do mechanical tests of glove stiffness provide relevant information relative to their effects on the musculoskeletal system? : a comparison with surface electromyography and psychophysical methods*. **Pages 326-334.**

The main purpose of the present study was to test the construct validity of two mechanical tests of glove stiffness using a surface electromyography (SEMG) methodology that would allow estimating the effect of glove stiffness on forearm muscle activation during a standardized grip contraction. The mechanical tests [free-deforming multidirectional test (FDMT) and Kawabata Evaluation System for Fabrics (KESF)] were applied on 27 gloves covering a wide range of stiffness. In 30 human subjects, a psychophysical assessment of these gloves was also carried on in addition to the SEMG test. The results showed that the sensitivity of the different tests to glove stiffness differences was slightly better for the FDMT (75% sensitivity) than for the psychophysical assessment (72%), while the SEMG test showed much lower sensitivity (13–31%, depending on the muscle). The SEMG test was highly correlated to the psychophysical assessment (0.88–0.95, depending on the muscle tested), and the FDMT (0.88–0.94) and KESF (0.77–0.86) mechanical tests, showing the construct validity of mechanical tests, particularly for the FDMT. It was concluded that mechanical tests provide relevant information relative to the effect of glove stiffness on the musculoskeletal system of the forearm.

- **Keywords:** Flexibility; Electromyography; Perceived exertion; Construct validity