



Published in final edited form as:

J Psychiatr Res. 2009 July ; 43(11): 987–996. doi:10.1016/j.jpsychires.2009.01.014.

Ecological Momentary Assessment in Aging Research: A Critical Review

Ashley E. Cain, B.S.^{1,4}, Colin A. Depp, Ph.D.^{1,4}, and Dilip V. Jeste, M.D.^{1,2,3,4}

¹Department of Psychiatry, University of California, San Diego (UCSD)

²VA San Diego Healthcare System, San Diego

³Sam and Rose Stein Institute for Research on Aging, San Diego

⁴Veterans Medical Research Foundation, San Diego

Abstract

Ecological Momentary Assessment (EMA) gathers respondent data on affective, behavioral, and contextual experiences as close in time to those experiences as possible. Potential advantages of EMA in aging research include reducing memory biases and gathering intra-individual data, yet there is little understanding about implementation. The goal of this critical review was to assess the feasibility and applications of EMA in psychological and behavioral research on aging. Through a comprehensive search of the online electronic databases, Psycinfo and Pubmed, for English-language peer reviewed journals published between 1990 and 2007, we identified 40 articles using EMA methods in older adults. Studies sampled participants between five times per day over one day to once a week for 210 days. Samples were generally not cognitively impaired, evenly split between healthy and clinical populations, and only 6 of 40 studies focused on psychiatric diagnoses. The most common assessment content solicited ratings on affect (n=15), activities of daily living (n=12), physical activities (n=10), and social exchanges (n=8). A total of 90 % of the studies that reported compliance reported rates over 80%. Uses of EMA varied widely, with research goals including validation of global measures, detection of subtle treatment effects, and for testing hypotheses about causal intra-individual relationships. Although these measures appear feasible and useful in aging research, recommendations for future studies include adapting measures to enable data collection among older participants with cognitive impairments and/or psychopathology, along with greater use of electronic data capture to improve compliance and increase ease of implementation.

© 2009 Elsevier Ltd. All rights reserved.

Corresponding Author: Colin A. Depp, Ph.D., Assistant Professor Sam and Rose Stein Institute for Research on Aging Department of Psychiatry University of California, San Diego 9500 Gilman Drive, 0664 La Jolla, CA 92093-0664 Tel: (858) 822-4251 Fax: (858) 534-5475, cdepp@ucsd.edu.

Disclosures of Conflict of Interest: None of the authors have any disclosures of interest to report

Contributors: Ashley Cain conducted the literature review, was involved in the design and writing of this manuscript.

Colin Depp was involved in the design and writing of this manuscript

Dilip Jeste assisted in the design, interpretation of the results, and preparation. All authors contributed to and have approved the final manuscript.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

Ecological Momentary Assessment; diary; research methods; aging; elderly; older adult

Introduction

Ecological momentary assessment (EMA) is defined by Shiffman et al. (2008) as “Monitoring or sampling strategies to assess phenomena at that moment they occur in natural settings, thus maximizing ecological validity while avoiding retrospective recall” (p. 3). Historically, EMA has represented an alternative to global self-report measures, encapsulating diaries, behavioral observation, self-monitoring, time-budget studies, experience sampling method, and ambulatory monitoring (Stone et al., 2007) EMA enables collection of data on the timing, frequency, or relative strength of symptoms, affect, behaviors, activities, and cognitive functions, with the general aim of assessing phenomena as close in time to their occurrence as possible, typically repeatedly over the course of a study (Moskowitz & Young, 2006). Given the dynamic interactions between affective, behavioral, and physical phenomena that are often the subjects of global self-reports used in aging research, as well as the influences of cognitive impairments on self-reports, EMA approaches may be useful for behavioral research in aging. However, while there are a number of excellent review articles on EMA approaches, (Beal & Weiss, 2003; Bolger et al., 2003; Dubbert et al., 2002; Johnson & Bytheway, 2001; McConnell & Copestake, 1999; Moskowitz & Young, 2006; Shiffman et al., 2008), the use of these methods in aging research have not been recently reviewed. Our goal was to evaluate the feasibility and application of EMA in behavioral research in older samples so as to provide recommendations for future research

EMA methods can be classified into three different categories: 1) Diaries, 2) Experience sampling, and 3) Event based sampling (Moskowitz & Young, 2006). These three approaches differ from each other in terms of design, use, and their proximity of timing with events or experiences of interest. Daily diaries are defined as “fixed-interval assessments with an assessment frequency of once per day, employing a retrospective coverage strategy” (Shiffman et al., 2008, p. 17). Experience sampling typically implements some form of signaling device, which randomly signals participants to make reports a fixed number of times per day (Moskowitz & Young, 2006). Another variation is event-based measurement, where self-reports are solicited at the time the variable of interest takes place (e.g., physical activity (Bolger et al., 2003).

