An Introduction to Computerized Experience Sampling in Psychology

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Experience-sampling procedures enable researchers to record the momentary thoughts, feelings, and actions of people in daily life. The authors explain how palmtop computers have expanded the repertoire of experience-sampling techniques and reduced or eliminated some traditional problems with pen-and-paper methods. As a running example, they illustrate the capabilities of the Experience Sampling Program (ESP), their configurable, freely distributable software environment for designing and running experience-sampling studies on Palm Pilots and Windows CE palmtops.

Keywords: experience sampling, palmtop, handheld computing, psychology, research

Much of what we know in psychology is based on what people tell us. When we measure people's feelings, behavior, or experiences, we often ask them to remember past experiences and to aggregate them into a single set of coherent responses on a self-report questionnaire. Recalling information is a reconstructive process influenced by a multitude of factors, however. The research on social cognition is replete with evidence that heuristics, cognitive structures, implicit theories, and motivations can lead to inaccurate recollections (for reviews see Bradburn, Rips, & Shevell, 1987; Eisenhower, Mathiowetz, & Morganstein, 1991; Greenwald & Banaji, 1995; Nisbett & Ross, 1980; Ross, 1989). People can be unduly influenced by salient experiences (i.e., vivid or recent examples) when computing averages or summaries (Eisenhower et al., 1991), especially when doing so in impoverished circumstances devoid of immediate contextual cues (as in sterile laboratory settings). Taken together, these characteristics limit people's ability to provide an accurate account of their behavior or experience through standard recall-based self-report procedures.

AUTHORS' NOTE: Development of an experience-sampling program (ESP) and preparation of this article were supported by a grant from the National Science Foundation to Lisa Feldman Barrett (SBR 9727896). Many thanks to the members of LFB's lab (including Tracey Madden, Eliza Bliss-Moreau, Tamlin Conner, Michael Suvak, Kevin McCarthy, Kirsten Lebo, Kristen Stevenson, Susana Miranda, Cynthia Kaschub, Meg Manning, Cecilia Sala, Mike Cassano, Pauline Mulleady, and Sara Cohen) for pilot testing earlier versions of ESP. Also thanks to Marc Weiss of TikiSoft, Inc. for contributing source code to the Palm Pilot version of ESP. Finally, thanks to Harry Reis for suggesting the idea of developing and releasing a freeware version of ESP and to Ed Diener for his moral support for this endeavor. Correspondence can be directed to Lisa Feldman Barrett, Boston College, Department of Psychology, 427 McGuinn Hall, Chestnut Hill, MA, 01246; e-mail: barretli@bc.edu

Social Science Computer Review, Vol. 19 No. 2, Summer 2001 175-185

EXPERIENCE SAMPLING: A WINDOW INTO DAILY LIFE

Experience-sampling procedures (also called ecological momentary assessment) (Stone & Shiffman, 1994) stand in stark contrast to standard self-report procedures. Although a form of self-report, they do not rely on memory, a need for aggregation, or an artificial context. Participants provide standardized descriptions of their momentary thoughts, feelings, and behaviors across the range of situations encountered in their daily lives, thereby allowing researchers to sample a broad range of variables in different environments. Experience sampling can occur at regular intervals (interval contingent), in response to events of interest (event contingent), or randomly throughout the day (signal contingent) (for a full discussion see Wheeler & Reis, 1991). Many detailed reviews of experience-sampling procedures exist (see Csikszentmihalyi & Larson, 1987; de Vries, Dijkman-Caes, & Delespaul, 1990; Hormuth, 1986; Hurlburt, 1997; Reis & Gable, 2000; Shiffman, 2000; Stone, Kessler, & Haythornthwaite, 1991; Stone & Shiffman, 1994; Wheeler & Reis, 1991).

