Ambulatory assessment: Issues and perspectives

Chapter (pp. 3 – 20)

In: Fahrenberg, J. & Myrtek, M. (Eds.). (1996). Ambulatory Assessment: Computer-assisted Psychological and Psychophysiological Methods in Monitoring and Field Studies. Seattle, WA: Hogrefe and Huber.

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Introduction

Ambulatory assessment designates a new orientation in behavioral and psychophysiological assessment. Since this approach relates to everyday life ("naturalistic" observation), the ecological validity of research findings is claimed and, consequently, a suitability for application. Individual differences in behavior and physiology as well as behavior disorders are investigated in real-life situations where relevant behavior can be much more effectively studied than in the artificial environment of laboratory research.

Such aims and concepts are not entirely new, but recently developed computer-assisted methods in ambulatory monitoring and field studies constitute a new methodology in psychology and psychophysiology. The present research is still primarily concerned with methodological issues and conducting pilot studies to explore the potentialities and limitations of ambulatory data acquisition in various domains. However, an increasing number of substantial research findings exist, some of which challenge theoretical positions that were attained based on laboratory observation.

Ambulatory assessment originated from a number of previously rather independent research orientations with specific objectives:

Clinical (bedside) monitoring was introduced as means of continuously observing of a patient's vital functions, e.g., respiratory and cardiovascular parameters under anesthesia, during intensive care and in perinatal condition. If relevant changes occur, i.e., if certain critical values are exceeded, an alarm is set off. Such monitoring is an essential part of biomedical instrumentation in hospitals. Further improvement in monitoring methodology may be expected in the future from computer-assisted trend analyses and pattern detection which apply a set of parameters (Epple & Bleicher, 1992; Webster, 1988).

Biotelemetry employs transmitter-receiver systems (radio-telemetry) in order to measure physical functions in real-life. Cardiovascular changes during intense strain at the workplace or during athletic performance are examples. A further application of biotelemetry has been the observation of migrating animals. Radio equipment basically makes two-sided communication possible, i.e., feedback, telestimulation and telecommand, in addition to telemetry. Advances in the miniaturization of transmitter systems, probes and implants are noteworthy here (e.g., Amlaner & Macdonald, 1980; Kimmich, 1988; Webster, 1988).

Ambulatory monitoring means continuous observation of free- moving subjects (patients) in everyday life as compared to stationary, bedside ("wired") monitoring. Ambulatory monitoring can be conducted either by biotelemetry or by a portable recording system (Littler, 1980; Stott, 1982; Tompkins, 1988). This observation method is appropriate for patients who exhibit significant pathological symptoms which, for a number of reasons, cannot be reliably detected in the physician's office or hospital as compared to a prolonged observation in everyday life. Such cases include ventricular arrhythmia, ischaemic episodes, sleep apnea, and epileptic seizures. Here, ambulatory monitoring, furthers valid diagnoses and, as well, the stabilization of medication.

Field research comprises observation in natural settings in contrast to the laboratory. Field research is an essential methodology in cultural anthropology, social research (e.g., Pelto & Pelto, 1973), and ethology. Likewise, in psychology and psychophysiology some research issues require field studies to obtain valid data (Patry, 1982a; Pawlik, 1988). Observations in a natural setting may be necessary for many research questions in social psychology, developmental psychology, differential psychology, and clinical psychology. Such field studies are especially relevant, for example, in research on stress-strain or in research on mechanisms that trigger off psychological and psychophysiological symptoms.

Behavioral assessment is a basic methodology in psychology for observation of interindividual and intraindividual differences. Behavior observation and behavior measurement are directed at manifest behavior rather than personality traits. Such behavioral assessments are commonly used in applied and clinical psychology and, accordingly, the ecological validity of such assessments is essential. In addition to laboratory observation that reveals stimulus-response contingencies more clearly, a variety of in-vivo (in situ) tests, simulated and quasi-naturalistic settings have been developed in behavioral assessment methodology. Noteworthy are behavioral approach/ avoidance tests (BATs) which were designed to assess behavior disorders and clinical symptoms (cf. Ciminero, Calhoun & Adams, 1986; Haynes & Wilson, 1979; Nelson & Hayes, 1986; Schaller & Schmidtke, 1983; Suen & Ary, 1989).

Ambulatory assessment – a term we have coined here – brings together those research orientations that correspond to each other in their basic ecological perspective. Ambulatory assessment involves the acquisition of psychological data and/or physiological measures in everyday life (i.e., natural settings) according to an explicit assessment strategy which relates data, theoretical constructs, and empirical criteria specific to the given research issue.

Such field studies are not solely concerned with the ambulatory monitoring of patients, but rather include a wide spectrum of objectives and applications. Common features are: recordings in everyday life; computer-assisted methodology; attempts to minimize method-dependent reactivity; maintaining ecological validity and, therefore, outstanding practical utility for various objectives – such as monitoring and self-monitoring; screening; classification and selection; clinical diagnosis; and evaluation – in many areas of psychology and psychophysiology (Fahrenberg, 1994; Fahrenberg & Myrtek, in press; Patry 1982a; Pawlik, 1988; Perrez, 1994; Suls & Martin, 1993; Turpin, 1990).

