State of the art in applied psychophysiology

Engineering Psychophysiology: Issues and Applications.
by R.C. Backs & W. Boucsein (Eds.).
Mahwah (N.J.), London, Lawrence Erlbaum Associates. 2000, 38 pp., ISBN 0-8058-2453-7, $40.00

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Introduction
Engineering Psychophysiology is a relatively new discipline engaged with research that applies psychophysiological methods to problems traditionally addressed within engineering psychology. The goal of the present book is to promote psychophysiology for a broader audience. Therefore, people that do not have much background in psychophysiology can read the book.

Psychophysiological measures have been uses for over hundred years now, but applications outside the laboratory are still rare. Small digital recorders make it possible nowadays to measure a large number of physiological signals outside the laboratory, during daily activities. Using psychophysiology in applied settings has a broad interest, which is demonstrated by the recent founding of the Psychophysiology in Ergonomics (PIE) society that has over 180 members from 15 countries. The editor of this book, Rolf Boucsein is the present director of PIE. Several books about psychophysiology have appeared the last decade. However, this book is unique in covering a broad range of aspects such as theory, hard- and software requirements, and examples form complex laboratory tasks and experiments in real life settings.

Due to its complexity, psychophysiology typically is a tool that needs a multidisciplinary approach. Knowledge about psychology, physiology, ergonomics, data processing etc. is required. One of the contributors of this book, Bert Mulder, died just before this book appeared. He was a very inspiring scientist who showed the enormous potential of applied psychophysiology. Especially his multidisciplinary approach was a great example for many of his colleagues.

Issues
In the first part of the book, an overview is provided about several *issues* such as methodological, theoretical, signal processing, and recording methods. The emphasis of these chapters is on application outside the laboratory. It becomes clear that psychophysiology can make valuable contributions to ergonomics. In applied settings there is a strong need for objective information about the mental state of the operator during task performance. Task environments are becoming more complex and the role of the operator is still very important. Psychophysiological measures have the potential to provide objective information about different states such as fatigue, stress, and workload. This information, can for example, be used to adapt the environment to the operator.
Although the introductory chapters make clear that psychophysiology is important for ergonomics, its methods are still far from being used as standard ergonomical tools. Technological developments have made it possible to make small portable recorders for measuring physiological signals in applied settings. However, using psychophysiological

measures is not only a matter of choosing an adequate recorder. Researchers must have knowledge about the underlying physiological mechanisms, signal processing, different kinds of artifacts and about the relation between different measures. This takes years of training and experience. Nevertheless, the many examples in this book demonstrate that psychophysiological measures are very valuable.

The first chapters in the book provide useful information about current theoretical models. The relation between cognitive activity and physiological processes is very complex. Questions like "Why does mental activity affect bodily systems and vice versa" can still not adequately be answered with current theoretical models. Far more knowledge is required to unravel this complex relation. It is shown that psychophysiological reactions are not the consequence of one task aspect, but reflect the state of the brain and body. State is different from arousal, which is no longer regarded as a causal agent. Cognition and emotion induces physiological reactions and vice versa. This is in line with recent developments in neurology. For example in "Descartes Error" (Damasio, 1994) that shows nice illustrations about the complex relation between mind and body. The terms "stress" and "workload" are often confused in the literature. In the framework that is presented her, a clear distinction is made between these two concepts.
A thorough overview is presented about the sensitivity of many psychophysiological measures to different states. This scheme can be used to select measures for specific research questions. With a combination of measures, information can be obtained about three different states: affect (focus of attention), effort, and preparatory activation.
The "issues" part of the book makes clear that bridging the gap between theory and reality is still a challenge for psychophysiologists.

Applications
The applications part of the book is a mixture between laboratory and real life studies. This indicates that there are not so many studies that demonstrate the real-life applicability of psychophysiology. Laboratory studies are still required to understand the complex patterns of reactions obtained from psychophysiological measures.
The laboratory studies that are presented in the book illustrate the potential of psychophysiology. For example, the usefulness of adaptive automation is demonstrated using continuous measures of brain activity (by measuring the electroencephalogram, EEG). It is demonstrated that it is possible to automatically adapt the task when the state of the subject changes. The "engagement" (relative high frequency in the EEG spectrum) was measured in small time steps (2 seconds) and the computer took over control when the state of the subject changed. It was shown that overall performance was better when the computer took over control when the level of engagement was increased. This seems rather strange, because subjects are expected to perform better when they are in a state of high alertness. This might be due to the kind of tasks that was used for the experiment. These results are very promising for real world applications. However, a lot of research has to be conducted in order to successfully apply this approach outside the laboratory. More research is needed refine the techniques, to know what kind of tasks are useful, and how operators change their strategies when they know that their state is monitored continuously. There are many applications in which this approach can be useful. For example, aircraft safety can be improved when pilots get a warning when their level of alertness decreases. Or computers can take over some tasks when operator's alertness decreases.

Heart rate is one of the physiological measures that has been used most often in psychophysiological studies. Both the sympathetic and parasympathetic branches of the autonomic neural system affect heart rate. A change in heart rate normally does not provide information about how activity of the two underlying neural branches changes. This book incorporates a chapter that demonstrates that heart rate may provide information about the underlying neural activity by using factor analysis. However, the authors do not provide very convincing data, because they use data for the factor analysis that are not independent. The variation in heart rate, especially high-frequency changes, provide information about the parasympathetic activity. The authors assume that changes in heart rate that can not be explained by this parasympathetic activity, the so-called residual heart rate, is a measure of sympathetic activity. By using both the heart rate variability and the residual heart rate measure for a factor analysis, the result of the factor analysis will always be two factors in which heart rate variability is loading on one factor and residual heart rate is loaded on the other factor. More validation studies are required before this method can be applied to data obtained in applied environments. There is still not enough knowledge about the relation between derived measures like heart rate variability and autonomic activity. Making these measures more abstract by using factor analysis will not provide more insight into underlying neural mechanisms.

A good example of a physiological measure that can relatively easy be used in applied environments is ocular activity. This can be obtained with different techniques. One of them is the electro-oculogram (EOG) that can be measured with electrodes around the eye(s). Different parameters from this signal, such as blink rate, blink duration, and blink amplitude provide information about various states like fatigue and cognitive factors. A thorough overview is provided about the usefulness of these measures in different environments.

Conclusion

The book provides a good overview of the state of the art in psychophysiology that is valuable for both expert and non-experts. The intention is to promote psychophysiology. But in reading the book, it becomes obvious that using psychophysiological measures required a lot of expertise and therefore, a lot of research has to be conducted before we can buy of-the-shelf applications.

Reference

Damasio, A. (1994). *Descartes' Error: Emotion, reason, and the human brain.* New York: Grosset/Putnam.

Procesgang publikaties
en I-rapporten voorzover van toepassing

Dit formulier steeds bij het stuk houden

Publikatie in:	Contemporary Psychology
Titel:	State of the art in applied psychophysiology
Auteur(s):	J.A. Veltman

Opdracht nr:	IWP nr:	Filenaam:

DEADLINE VERZENDING: 9-2-2001	Datum indienen:

Programmaleider: Paraaf: Datum: 5/2/2001	Commentaar: Prima.	
Afdelingshoofd: Paraaf: Datum:	Commentaar:	Directeur: Paraaf: Datum:

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Akkoord verzenden	
Paraaf auteur	Paraaf afdelingshoofd .....

Verzending publikatie naar tijdschrift d.d. .....

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