Experience-sampling procedures reduce the methodological disadvantages of standard self-report procedures. Experience sampling does not require retrieval or reconstruction of data from memory but rather involves access to and accurate reporting of information available to conscious awareness. As a result, experience-sampling procedures minimize the cognitive biases noted previously. Of course, people can report only on things of which they are self-reflectively aware. The validity of experience-sampling procedures rests on the assumption that individuals have access to the relevant information and are willing to report it (Shiffman, 2000). Moreover, experience-sampling procedures cannot account for (or correct for) all of the processes that transform conscious experience into information available for report (for a discussion of the distinction between conscious experience and self-reflective awareness, see Chalmers, 1996). Perhaps experience sampling is best thought of as a procedure that allows participants to report the contents of awareness along with the situation in which that awareness takes place.

Experience-sampling procedures not only help to control for certain disadvantages of standard self-report procedures but also have distinct methodological advantages. First, they allow a researcher to empirically characterize a participant's general pattern of experience or behavior by statistically aggregating across trials (and contexts; e.g., Feldman Barrett & Pietromonaco, 1997). Moreover, they also allow for a contextual analysis of behavior. In one sense, experience-sampling procedures allow researchers to conduct studies with intensive, repeated-measure designs. Individuals report their behavior and associated experiences over the range of situational circumstances experienced in everyday life. Using statistical procedures involving random coefficient multilevel modeling (Bryk & Raudenbush, 1987, 1992; Kenny, Kashy, & Bolger, 1997; Kreft & de Leeuw, 1998), researchers can model the influence of within-subject and between-subject factors simultaneously on a variable of interest. Thus, the researcher can assess the degree of interaction between elements of the immediate situation and characteristics of the person to influence momentary thoughts, feelings, and behaviors.

Second, they allow for modeling behavior over time. Experience-sampling procedures can produce studies with brief longitudinal designs (e.g., Affleck, Tennen, Urrows, & Higgins, 1994). Time series analysis or random coefficient multilevel modeling can model change in a variable of interest by including time as a relevant predictor variable.

Third, they allow for study of phenomena unethical or impractical to reproduce in the lab. For example, full-blown emotional episodes are difficult to evoke in the lab because some of the real-life triggers would be considered unethical to introduce. Experience-sampling procedures take advantage of naturally occurring events to study emotions evoked in daily life (e.g., Feldman Barrett, 1998).

Fourth, experience-sampling procedures can test, rather than assume, the validity of a nomothetic approach. The term *nomothetic* broadly means to attain knowledge about people in general, as opposed to persons in particular. Researchers often assume nomothesis, that is, that patterns of experience and behavior seen for a group hold for all individuals within a population. This assumption can be tested using experience-sampling procedures by summarizing experience or behavior of one individual over time (and across situations) and testing whether the pattern generalizes across individuals in the sample. For example, in our work we test whether individuals can distinguish equally well between emotional states that are typically assumed to be discrete. Although happiness, fear, sadness, hostility, guilt, surprise, and interest are considered discrete either for psychobiological (e.g., Ekman, 1992; Izard, 1977) or social (e.g., Stein & Trabasso, 1992) reasons, we have found, using experience-sampling procedures combined with structural analyses, that individuals vary greatly in their tendency to represent their emotional experience in highly differentiated, or discrete, responses (Feldman Barrett, 1998).

Experience-sampling procedures have been applied successfully to study a range of phenomena in psychology and behavioral medicine. A nonexhaustive list includes the study of behaviors (e.g., alcohol consumption, Swendsen et al., 2000; smoking, Jamner, Shapiro, & Jarvik, 1999; Shiffman et al., 1997; eating, Steiger, Gauvin, Jabalpurwala, Seguin, & Stotland, 1999; and symptom reporting, Larsen & Kasimatis, 1991), stress (e.g., Bolger & Schilling, 1991), emotional experience (e.g., the discreteness of emotional experience, Feldman Barrett, 1998; Larsen & Cutler, 1996; the trajectory of emotional experience, Marco & Suls, 1993; the variability in emotional experience, Larsen, 1987; gender differences in emotional experience, Feldman Barrett, Robin, Pietromonaco, & Eyssell, 1998), interpersonal processes (e.g., intimacy in dyads, Laurenceau, Feldman Barrett, & Pietromonaco, 1998; family process, Larson & Almeida, 1999; social support, Harlow & Cantor, 1995; attachment processes, Pietromonaco & Feldman Barrett, 1998), personality (Cote & Moskowitz, 1998; Feldman Barrett & Pietromonaco, 1997), as well as psychophysiological responding (e.g., ambulatory blood pressure, Kamarck et al., 1998; Steptoe, Cropley, & Joekes, 2000).