Tape recorders and event recorders have been succeeded by more advanced instrumentation. Nowadays digital recorder/ analyzer systems are available that allow for multichannel recordings and real time analysis. Pocket computers may be used as "electronic diaries". Thus, a methodology exists which is suited to the precisely timed acquisition of behavioral measures, performance data, self-ratings of mood changes, symptoms, coping strategies, etc. Further potentialities of computer-assisted data acquisition – for example,

strategies of feed-back and interactively conducted assessment and the integration of knowledge-based systems – have yet hardly been explored.

In medical research and practice tape recorders and biotelemetry have already been employed for many decades for diagnosis and ambulatory monitoring of risk patients. The 24-hour electrocardiogram now is a widely used, routine method in cardiology and, likewise, the ambulatory monitoring of blood pressure has become a common method. However, in psychology and psychophysiology the progress in instrumentation and the development of pocket-size computers and recorder systems have only been hesitatingly incorporated into the research methodology. Yet, the obvious ecological validity of such assessments and an increasing number of relevant findings should encourage their further application. This is especially the case when researchers are concerned with the practical utility of their findings, i.e., a direct transfer from research to application.

Instrumentation

Psychological data acquisition

From the beginning of experimental research, event-recorders for the timed registration of stimuli and responses have been indispensable in the psychological laboratory. Among the many types of mechanical, electromechanical and electronic devices were also portable timers, counters, and recorders. Such devices were either used by observers or subjects previously instructed on the available keys and categories for recording behavior. Particularly in clinical psychology, the monitoring and self-monitoring of symptoms was achieved with these devices (cf. Kratochwill, Mace & Mott, 1985; Rugh, Gable & Lemke, 1986; Sidowski, 1977; and the journals: Behavior Research Methods, Instruments & Computers; Behavioral Assessment; Journal of Applied Behavior Analysis).

The so-called “beeper” studies in which a programmable wristwatch provided an acoustic signal (beep) in order to prompt the subject to respond to a questionnaire concerning activities, mood, etc. is worth mentioning. Such questionnaires were used, for example in time budget research and in clinical psychology (Experience Sampling Method, ESM, Csikszentmihalyi & Larson, 1987; de Vries, 1992). Self-ratings on diary cards and an electronic data logger have been employed in medical research to evaluate symptomatic response. Hand-held computers also have a long tradition in animal research and human ethology (Noldus, 1991).

The recording of psychological data in everyday life became much easier through the availability of pocket-sized (hand-held, palm-top) computers. A suitable computer (e.g., Psion 3a, Casio PB1000) has sufficient memory capacity, a clock, a piezo-electric beeper, and an operating system that allows for flexible programming. An LCD is used to display questions and rating scales or multiple-choice items which can be answered by pressing a key, moving the cursor and pressing a key, or by typing a response (cf. Brügner, 1995; Heger, 1990b; Noldus, 1991; Pawlik & Buse, 1982; see als Myrtek, this volume). Table 1 depicts the classes of variables that may be protocolled.

The application of programmable pocket-PCs in ambulatory assessment has many advantages:

- alarm functions for prompting the subject at predefined intervals and a built-in reminder signal;
- reliable timing of input, delay of input, and duration of input;

- flexible layout of questions and response categories;
- branching of questions and tailor-made sequential or hierarchical strategies;
- previously recorded responses are concealed from the subject.

Generally, a higher reliability and ecological validity of such assessments can be assumed. Paper-and-pencil questionnaires and diaries lack such flexibility and exact timing of responses.

Even if subjects are told to monitor their mood and symptoms several times daily, such reports are often made from memory. Such retrospective ratings are, obviously, less accurate. Furthermore, a retrospection effect may exist. Subsequent events and experiences may systematically influence and even distort the subjective evaluation and weighting of previous states (De Longis et al., 1992; Hedges, Jandorf & Stone, 1985; Schandry & Leopold, this volume; Smith & Safer, 1993). Käppler (1994) compared the averages of 20 daily self-ratings and a retrospective rating made from memory employing the same set of items. The retrospective ratings indicated more negative mood and worries than was to be expected from the actual ratings.

Dealing with a pocket-PC requires little training. The programming, however, should control for both deliberate and unintentional operating errors. The content of the protocol, e.g., items, scales and categories, should, of course, be illustrated and explained to the

Table 1: Potential contents of a computer-assisted protocol

Objective setting features (observables)
location (place) and time
persons and objects
tasks and stimulus conditions
ambient variables, e.g., temperature, noise
specific events

Behavior-report (observables)
posture and physical activity
speaking, actions, and social interactions

Performance data (measures)
objective test scores, e.g., reaction time test
self-measurements, e.g., blood sugar level

Behavior observation concerning other subjects
ratings of behavior and social interaction

Self-report (ratings)
subjective state, e.g., mood, emotion, strain
introspective experience, e.g., physical symptoms, pain
evaluation of settings, i.e., situational aspects
actions and goals, coping process
motives and thoughts relating to setting/situation
comments on tasks and specific events

Further aspects
timing of input (signal compliance)
initiation of measurements (self-monitoring)
event marker
artifacts and missing data
comments concerning acceptance, reactivity, and compliance

subjects. Further training may be needed if complex relationships have to be reported (e.g., Perrez & Reicherts, 1989). The acceptance of such computer-assisted assessment is usually unproblematic and, on the average, the compliance with this method is satisfactory. The applications of computer-assisted and paper-and-pencil methods in order to record self-ratings of emotional state were compared by Hank and Schwenkmezger (this volume), who also investigated signal compliance in different settings.

