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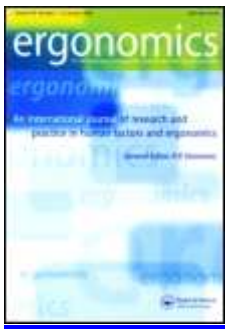

Yan Liu; Gavriel Salvendy. *Effects of measurement errors on psychometric measurements in ergonomics studies : implications for correlations, ANOVA, linear regression, factor analysis, and linear discriminant analysis*. S. 499–511.

This paper aims to demonstrate the effects of measurement errors on psychometric measurements in ergonomics studies. A variety of sources can cause random measurement errors in ergonomics studies and these errors can distort virtually every statistic computed and lead investigators to erroneous conclusions. The effects of measurement errors on five most widely used statistical analysis tools have been discussed and illustrated: correlation; ANOVA; linear regression; factor analysis; linear discriminant analysis. It has been shown that measurement errors can greatly attenuate correlations between variables, reduce statistical power of ANOVA, distort (overestimate, underestimate or even change the sign of) regression coefficients, underrate the explanation contributions of the most important factors in factor analysis and depreciate the significance of discriminant function and discrimination abilities of individual variables in discrimination analysis. The discussions will be restricted to subjective scales and survey methods and their reliability estimates. Other methods applied in ergonomics research, such as physical and electrophysiological measurements and chemical and biomedical analysis methods, also have issues of measurement errors, but they are beyond the scope of this paper. As there has been increasing interest in the development and testing of theories in ergonomics research, it has become very important for ergonomics researchers to understand the effects of measurement errors on their experiment results, which the authors believe is very critical to research progress in theory development and cumulative knowledge in the ergonomics field.

- **Keywords:** measurement errors; reliability; statistical analysis

Stefan Röttger; Krisztina Bali; Dietrich Manzey. *Impact of automated decision aids on performance, operator behaviour and workload in a simulated supervisory control task*. S. 512–523.

In studies reporting automation effects on overall system performance and on the operator, the methods used to measure workload often did not appropriately reflect the complexity of this construct. The present study addresses the impact of automation on operator workload and behaviour in process control fault management. Workload effects were assessed with subjective, cardiovascular and secondary task performance indicators. Interactions with the interface of the process control simulation directed at

gathering information and controlling the system were recorded. Automation made operators more efficient, allowing faster fault management with less information sampling and control actions. Subjective workload ratings were significantly lower in the assisted conditions as compared to manual, which was not reflected in cardiovascular and secondary task measures. Participants' information sampling activity did not differ between medium and high level of automation. Results suggest that participants paid constantly high attention to their task even with highly automated support.

- **Keywords:** automation; decision aid; process control; fault management; mental workload; performance; operator behaviour

Ash M. Genaidy; Magda M. Rinder; Reynold Sequeira; Amal D. A-Rehim. *The Work Compatibility Improvement Framework : theory and application of improvement action and intervention strategies*. S. 524–559.

Challenges facing management of manufacturing firms can be transformed into asset gains by giving careful consideration to the worker-work environment interface. The benefits of a 'healthy' interface may lead to sizable reductions in rising health care costs and retention of highly qualified workers. This paper presents a novel approach for the 'improve' phase of the Work Compatibility Improvement Framework. The work tasks of this research consisted of: (a) fundamentals of cognitive-based improvement action and intervention; (b) design concepts and process of improvement action/intervention generation; (c) assessment model of estimated gains in company's assets; (d) application demonstration in the manufacturing sector. The process of improvement action/intervention generation is described, preceded by a description of the fundamentals of cognitive-based improvement action and intervention and system architecture. This is followed by a documentation of estimated asset gains as a result of the improvement plan. The results showed that expert workers were, on average, 78% in agreement with the algorithm-identified improvement actions. Their knowledge was used to update the recommended actions as well as to detail the multiple strategies required to address the improvement actions. As a result, an integrated improvement plan was developed resulting in estimated asset gains of $1.6 million, which was validated by the general manager. The research reported herein documented the theory and application of the 'improve' phase of the Work Compatibility Improvement Framework. The economic assessment of the suggested improvement is also reported and this has proved to be an important driver to secure the firm collaboration of manufacturing enterprise management. An integrated improvement solution plan backed by a detailed economic assessment of suggested improvements is essential to demonstrate the full potential of workplace micro- and macro-ergonomic interventions.