In sum, experience-sampling procedures facilitate ecologically valid research. They allow researchers to obtain a representative sample of experience and behavior for each participant in his or her natural environment. In the broadest sense, these procedures are well suited to implement a classic person-situation approach (Lewin, 1951) to psychological research (cf. Conner & Feldman Barrett, 2000).

HISTORY OF EXPERIENCE-SAMPLING PROCEDURES

Experience-sampling studies began with pencil-and-paper measures (such as the Rochester Interaction Record, Nezlek, Wheeler, & Reis, 1983; Wheeler & Reis, 1991) or other standardized rating forms (e.g., Feldman, 1995) containing a series of items with anchored Likert-type scales. Typically, these were completed at set times during the day (interval-contingent sampling) or in response to particular situations or events (event-contingent sampling). Signal-contingent sampling approaches required a device to prompt participants randomly several times per day, so many researchers used electronic pagers (e.g., Csikszentmihalyi & Larson, 1987) or watches (e.g., de Vries et al., 1990) for this purpose.

These older procedures have several disadvantages. First, participant compliance cannot be accurately assessed. Many researchers have attempted to estimate compliance from debriefing interviews. These estimates range from very good (e.g., Feldman, 1995; Jamner, personal communication, February 5, 2000) to very poor (e.g., Litt, Cooney, & Morse, 1998). To some extent, compliance issues probably vary with the population sampled and the task demands of the study. Second, it is not possible to randomize item presentation, increasing the likelihood of response bias due to item context (e.g., Harrison & McLaughlin, 1993). Third, data management is difficult, with all data being entered by hand or by scanning formatted scantron sheets, introducing considerable human error. Fourth, it is not possible to rule out sampling bias in the interval- or signal-contingent sampling procedures in which participants choose when to respond (rather than being randomly cued, cf. Feldman Barrett, 1998).

COMPUTERIZED EXPERIENCE SAMPLING

Researchers moved to computerized experience-sampling procedures, in which data is collected by handheld electronic devices. (We will use the generic term "palmtop" to refer to any such device.) Participants carry palmtops for the sampling period and record their behaviors or experiences. In our lab, we use Handspring Visors using the PalmOS, and Hewlett Packard 360LX palmtops using Windows CE, both running custom software called Experience Sampling Program (ESP) (Barrett & Feldman Barrett, 1999)[1]. ESP is a configurable engine for experience-sampling studies. The experimenter provides a list of questions and their acceptable responses (e.g., the numeric keys 1-7 to represent a Likert-type scale, or on-screen buttons with given labels), and configures ESP to present these questions in trials. Trials may be interval-, event-, or signal-contingent, with adjustable levels of prompting, and questions are presented in fixed or random order. The participant's responses and reaction times are stored on the palmtop and later transferred to a master computer for analysis. We have used ESP primarily for signal-contingent, random sampling (e.g., Feldman Barrett, 2000), issuing randomly scheduled audible prompts to cue participants to record their experiences. Prompting lasts for 10 seconds, and the participant has 60 seconds to respond. If the prompt is missed, ESP cues the participant again 5 minutes later. If the participant again does not respond within 60 seconds, the trial is recorded as missed. If a participant does respond, the item responses and associated reaction times are recorded. (For other examples of computerized experience sampling, see descriptions of the electronic diary, Shiffman, 2000, and electronic interview, or ELI; Affleck et al., 1998).

ADVANTAGES

Experience sampling by computer has numerous advantages over paper-and-pencil methods, primarily due to the flexibility of software.

Precisely controlled timing. Computerized experience sampling allows researchers to have precise control over various timing elements in the study. Trials can be programmed to occur at precise times. For example, ESP can schedule trials at regular or random intervals at any time or within a restricted time interval (say, 8:00 a.m. to 11:00 p.m.) and can control the number of trials per day and the total number of trials in the experiment. In addition to delivery of trials, researchers can specify a time window within which a participant must respond. For example, ESP optionally enforces time limits on responding to a trial or a stimulus. If a participant attempts to respond outside the window, ESP does not record the response.