Special recording devices have been developed for certain research questions (Jain, Mutz & Mucha, 1992; Lang, Ostermeier, Forster & Handwerker, 1991; Pawlik & Buse, 1982; Myrtek et al., 1988). But most researchers apparently chose from the generally available pocket-PC. Today's pocket-PCs also allow for programming of performance tests, whereby vigilance tasks, reaction time tasks, memory tasks, etc. are displayed on the screen (cf. Buse & Pawlik, this volume).

The instrumentation of ambulatory assessment furthermore includes voice recording by means of dictating systems that allow for the recording of approximately 60 to 120 minutes on microcassette or microdisc. Krüger and Vollrath (this volume) employed a throat microphone to obtain recordings for the analysis of speech pattern in social situations.

Physiological recordings

The monitoring of the electrocardiogram was developed by Holter (1961, 1976; cf. Kennedy & Wiens, 1985) and, thus, "Holtering" became synonymous for ambulatory monitoring of the ECG and other electrophysiological functions. A few years later, portable recorders for semi-automatic and automatic, non-invasive registration of arterial blood pressure came into use (Schneider, 1968; cf. Meyer-Sabellek, 1991) and, also, for ambulatory EEG recording (Ives, & Woods, 1975) and ambulatory sleep recording (Wilkinson, Herbert & Branton, 1973).

The majority of research publications deal with the 24-hour monitoring of either the ECG or blood pressure. Technical progress has been most apparent in this domain, for example real-time analysis of essential ECG-changes, such as ST-depression and arrhythmia's, and improved BP measurement by algorithms that detect measurement errors. Ambulatory monitoring of the ECG and BP are very common methods here. Committees have been set up to provide technical recommendations and guidelines on how to examine the reliability of these methods (cf. Kligfield, 1989; Middeke et al., 1992; O'Brien et al., 1991; Sheffield et al., 1985).

Analog recorder in conjunction with the appropriate sensor/transducer technique were also employed in the ambulatory monitoring of heart rate, pulse wave velocity, impedance cardiogram, systolic time intervals, respiration, sleep apnea, electroencephalogram, polysomnogram, electromyogram, physical activity, temperature, electrodermal activity, gastrointestinal, urodynamic and genital functions (cf. overviews by Fahrenberg & Myrtek, in press; Turpin, 1990; and the Journal of Ambulatory Monitoring). In addition to such specialized equipment, then, multi-channel analog recorders in modular designs, e.g., the Medilog-System (Oxford Instruments), have become available.

The development of multi-channel digital recorder/analyzer systems began in the eighties (e.g., Kunz, Mertens & Oeste, 1982; Miles & Rule, 1982) and has since progressed so fast that every market survey is soon out-dated (e.g., Heger, 1990b; Krönig, 1995; Meyer-Sabellek, 1991). General purpose digital recorder/analyzer have been designed for long-term recordings. In addition to general purpose analog input channels and marker channels, here, specific channels, for example, for recording blood pressure, temperature and

electrodermal activity, may be available. Specific features include software programmable amplifier gain and high-pass and low-pass filtering plus valuable pre-processing options and real-time analysis of input.

Digital storage is usually done on RAM and, possibly on a disk (for example, a 131 MB disk allows for an eight-channel recording with a sampling rate of 100 Hz for 36 hours). The post-processing is dealt with by programs developed by the user, but standard software for parametrization, statistical analysis and graphic presentation of results will be increasingly important in this field. Such general purpose recorder/analyzer systems include the AMS (Free University, Amsterdam), Bioport (Zak GmbH, Simbach), Par-Port (Par-Elektronik GmbH, Berlin), Physio-Logger (med-Natic GmbH, München), and Vitaport (Vitaport GmbH, Erftstadt).

Recent progress in ambulatory assessment that has utilized the real-time analysis of physiological recordings for feedback and control has proved most interestingly. The subject/patient is prompted by a signal to respond to a set of questions concerning the setting, their present behavior and subjective state if a distinct increase in heart rate (accounting for effects due to physical activity) occurs (see Myrtek et al., this volume). The available equipment would already make many innovative assessment strategies possible, for example, blood pressure measurement could be triggered depending on predefined critical values concerning the ECG (e.g., heart rate change, arrhythmia's, ST-depression). Such interactive strategies are readily accessible, but have hardly been applied in psychophysiology.

Neither the device technology in digital recorder/analyzer systems nor the progress in ambulatory monitoring of endocrine responses are within the scope of this introduction (but cf. Dimsdale, 1989; Kirschbaum, Reed & Hellhammer, 1992).

Psychophysiological recordings

The methodology of psychophysiological research would greatly profit from concurrent recordings of physiological responses and behavioral changes. As such a device does not exist at present, suitable equipment has to be combined for certain research questions, for example in the psychophysiological investigation of blood pressure responsiveness. This configuration may consist of a multi-channel recorder for blood pressure, heart rate, and activity, a pocket-sized computer to obtain self-ratings (cf. Schmidt & Jain, this volume), and, furthermore, a dictating system (e.g., walkman recorder) to obtain the subject's comments on the more specific aspects of behavior settings and events (cf. Fahrenberg, this volume).

Such equipment is still rather heavy and may be uncomfortable to the subject. Technical progress, however, is foreseeable. Concurrent recordings of emotional state, characteristics of the actual setting, target behavior or symptoms, and physiological changes would provide a comprehensive multimodal assessment. This methodology should facilitate the assessment of response contingencies across systemic levels (for example symptom-context-analyses) with high ecological validity.