- **Keywords:** business sustainability; human performance; intervention; incremental and discontinuous improvement

Andrew Petersen; Rod Barrett. *Postural stability and vehicle kinematics during an evasive lane change manoeuvre : a driver training study*. S. 560–568.

The purpose of this study was to investigate the effect of a 2-day driver-training course that emphasised postural stability maintenance during critical driving situations on postural stability and vehicle kinematics during an evasive lane change manoeuvre. Following training, the trainee group experienced enhanced postural stability during specific phases of the task. In terms of vehicle kinematics, the main adaptation to training was that trained drivers reduced the extent to which they experienced vehicle decelerations during rapid turning compared to controls. Such a strategy may confer a safety benefit due to the increased risks associated with simultaneous braking while turning during an evasive manoeuvre. The newly learned strategy was consistent with

the strategy used by a group of highly skilled drivers (driving instructors). Taken together, the results of the study suggest postural stability may be a useful variable to consider in relation to the skill-based component of hierarchical driver training programmes. The findings of this study provide some preliminary evidence to suggest that postural stability may be an important consideration when instructing individuals on how to safely negotiate obstacles during driving.

- **Keywords:** acceleration; skill; stability; steering; vehicle control

Brian D. Lowe; Edward F. Krieg. *Relationships between observational estimates and physical measurements of upper limb activity*. S. 569–583.

This study examined the internal validity of observational-based ergonomic job analysis methods for assessing upper limb force exertion and repetitive motion. Six manual tasks were performed by multiple 'workers' while direct measurements were made to quantify force exertion and kinematics of the upper limb. Observational-based analyses of force and upper limb motion/repetition were conducted by 29 professional ergonomists. These analysts overestimated the magnitude of individual force exertions - temporal aspects of force exertion (duty cycle) were estimated more accurately. Estimates of the relative severity of repetitive motions among the jobs were accurate. Absolute counts of repetitive motions were less accurate. Modest correlations (r^2 = 0.28 to r^2 = 0.50) were observed between ratings of hand activity level and measured joint velocities. Ergonomic job analyses relying on systematic observation should be applied and interpreted with consideration given to the capabilities and limitations of analysts in estimating the physical risk factors. These findings are relevant to a better understanding of the internal validity of ergonomic job analysis methods based on systematic observation. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

- **Keywords:** repetition; force exertion; WMSD risk factors; upper limb

Prabir Mukhopadhyay; Leonard W. O'Sullivan; Timothy J. Gallwey. *Upper limb discomfort profile due to intermittent isometric pronation torque at different postural combinations of the shoulder-arm system*. S. 584–600.

Twenty-seven right-handed male university students participated in this study, which comprised a full factorial model consisting of three forearm rotation angles (60% prone and supine and neutral range of motion), three elbow angles (45°, 90° and 135°), three upper arm angles (45° flexion/extension and neutral), one exertion frequency (15 per min) and one level of pronation torque (20% maximum voluntary contraction (MVC) relative to MVC at each articulation). Discomfort rating after the end of each 5 min treatment was recorded on a visual analogue scale. Results of a repeated measures analysis of covariance on discomfort score, with torque endurance time as covariate, indicated that none of the factors was significant including torque endurance time (p = 0.153). An initial data collection phase preceded the main experiment in order to ensure that participants exerted exactly 20% MVC of the particular articulation. In this phase MVC pronation torque was measured at each articulation. The data revealed a significant forearm rotation angle effect (p = 0.001) and participant effect (p = 0.001). Of the two-way interactions, elbow*participant (p = 0.004), forearm*participant (p = 0.001) and upper arm*participant (p = 0.005) were the significant factors. Electromyographic activity of the pronator teres and biceps brachii muscles revealed no significant change in muscle activity in most of the articulations. Industrial jobs involving deviated upper arm postures are typical in industry but have a strong association with injury. Data from this study will enable better understanding of the effects of deviated upper arm postures on musculoskeletal disorders and can also be used to identify and control high-risk tasks in industry.

- **Keywords:** upper arm; flexion; extension; pronation torque; pronation; supination

Soo-Jin Lee; Yong-Ku Kong; Brian D. Lowe; Seongho Song. *Handle grip span for optimising finger-specific force capability as a function of hand size*. S. 601–608.