Tracking compliance. Computerized experience-sampling procedures can record compliance rates objectively. If the participant does not respond within a specified amount of time once a prompt is initiated, the trial is recorded as missed. Tabulating these missed trials, which can be done by software, produces an objective index of compliance. For example, we have written a small program that extracts this information from ESP (called ESPcount) so that we can give participants weekly feedback on the percentage of trials they successfully completed or missed. This helps keep up participant motivation and allows research assistants to track compliance rates.

Characteristics of rating behavior. Another advantage of computerized experience-sampling procedures is that ancillary information can be collected. For example, ESP records the time it takes participants to respond to each item within a trial. Response times are recorded with a high degree of accuracy by computer, typically to the 50th or 100th of a second depending on the operating system.

Reduction of human error. Computerized experience-sampling procedures also reduce the chance of human error when managing the data. Modern palmtops can transfer data (or "hotsync") to and from a master computer using simple, out-of-the-box software, eliminating error-prone manual data entry. With careful planning, if the software saves its data in a format usable by Statistical Analysis System (SAS), Statistical Package for the Social Sciences (SPSS), or other statistics software, the data can be imported directly into these packages for analysis, eliminating yet another data management issue. For example, ESP stores data as plain text in fixed columns easily readable by statistics packages.

Participant recruitment. A less quantifiable advantage is the enthusiasm of participants to use technology in experiments. Debriefing interviews suggest that individuals volunteer for computerized experience-sampling studies because they find the technology novel and exciting. This enthusiasm does not necessarily last through the study, however, and so does not seem to reduce drop-out rates (but see below for discussion of participant attrition).

DISADVANTAGES

Although computerized experience sampling has clear advantages over traditional methods, it also poses some notable challenges.

Programming. Until recently, the primary disadvantage of computerized experience sampling has been lack of software. Researchers typically resort to costly commercial software packages or require custom-written programs, either with a specialized development system (e.g., Pendragon Forms, `http://www.pendragon-software.com/`) or in a traditional programming language, to implement the desired experiment. Typically, this meant the researchers would have to learn to program or else hire a programmer to design and implement a program for them. The situation is improving, however, with the release of free, user-configurable, experience-sampling packages such as ESP (`http://www2.bc.edu/~barretli/esp/`). This open-source software package permits an experimenter to design and run an experience-sampling study under PalmOS or Windows CE without any programming required. It is freely distributable under the GNU Public License (`http://www.gnu.org/copyleft/gpl.html`), and because its source code is included, ESP can be freely modified to suit other needs.

Setup and maintenance. Initial setup of an experiment can be time-consuming. Software must be installed on the fleet of palmtops, and unless this process is automated, it can be burdensome and error prone. Even with automation, human assistance is needed to connect palmtops one by one to an installation computer and test them afterward. More typically, installation is a multistep process, and each time a software update is necessary, the process repeats.

Moreover, once the machines are configured, they must be maintained. For example, batteries for the palmtops must be replaced regularly. This is vital because palmtops have no permanent storage (i.e., no hard disks): If batteries run out, data will be permanently lost. Battery lifetime varies greatly on palmtops depending on brand, model, and usage patterns. Bringing a large number of participants into the lab to change batteries is an expense, in both time and money, that must be carefully planned so as not to interfere with the experiment. Some palmtops use rechargeable batteries, but participants cannot be relied on to charge them, and maintaining a sufficient supply of charged batteries in the lab can be complicated or expensive. We use nonrechargeable batteries in our lab (which we recycle after use, to be ecologically responsible).

Commandeering the machines. Related to battery life is the problem of participants using the palmtops for other purposes. If participants play with the palmtops, the batteries can discharge rapidly, terminating trials prematurely and losing data. Such misuse can also interrupt data collection and/or interfere with the palmtop's recording of reaction times. In our experience, stern warnings to participants about conserving battery life have little effect, and when confronted with clear evidence of this misuse, participants frequently deny it. To combat this problem we used technology to prevent any programs other than ESP from running. ESP for PalmOS has an option to take over the machine, preventing task switching. ESP for Windows CE takes another approach, running a second program, called the Reaper, in the background that kills any other programs the participant runs.[2] It scans the system process list every 5 seconds, and any disallowed programs are terminated. ESP automatically disables the Reaper during trials because its operation would otherwise interfere with reaction-time measurement, and automatically reenables it afterward.