The laboratory-field issue

Field study and laboratory experiment have often been regarded as alternative strategies in psychological research. The laboratory provides an artificial, though standardized setting that is designed to elicit distinct behavioral responses, and thus allowing for controlled observation and experimentation. “Field” designates the multitude of real life settings where behavior occurs naturally, e.g., without being induced by an investigator.

The discussion of the laboratory-field issue has a long and often controversial history reflected by essential keywords like realism (Lebensnähe, Lewin, 1927), ecological validity and representative design (Brunswik, 1956), internal and external validity (Campbell & Stanley, 1963), socio-ecological units (Barker, 1968), and naturalistic observation (Willems & Raush, 1969). A short account of this controversy may suffice here (cf. Fahrenberg & Myrtek, in press; Patry, 1982a; Pawlik, 1988). Textbooks on research methodology point out certain features, referred to as advantages or disadvantages in evaluating laboratory experiments and field studies. Many of these statements can be subsumed under the perspective of internal vs. external validity (see Table 2). However, more differentiation appears to be needed in the laboratory-field issue.

A substantial amount of the research published by laboratories is not experimental in a strict sense. Research on patients, for instance, often employs several clinical groups or healthy controls that, per se, are not equivalent groups. The permutation of laboratory tasks or tests was often dismissed in research on individual differences in favor of presentation in a fixed order so that comparisons between subjects could be made. On the other hand, field experiments exist that actually employed a randomization of treatments, i.e., investigating the effect of caffeinated vs. decaffeinated coffee on subjective state and symp-

Table 2: Common, although questionable notions of laboratory experiment and field study

Laboratory Experiment	Field Study
Advantages/ Benefits	
precision in hypothesis testing and (causal) inferences	ecological validity
isolating stimuli, manipulation of independent variables	representative design concerning settings and behavior
rigorous control of extraneous variables, control of measurement error (reliability)	derivation of context-(setting-) specific relationships
random assignment of subjects and treatments	utility of results and treatments, direct applicability
Disadvantages/ Shortcomings	
reductionistic approach	complexity of effects
artificial setting, questionable generalizability to real-life	lack of precision in detecting functional (causal) relationships
subject and experimenter effects, test apprehension, effects of anticipation and attribution, experimenter expectancy effects	problematic control concerning independent and dependent variables, covariates, and extraneous variables method-dependent artifacts (reactivity)
method-dependent artifacts (reactivity)	
Practical Aspects	
reductionistic approach	complexity of effects
artificial setting, questionable generalizability to real-life	lack of precision in detecting functional (causal) relationships
subject and experimenter effects, test apprehension, effects of anticipation and attribution, experimenter expectancy effects	problematic control concerning independent and dependent variables, covariates, and extraneous variables
method-dependent artifacts (reactivity)	method-dependent artifacts (reactivity)

toms (e.g., Höfer & Bättig, 1994). Thus, the traditional view that sharply contrasted laboratory and field research should be replaced) by a wider perspective. Among the noteworthy methodological developments were contributions that came from generalizability theory and from environmental psychology that pertain to the theory of settings and boundary variables.

The generalizability theory (Cronbach, Gleser, Nanda & Rajaratnam, 1972) assumes a universe of observations specified with respect to certain facets including scores, observers, trials, days of observation, boundary variables, etc. Generalizability studies provide estimates for the amount of variance that can be attributed to certain facets. This provides a guide for the investigator in deciding what universe of observation is to be selected and what range of generalizability can be obtained, whereby reliability and available means have to be accounted for.

A distinction has been proposed between a focal setting in the laboratory or field designed for data acquisition and, on the other hand, a criterion setting where the application of research findings is intended (Fromkin & Streufert, 1976). Relationships between independent variables (i.e., tasks) and responses may differ for both arrangements. Specific features of these settings that constitute such critical differences are called boundary variables. Some potential boundary variables are e.g., meaning and relevance of the task to the subject, characteristics of stimulus persons, interpersonal contacts, awareness of research, and consequences of behavior (Fromkin & Streufert, 1976). The range of generalizability (external validity) can be determined by the investigation of such boundary variables that may stand between specific studies and specific realms of application.

The concepts of generalizability and boundary variable, thus, have attained operational definitions. The concept of naturalistic observation, likewise, requires a more precise definition. Behavior is natural if the following conditions apply: (1) the behavior is already contained in the individual's repertoire; (2) if the activity occurs in a natural setting familiar to the subject rather than in a specifically designed research environment; and (3) if this behavior is spontaneous, i.e., independent of the investigator. Further aspects can be included in this taxonomy, e.g., whether subjects know that assessments are being made and whether they are aware of the specific hypothesis under investigation (Patry, 1982b; Tunnell, 1977).

A wide spectrum of settings ranging from natural to rigorously controlled laboratory settings has been employed in psychological research. The behavior assessment methodology comprises a variety of in-vivo (in-situ) tests, simulated and quasi-naturalistic settings, e.g., behavioral approach/avoidance tests.