Five grip spans (45 to 65 mm) were tested to evaluate the effects of handle grip span and user's hand size on maximum grip strength, individual finger force and subjective ratings of comfort using a computerised digital dynamometer with independent finger force sensors. Forty-six males participated and were assigned into three hand size groups (small, medium, large) according to their hands' length. In general, results showed the 55- and 50-mm grip spans were rated as the most comfortable sizes and showed the largest grip strength (433.6 N and 430.8 N, respectively), whereas the 65-mm grip span handle was rated as the least comfortable size and the least grip strength. With regard to the interaction effect of grip span and hand size, small and medium-hand participants rated the best preference for the 50- to 55-mm grip spans and the least for the 65-mm grip span, whereas large-hand participants rated the 55- to 60-mm grip spans as the most preferred and the 45-mm grip span as the least preferred. Normalised grip span (NGS) ratios (29% and 27%) are the ratios of user's hand length to handle grip span. The NGS ratios were obtained and applied for suggesting handle grip spans in order to maximise subjective comfort as well as gripping force according to the users' hand sizes. In the analysis of individual finger force, the middle finger force showed the highest contribution (37.5%) to the total finger force, followed by the ring (28.7%), index (20.2%) and little (13.6%) finger. In addition, each finger was observed to have a different optimal grip span for exerting the maximum force, resulting in a bow-contoured shaped handle (the grip span of the handle at the centre is larger than the handle at the end) for two-handle hand tools. Thus, the grip spans for two-handle hand tools may be designed according to the users' hand/finger anthropometrics to maximise subjective ratings and performance based on this study. Results obtained in this study will provide guidelines for hand tool designers and manufacturers for designing grip spans of two-handle tools, which can maximise handle comfort and performance.

- **Keywords:** optimal grip span; two-handle tool designs; hand size; performance

Na Jin Seo; Thomas J. Armstrong. *Friction coefficients in a longitudinal direction between the finger pad and selected materials for different normal forces and curvatures.* S. 609–616.

This study investigated the effect of object curvature, normal force and material on skin friction coefficient. Twelve subjects slid their middle fingertip pad against a test object with small (11 mm), medium (18, 21 mm) or large (flat object) radii of curvature, while maintaining a normal force of 1, 10 or 20 N. Tested materials were aluminium and four rubber hoses. The average friction coefficient was 0.6 for aluminium and 0.9 for the rubber hoses. As normal force increased from 1 to 20 N, the average friction coefficient decreased 46%. Friction coefficient did not vary significantly with object curvature. The citation of friction coefficient data requires careful attention to normal force levels with which they are measured, but not so much to object curvature between 11 mm and infinity. This study provides skin friction coefficient data that are needed for design of objects that are manipulated with the hands. The investigation of the effect of object curvature on skin friction coefficient has important implications to ergonomics practices as many objects handled in everyday activities have curved surfaces.

- **Keywords:** coefficient of friction; skin friction; surface curvature; skin deformation; hand friction

Channa P. Witana; Ravindra S. Goonetilleke; Emily Yim Lee Au; Shuping Xiong; Xingfang Lu. *Footbed shapes for enhanced footwear comfort*. S. 617–628.

A shoe wearer's comfort is related to the shape of the footbed of a shoe. Even though the footbed shape is important in footwear design, there exists no methodology to evaluate the existing guidelines used in last making. Thirty-two females participated in an experiment where heel seat length, heel seat inclination and heel height were investigated using the profile assessment device. The dependent variables were plantar pressure and perceived feeling of each participant. The results show that perceived feel is best for wedge angles of 4° and 5° at a heel height of 25 mm, 10° and 11° at a heel height of 50 mm and 16° and 18° at a heel height of 75 mm. A regression model was derived and this explained approximately 80% of the variation of perceived feeling with the contact area, peak plantar pressure and percentage of force acting on the forefoot region. Both heel wedge angle and heel seat length play an important role in the perceived feel of high-heeled shoes. This study, in relation to the load-bearing heel part of a shoe, highlights the importance of good footbed design. The findings can be used to design footwear with enhanced comfort.

- **Keywords:** feet; footbed; footwear; fit; comfort; wedge; orthotics; high-heel; pressure; plantar shape