Casualties. When entrusting sensitive computing devices to a crowd, some damage or loss of equipment is inevitable. The frequency and extent of damage to the palmtop fleet likely will depend on characteristics of the sample and design features of the study (such as length of the sampling period). In our lab, we have had a fairly low casualty rate. From a fleet of 50 HP 360LX machines that have been in constant use for 2½ years, we average two palmtop repairs (e.g., cracked screens or machines that have been dropped) per semester. None has been lost or stolen to date.

Reactivity. Any experience-sampling procedure has the potential to create measurement reactivity (Shiffman & Stone, 1998). Several inquiries per day about experience or behavior might increase self-reflected awareness, thereby influencing the very phenomena we want to measure. This turns out not to be as big a problem as one might expect (Cruise, Broderick, Porter, Kaell, & Stone, 1996). For example, in our lab we have checked the temporal stability of emotional responses by looking at split half reliability coefficients. The stability of emotion ratings across time is fairly good (Feldman Barrett, 1998). Additional evidence suggests that response reactivity occurs mainly when participants are trying to change the behavior of interest (McFall, 1970). Moreover, it should be possible to use growth curve analyses to check for systematic changes in reaction time over the sampling period. If there is a systematic reduction in mean reaction time over trials, this might suggest that judgments are becoming more automatized over time.

Participant burden. To guard the integrity of the data stored on palmtops, participants may need to visit the lab on one or more occasions to upload their data to a master computer. This is both to ensure compliance (i.e., to make sure participants are sampling as instructed) and to make backup copies of the data in case a palmtop becomes damaged or lost. At the same time, the experimenter can perform additional tasks with participants in the lab, which in itself is sufficient reason to have participants come in. For example, while measuring emotional granularity using ESP, we have participants complete social cognition-inspired tasks during weekly lab visits while their experience-sampling data is uploaded. These tasks assess the availability and accessibility of both declarative and procedural emotion knowledge, which we hope will tell us whether the characteristics of emotion knowledge are associated with reported experience of discrete emotional states.

Participant attrition. Because experience-sampling studies can require considerable effort by participants, drop-out rates are higher than those of standard laboratory studies. We use a complex remuneration structure to keep motivation high and to communicate our appreciation to participants. In addition to paying participants at the completion of the study, we provide small perks at each lab session (e.g., a movie ticket). Participants also earn lottery tickets to win palmtops, university clothing, or gift certificates donated by local businesses.

PRACTICALITIES

When planning an experience-sampling study, there are practical issues to consider. We highlight several important ones.

First, it is important to choose an appropriate computing platform. If developing custom software, an experimenter should carefully evaluate the operating systems and programming models available, as they can have a substantial effect on the ease or difficulty of creating appropriate software. The major palmtop operating systems are PalmOS and Microsoft Windows CE, which are distinguished by their built-in features and third-party software applications. One example is the control of timing. Windows CE permits an application to run multiple timers simultaneously, so it is easy to schedule multiple trials or stimuli in the future; PalmOS has only a single timer per application, requiring more programmer effort to schedule more than one event at a time. On the other hand, PalmOS arguably has a simpler, leaner programming model than Windows CE, which can mean a shorter learning curve for programmers.

Accuracy of timing is another issue, as each platform has different capabilities. Windows CE, for example, is accurate to 1/50th of a second, whereas PalmOS is accurate to 1/100th of a second. If higher precision is needed, these platforms cannot be used.

Another issue is the choice of input device. Some palmtops have touchscreens, some have keyboards, and some both. Touchscreens have more flexibility, as they can display soft buttons with arbitrary labels, but participants might not tap them reliably, depending on the sensitivity of the screen and the size and layout of the buttons. Keys on a keyboard are more reliably pressed than soft buttons, but the labels are fixed and participants might need to "hunt and peck" to locate the right key. Some keyboard models are also bulky to carry around.