The pertinent question remains, however, whether an equivalent type of behavior occurs in these settings ("gleicher Geschehenstyp" Lewin, 1927). Three possible kinds of representation were distinguished by Gadenne (1976): a certain behavior may be representative of a theoretical issue, a typical field of application, or a subject sample. Obviously, neither the first nor the second aspect of representation allows for an inference based on a sampling technique. Instead, the investigator should state those elements of the theoretical propositions which are specific to settings (contexts) and, furthermore, should delineate the intended domains of application. Gadenne (1976) holds the view that there is a common logic of research in the laboratory and in the field. The context specificity of explanatory hypotheses is an essential aspect of theories and, consequently, of the operational definition of theoretical constructs. Therefore, it would not be justified to generally assume a two-stage strategy for normal research, i.e., from laboratory experiment to generalizability studies in the field.

Laboratory-field comparisons are designed to examine the validity of findings obtained in the laboratory to predict performance in real-life. In the development of psychological tests such empirical validation studies play an important role. More recently, it has been questioned whether certain diagnostic techniques and measurements in the physician's office or in the psychophysiological laboratory, e.g., blood pressure measurement, reliably predict individual differences in real-life. Laboratory-field comparisons revealed significant discrepancies. Office hypertension is a good example of how certain features of the setting and their meaning to the subject may play an important role in assessing individual differences: Blood pressure readings are elevated if the measurement is made by the physician, but normal readings are obtained in everyday life.

Laboratory-field comparisons were valuable in the evaluation of methodological issues as well as practical aspects. Field studies, apparently, are more suited for prolonged observation that may extend over days and weeks. Accordingly, there is more chance for the detection of rare events and symptoms that occur at low frequencies or only in certain settings. Generally, larger response magnitudes and more realistic effect sizes may be expected in natural settings. Prolonged observation periods make the averaging/ aggregation of measurements possible so that reliability and stability of measures may increase substantially. But field studies can be seriously threatened by the confounding of multiple effects which tend to produce "noise" and, eventually, require relatively large subject samples in order to obtain valid estimates for main effects. However, depending on the research question specific interactions may be of special interest to the investigator. The laboratory experiment remains indispensable for the necessarily reductionistic testing of explanatory hypotheses. Furthermore, the laboratory may serve as a standard of reference for the evaluation and improvement of methods for observation and measurement.

Considering the multitude of research strategies and quasi-experimental designs, it may be misleading to refer to laboratory or field study without indicating the features of the specific study under discussion. It would also be oversimplified to state methodological advantages of the laboratory experiment as obstacles in field studies and vice versa, i.e., to retain the notion of basically different research strategies instead of a wider perspective that includes laboratory and field as complementary approaches.

Basically, such an approach would lead to new types of design that should bridge the gap between laboratory and real-life settings, for example by including standardized settings in the ambulatory monitoring of blood pressure changes in order to obtain baselines and response magnitudes for reliable between-subjects and within-subject comparisons. This approach also necessitates the search for distinctive boundary variables that may affect (1) the reliability/objectivity of measurement (cf. office hypertension), and (2) the relationship between independent and dependent variables. In conclusion, the design of ambulatory assessment should provide an explicit assessment strategy (Stemmler, this volume).Methodological issues

Setting and situation, context and boundary variable

Ambulatory assessment relates to a specific setting or a sequence of settings in real-life as compared to a standard laboratory environment. The psychology of settings and situations, therefore, is a fundamental issue here. However, generally accepted definitions for "setting" and "situation" cannot be found in the literature and, possibly, such definitions cannot be expected due to the controversial theoretical and methodological issues involved (for further discussion cf. Fahrenberg & Myrtek, in press; Furnham & Argyle, 1981; Kaminski, 1988; Pawlik & Buse, 1982; Stemmler, 1992; Stokols & Altman, 1987; Strohsahl & Linehan, 1986; Wicker, 1987). The following distinction is suggested here:

Setting refers to external environmental conditions, e.g., an objective description of location, time, persons and objects present, and other characteristic features of a distinct part of the field. For a given setting, certain behaviors are more probable while other behaviors seldom or never can be observed. Many settings, thus, contain rather specific tasks and incentives, constituting the demand characteristics that elicit typical behavior programs.

Situation refers to an internal representation of a setting, i.e., a subjective description relating to experience and evaluation which constitutes the frame of reference for the individual's emotions, actions and social interactions. A situation can usually be characterized by a focal action or action tendency. Taxonomies for settings and situations have been suggested (e.g., Frederiksen, 1972; Sells, 1976), but, apparently, have not been generally accepted. Such taxonomies may refer to (1) the objective features of a setting, (2) behavior that is typically elicited in a certain setting, and (3) the evaluation of situational aspects which indicate the relative similarity of certain situations (e.g., Magnusson & Ekehammar, 1978).

A universe of settings and a universe of situations exist, but the notion that a random sample of natural settings can be obtained appears to be inadequate because a distinct population of settings/situations cannot be conceived. Sampling techniques in this respect have to be replaced by the appropriate selection of settings or aggregates of settings. Pawlik and Buse (1988), for instance, derived aggregates for classes of settings and classes of situations in order to investigate inter-setting consistency and inter-situation consistency in individual differences of behavior.

The rationale for selecting appropriate settings/situations is therefore an essential step in designing ambulatory assessment strategies. The validity of research findings and the practical utility depend on a sound theoretical and empirical justification of such decisions.

Diaries employed in ambulatory blood pressure monitoring often contain rather crude categorizations of settings, namely workplace, at home, and sleep. A psychological approach that provides essential distinctions is called for. Which setting is rather frequent or outstanding in the individual's time budget? Which setting is especially significant from a psychological-biographical point of view? Which setting is familiar enough to all subjects in the sample, which renders a between-subjects comparison possible? Which setting could be designed as a standardized condition for behavioral assessments (in-vivo testing)? In evaluating a 24-hour monitoring, furthermore, it may is essential to know whether the subject spent much time in unfamiliar settings or whether the daily course of events can be assumed to be representative, i.e., rather typical of this subject.

Both, settings and situations constitute the context for the protocol that contains observations, self-reports, and physiological measurements. Accordingly, a multitude of context variables can be enumerated which may possibly affect the findings. Thus, the concept of a boundary variable was introduced (cf. Section 3) to signify a context variable that obviously (1) influences the relationship between variables and (2) may disturb the transfer of results from a focal setting to a criterion setting.

Sampling and segmentation

Ambulatory assessment, like laboratory research, requires the selection of variables, the design of time and event sampling, the segmentation of records, and appropriate data reduction in order to obtain indices suited for statistical inferences. None of these methodo-

logical aspects appear to be characteristic for field studies; however, time and event sampling and, accordingly, strategies in data reduction may play a more important role here. Many strategies of data acquisition are conceivable; these range from 24-hour continuous observation in ambulatory monitoring of the ECG to a complex design which combines time and event sampling of subjective state, and, furthermore, may even include ratings of momentary state, as well as retrospective ratings (cf. Fahrenberg et al., 1991; Pawlik, 1988; Perrez & Reicherts, 1989). Suls and Martin (1993) suggested a classification system for in situ methods. Report sources are self-report, surveillance-report by a trainend observer, and automated report. The recording of frequencies of behaviors may be conducted interval-contingent, signal-contingent or event-contingent. Heger (1990b) distinguished active, passive, and reactive participation of subjects in ambulatory monitoring.

An adequate design of time sampling assumes that the time course of the relevant phenomena (latency, frequency and duration) is known. Yet the time-schedule of observations or measurements is actually often the result of a compromise between cost and utility aspects and the subject's compliance to the repeated measurement. For the ambulatory monitoring of the ECG, a cost-benefit analysis has been suggested since the rate of detection of certain abnormalities in cardiac functions may depend on the duration of screening. In blood pressure monitoring the guidelines indicate that measurement intervals of 15 or 20 minutes during the day and 30 minutes at night may suffice for a valid assessment of blood pressure level and variability (cf. Middeke et al., 1992; Pickering, 1991).

Segmentation denotes the distinction of data periods which, according to theoretical or empirical criteria, constitute relatively homogeneous units of functioning within an extended course of observation. Segmentation is an often problematic but essential step, i.e., to separate pre-task and task, rest and activity, symptomatic and asymptomatic intervals, awake and asleep. In physiological recordings, steady state or response criteria can be used for segmentation and, possibly, concurrent recordings of physical activity provide cues to eliminate data periods containing artifacts. The segmentation of prolonged recordings is necessary in order to attain the essential data periods that allow for interindividual comparison, contingency analysis, and symptom-context-analysis.

The observation of distinct stimulus-response relationships will generally be more difficult in ambulatory recordings than in the laboratory. Obvious changes in behavior and physiology that are attributable to either an external event or the subject's actions may occur. Such "episodes", e.g., relevant segments that stand out from a stationary process, can be defined according to psychological and physiological criteria. Psychological and physiological episodes may coincide; however, many investigators have reported essential discrepancies, e.g., "quiet" physiological reactions or subjective symptoms without adequate somatic changes.

In psychological research various designs for computer-assisted ambulatory assessment have already been employed, whereby some of these assessments lasted for many days or weeks. In psychophysiology and in medicine, the restriction to a single 24-hour recording appears to be the preferred format due to the costly equipment. The contributions to this volume illustrate a wide spectrum of designs and assessment strategies (for further discussion cf. Stemmler, this volume; Buse & Pawlik, 1984; Delespaul, 1992; Fahrenberg & Myrtek, in press; Nelson & Hayes, 1986; Suen & Ary, 1989).

Office hypertension – an illustration

This introduction to methodological issues in ambulatory assessment had, so far, to follow rather abstract considerations. The assessment of office hypertension may serve to illustrate essential terms and, also, substantiate the noteworthy relevance of such recordings in everyday life.

The physician's office is a *setting* for observation and measurement. Blood pressure recording is among the *expected behavior* programs and the sphygmomanometer or electronic BP measurement device apparently provides *demand characteristics*. The patient's apprehensive evaluation is a common *experience* here. The anticipation of higher than normal readings may elicit emotional concern and, possibly, an action tendency directed at a higher compliance to medication – altogether typical aspects of this *situation*. It has been generally assumed that such measurements reliably predict BP level in real-life. 24-hour ambulatory recordings have proved that this assumption was not true for many patients who received medication although they were not hypertensive in everyday life (see Pickering, 1991). *Laboratory-field comparisons* revealed the existence of so-called office hypertension and underlined the necessity of ambulatory monitoring for diagnosis and medication adjustment in hypertensives. In such a case, the possibility exists that BP readings taken by a nurse are not elevated (Mancia et al., 1987). Doctor and nurse, then, can be understood as relevant *boundary variable* (critical difference) for these settings.