THE FUTURE

Further technological advances are creating new possibilities for experience-sampling researchers.

Wireless Networking

With the advent of wireless Internet access, experience-sampling studies may leverage this technology to simplify the experimenter's tasks. Instead of collecting data on individual palmtops to be transferred later to a master computer for analysis, the data can be transmitted over a wireless network directly to the master computer. This transmission, which could occur either in batches or immediately as participants respond, avoids the need for participants to return to the lab for data transfers.

A second advantage of wireless access relates to software maintenance. Instead of deploying and maintaining complex software on the palmtops, researchers could install only a lightweight palmtop application that queries a master server (over the wireless network) for instructions. This facilitates software updates because the master server may be modified without recalling the palmtops to the lab. It also permits participants to be randomly assigned to conditions at any time by the server rather than precomputing random assignments prior to an experiment.

These improvements in data collection and software maintenance together contribute to a third advantage, increased interactivity. Compliance can be tracked in a timely manner, and feedback regarding response rate can be delivered to participants as soon as problems are identified (rather than at the end of a week). Under centralized control, the software can adjust its behavior based on participant responses. Actions taken by one participant may be made to affect the software's state, which in turn may change the software's behavior on another participant's palmtop. Participants may also communicate via the palmtops, and tasks begun by one participant may be continued by another.

A fourth advantage is availability of third-party data sources. Numerous vendors provide wireless data and services on the Internet, from stock quotes to language translators, and these could be queried by software during an experiment. It should be mentioned, however, that integration of multiple data sources is a nontrivial issue (e.g., Sheth & Larson, 1990) that would likely involve custom programming.

On the other hand, wireless networking brings some added costs. First, wireless network connectivity can be expensive for large fleets of palmtops, easily $25 per month per palmtop or more. Typical rate plans bill every month whether the palmtop is used or not, so a frugal experimenter might have to discontinue and reinstate network access for each palmtop for each experiment, a maintenance nightmare. Larger projects might consider setting up their own wireless network, but this is a significant undertaking. Second, wireless networking requires added attention to data security and integrity. Although experiments with nonnetworked palmtops may use hotsyncing with a stand-alone master computer, wireless transmissions can be intercepted by a third party or lost due to network glitches. These risks can be mitigated through use of network encryption technologies, such as SSH (Secure Shell) (for an overview, see Barrett & Silverman, 2001) which is available free for both PalmOS and Windows CE. Third, experiments may experience delays due to network congestion or outage. Such delays may be reduced through robust programming practices, for example, use of asynchronous network calls when responses are not needed immediately but cannot be eliminated unless the entire network happens to be under the experimenter's rigid control.

Experiments in the Context of Daily Life

Finally, it should be possible to extend laboratory-based experimental procedures for use in more natural settings outside the lab. For example, computerized experience sampling could determine whether features of the environment prime particular mental representations. In an event-contingent sampling procedure, participants could identify when particular attitude objects are present in their immediate situation, which in turn would launch a program to estimate the automatic activation of evaluative mechanisms (for a description of the automatic evaluation effect, see Bargh, Chaiken, Govender, & Pratto, 1992). As another example, dual-process theories could be tested to determine whether effects observed in the lab (e.g., those reported in Devine, 1989, or in Gilbert & Hixon, 1991) generalize in situ. ESP could be modified to deliver priming or cognitive load manipulations to determine their influence on momentary self-reports. Moreover, theories, goals, or motivations could be activated (via priming procedures delivered by palmtops) to determine how they interact with elements of the immediate situation to produce changes in encoding, immediate experience, or behavior.

CONCLUSION

Experience-sampling procedures hold considerable promise for social and behavioral research. They minimize many problems inherent in standard self-report procedures, and they have particular advantages as a window into daily experience and behavior. Computerized procedures hold considerable promise not only by making experience-sampling methods more accessible and practical to implement but also by leveraging technological advances to develop them into powerful scientific tools.

NOTES

1. Some researchers use Palm Pilot or Psion electronic organizers.
2. Such techniques are not foolproof. They can be overcome if the participant simply performs a hard reset of the palmtop, which cannot be prevented through software.

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