Segmentation of the recordings would distinguish data periods "waiting", "at rest", "physical examination", "interview", etc. Concurrent psychological and physiological *episodes* may occur when increased health concern and a sudden BP rise are elicited by a specific interview question. A *physiological episode* may be assumed when a sudden change to an upright position causes a decrease in diastolic blood pressure and increase in heart rate; a mere *psychological episode* is evident when a self-report indicates an anxiety state without obviously corresponding changes in the physiological recordings.

Acceptance, compliance, and reactivity

Ambulatory assessment that employs a pocket-PC or recorder depends on a favorable attitude and appropriate motivation of the participating subjects. It is essential that the equipment is readily accepted and that a good compliance to instructions is established.

The acceptance of the pocket-PC in psychological field studies and, generally, the acceptance of ambulatory monitoring appears to be much higher than initially expected by the investigators (Hageböck, 1994; Heger, 1990a; Käppler, 1994; Murelle, Ainsworth, Bulger & Holliman, 1992; Schwenkmezger & Hank, 1993; Skinner & Allen, 1983). However, it should be noted that most studies dealt with either patients or paid voluntary student subjects. The attitude may be different for other populations or environments, for example at the workplace, in business and in industry, although the ambulatory monitoring of the ECG or BP is practiced quite often nowadays. The awareness of being equipped with a new electronic device can be a motivating condition. Furthermore, motivation can stem from participation in a relevant diagnostic procedure or in a research project, and the willingness to learn about oneself: "Everybody is his/her own blood pressure researcher (behavior analyst)".

A follow-up interview or questionnaire obtainable when the equipment is returned by the subject may be useful, for example, to understand the reason for incomplete diary information and to indicate further problematic aspects and possible improvements (post-monitoring interview, cf. Heger, 1990a; Jain, 1995; Käppler, 1994; Kessler, Chakko & Kessler, 1994). Such reports indicate that subjects felt disturbed when beeps occurred rather frequently, e.g., at intervals of less than an hour, especially when somebody was present or when an interesting activity was interrupted. The post-monitoring interview may disclose whether, on the average, the weight of the recorder, placement of sensors, and operating characteristics were acceptable or not. In BP monitoring, the noise of the pump when inflating the blood pressure cuff had an especially irritating effect for patients and bystanders. Manufacturers, meanwhile, have succeeded in significantly reducing operating noise in today's BP recorders.

A specific advantage of a computer-assisted method in obtaining self-reports is the exact protocol of the subject's compliance to instructions that repeatedly demand a response to beeps and questions. A reduced signal compliance is evident when the alarm is answered with delay, is overheard or deliberately ignored. Setting compliance is indicated by the rate of delays and missing data that occur in certain settings (cf. Hank & Schwenkmezger, this volume).

Reactivity means that the method of observation and measurement itself is a source of unwanted variance due to specific interactions, e.g., awareness, adaptation, sensitization, and coping tendencies (cf., Haynes & Horn, 1983; Stern, 1986; Watson & Pennebaker, 1991). Such reactivity may include a bias that is common to a class of methods or specific to one method. Obviously, non-reactive methods are an exception in psychological assessment and physiological measurement in accordance with Heisenberg's uncertainty principle: the attempt to measure a phenomenon may distort this phenomenon.

The question remains whether computer-assisted ambulatory assessment is likely to elicit a specific method-dependent reactivity not present in controlled laboratory settings. Thus, subject-experimenter interaction, expectancy effects, impression management, response sets such as social desirability or faking, and misunderstandings of instructions or tasks are not under consideration here. Three aspects of reactivity, however, appear to be rather specific for ambulatory assessment. Subjects may (1) tend to keep out of certain settings during the recording in order to avoid being monitored there; (2) tend to unintentionally or deliberately manipulate the recording systems, shift settings of the PC and even may try to get access to the program; and (3) try to test their capacities or the equipment by unusual patterns of behavior, exercise or vigorous movements.

At present, only the post-monitoring interview may reveal such effects and an evaluation is rather difficult. Little is known yet about whether it is advisable to include in the computer-assisted questionnaire a few control items and questions that directly refer to actual (non-)compliance and method-dependent effects, for example, the subject's being irritated by the beeps or having specifically changed the usual routine of daily life. The issues of acceptance, compliance, and reactivity are further referred to in contributions to the present volume.

Ethical aspects

Ethical issues that are specific to ambulatory monitoring studies have hardly been discussed yet (Schuler, 1982). Appropriate data protection is but one aspect, as ambulatory assessment may violate privacy more easily than other methods. Furthermore, significant

others and bystanders may become involved when the observation and evaluation of settings are demanded. Obtaining the subject's informed consent before the recording starts is essential, but may be problematic since the exact course of daily activities and events cannot be anticipated. Moreover, it may be more difficult to explain the essential hypothesis of the investigation, variables, and methods of analysis than in the laboratory. The post-monitoring-interview is thus well suited to recall specific events and discuss problem-

Perspectives

atic aspects.

In this introduction some advantages and limitations of ambulatory monitoring and assessment were discussed. The ecological perspective may lead to the attitude that psychological research should generally begin with observations in natural settings and then, eventually, move on to the laboratory for the investigation of distinct causal explanations. The experimental psychologist will, however, continue to favor the opposite strategy that relies on the laboratory and seeks for generalizations and practical utility afterwards.

However, such two-stage models of research and, even more, the long-lasting controversies over the fundamental dichotomy in laboratory-field methodology have become obsolete. A broader perspective which acknowledges the relative merits and limitations of distinct assessment strategies relating to a specific research question is more appropriate. In this case, for example, laboratory-field comparisons, field experiments, and the inclusion of standardized settings and test conditions in the design of ambulatory monitoring provide a valuable extension to conventional research designs. It is conceivable that laboratory research and ambulatory assessment may complement one another in many instances. The perspective here is that a variety of integrated laboratory-field designs will be developed in research methodology.

Computer-assisted ambulatory assessment has already led to essential new research findings in psychology and psychophysiology. However, the potentialities of digital computers have by no means been exhausted. Certain operating functions of a recorder/analyzer system are fully defined; others may be programmable or controlled interactively by the subject or can be automatically adjusted depending on the actual measurements. Real-time analysis has already been mentioned. Such signal processing may reveal patterns, trends and contingencies, provide feedback to the subject or trigger specific system functions, e.g., initiate the pocket-PC to start the questionnaire or a blood pressure measurement. Furthermore, the computer program can be used to elicit rather specific answers through the multi-level branching of questions and, also, to store individual response patterns in order to facilitate, adapt or short-cut subsequent assessments.

New strategies in computer-assisted methodology are conceivable that would include knowledge-based approaches to assist in the self-monitoring of symptoms, i.e., hypertensive blood pressure or glucose level and target behaviors like smoking. Keeping records of subjective symptom ratings, previous measurements, medication, and trend estimates could be helpful for the self-management of symptomatic behavior.

Some of these considerations may be speculative at present, but the progress in instrumentation and software development is evident. The methodology is certainly much more advanced as compared to previously used simple event recorders or the experience sampling method, employing a wristwatch and a paper-and-pencil diary. The prospects here are that innovative device technology, increase in storage capacity and advanced operating systems – e.g., for real-time analyses and interactive strategies – will become

available. Such progress will come faster than the willingness of most psychologists and psychophysiologists to test these options.

Basic limitations in ambulatory assessment methodology were also discussed here. Among these limitations there are two outstanding obstacles: the confounding of various effects and the obvious difficulties in appropriately comparing between subjects or within subjects if the pattern of activities strongly differs. A number of factors are inevitably left uncontrolled when conducting field studies. Such factors confound results and thus limit the internal validity of the results.

The ambulatory monitoring of ECG and BP has been widely accepted as an essential method in medical research and practice. One should note, however, the validity of this approach is not severely threatened by either the confounding of effects or the heterogeneous conditions of everyday life. The relevant issue is whether ECG abnormalities occur or not and, likewise, whether the average blood pressure is elevated in everyday life or not. A further differentiation of diagnostic findings may be of secondary interest. It can be concluded that ambulatory assessment methodology is especially useful for this kind of task. The reliability of observation was improved through prolonged recording, and the validity was backed up by adding ecological validity. A similar assessment strategy should be useful for many applications in psychology and psychophysiology.

The confounding of effects and individual differences in daily routine will most probably raise more concern when specific contexts and variables within and between subjects have been investigated. Such methodological aspects should be made explicit when an assessment strategy is defined (see Stemmler, this volume).

The benefits of ambulatory monitoring for diagnosis and management of cardiovascular diseases, and also more recent applications, for example polysomnograms and recordings of sleep apnea, are beyond doubt. The Medline key word “ambulatory monitoring” had 2108 entries (ECG 1832, blood pressure 211, other 65) between 1991 and October 1995. Ambulatory monitoring is not a major keyword in Psyclit (as a textword, it has 49 entries for the period 1984 to Sept. 1995), although many investigations in clinical psychology refer to observations in everyday life.

Substantial findings, however, were also obtained by computer-assisted ambulatory assessment in psychology and psychophysiology. The present book provides a comprehensive overview on the state of the art. Some of the findings substantiate theories and evaluations which rely on laboratory observation. But it is evident that other research findings challenge previously held views. Office hypertension was used as the illustrative example here, but there are many contributions from differential and clinical psychology, work psychology, etc. Ambulatory assessment has also been especially fruitful in generating new research questions concerning, for example, the issue of behavior consistency or the discrepancies (response fractionation) between reported symptoms and actual measurements.

In conclusion, computer-assisted ambulatory assessment is an emerging new methodology. Progress is obvious not only in instrumentation, but in assessment strategies as well. Ambulatory assessment, like any other method, has problematic aspects, in particular how to account for multiple effects in the recordings, but the benefits are evident:

- *recording* of relevant data in natural settings;
- *real-time measurement* of behavioral and physiological changes;
- *interactive real-time assessment* by automatically prompting the subject to respond to questions or instructions;

- *real-time assessment and feedback* by reporting physiological changes to the subject – either with or without informing as to which changes actually occurred;
- *concurrent assessment* of psychological and physiological changes (events, episodes);
- *correlation and contingency (symptom-context) analysis* across systemic levels as suggested in triple-response models (multi-modal assessment);
- *ecological validity* of findings and suitability for direct application.

Genuine research findings in relevant fields suggest further development and application of ambulatory assessment methodology.

The present book emerged out of a series of meetings from the last ten years and, particularly, from contributions to the recent Workshop “Ambulantes Monitoring und Assessment”, May 18-20, 1995, at the University of Freiburg i. Br., which was supported by the Deutsche Forschungsgemeinschaft (German Research Council).

The participants of this workshop decided on an English language publication in order to reach the English speaking audience in psychology and psychophysiology. The translation

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may have affected the stylistic elegance but, hopefully, not the meaning and message.

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