Each of these approaches may provide a more comprehensive picture of a person's activities and affect than global measures, revealing everyday events or feelings that may be viewed as trivial and thus easily forgotten (Milligan et al., 2005). Particularly when respondents are asked to describe emotional experiences, global questionnaires often exhibit recall biases in regard to past events. For example, respondents recall events as more negative with increasing time elapsed (Schaie & Carstensen, 2006). As well, recall may be influenced by the respondent's mood at the time of assessment. Experimental research indicates that subjective experiences and their intensity are poorly retained in memory, and are often based on inference strategies or peak moments (Schwarz, 2007). Measures of performance in controlled laboratory settings can limit these recall biases, yet often lack ecological validity (Moskowitz & Young, 2006). However, the participant burden in EMA studies is usually greater than with more global types of assessment, as many of the EMA methods involve a significant time commitment over days, weeks, or months (Moskowitz & Young, 2006). Although these methods should limit retrospective recall biases that might be increased by

memory deficits, prospective memory is required to remain compliant with data entry, and, thus compliance may be a concern among older adults.

We identified only one review of EMA methods in older adults, which was published in 1990 (Ujimoto, 1990). We conducted a critical review evaluating the feasibility and application of EMA methods in behavioral research in older populations, published between 1990 and 2007. Specifically, we synthesized research findings from four main arenas: 1) Sampling and Administration Feasibility: we collected data on the sample characteristics, timing, and duration of data collection; 2) Design: we assessed the frequency of differing study approaches (e.g., event-based) and data input methods (e.g., electronic vs. paper), 3) Compliance: we examined the drop out rate and amount of missing data, and 4) Application: we assessed what kinds of research questions were addressed and the content of the instruments used.

Methods

Article Selection and Search Strategy

We restricted our searches to studies published in English-language peer-reviewed journals between 1990 and 2007, whose samples were limited to adults over age 50. We excluded studies that included any participants younger than age 50 as well as those that solely gathered data on dietary habits, physical symptoms, or sleep. The decision to include papers with participants older than age 50 (rather than a more typical older adult age cut off such as age 60 Hazzard, 2003) was based on the observation that several studies stated an intention study older adults and used 50 as the minimum age requirement. In an effort to include as many studies as possible with older adults, we decided to set our minimum age criterion to age 50. However, we chose not to include papers that used EMA across the lifespan but that examined age effects (e.g. (Carstensen et al., 2000)). Since our focus was on data with relevance to psychiatry, we sought to include studies with EMA-based measures of affect, cognition, behavior, or physical/social activity. We excluded a large number of studies that solely targeted physical symptoms (e.g., pain) or self-monitoring of basic physical functions (e.g., sleep, dietary intake). For papers that were derived from the same sample, we included the earliest published paper, which we found to have the most information on compliance. No restrictions were placed on minimum number of participants. Searches were conducted in Psycinfo and PubMed databases. Specific search terms included “diary”, “experience sampling”, “ecological momentary assessment”, and time use + “elderly and/or aging.” We also identified additional studies via reference lists of relevant papers.

Data Extraction and Synthesis

Title and abstract information was imported into Refworks and evaluated against the specific inclusion and exclusion criteria. Initially, abstracts were screened for exclusionary characteristics, and subsequently full-text articles were obtained. Each article that was excluded was placed into one of seven exclusionary categories: 1) published before 1990. 2) not in English, 3) participants under the age of 50, 4) did not use any form of a diary, 5) food, sleep, and fall diaries, 6) physical symptom diaries, and 7) follow-up studies from the same sample. The final paper selection was resolved in a consensus meeting between AC and CD, during which papers were allocated to inclusion or exclusion (see Figure 1). Among the studies that were selected, we extracted information on the sample characteristics (number, population, and exclusionary criteria), assessment timing, duration of the study, data input method, compliance, and research aims. Mean ages were weighted by sample size.

Results

Studies Selected

After removing duplicate references found in both databases, a total of 520 unique studies were identified through keyword searches on Psycinfo and Pubmed. After reviewing abstracts and subsequently full-text articles and their reference sections, 40 articles were selected for this review (See Figure 1 for a detailed flowchart describing the outcomes of the selection process).

Sample Characteristics

The mean number of participants was 237.1 (sd = 649.3, range = 10-3950; median = 77.5) (Table 1). The mean sample size is skewed by 2 studies with samples in the thousands (Mollenkopf et al., 1997; Mollenkopf et al., 2004). Excluding these two studies, the mean sample size was 108.6 (sd = 135.6, range = 10-669). The mean sample-weighted age of participants was 72.7 years (sd = 5.2). For those papers that reported the age range, the participants' ages ranged from 50 to 97 years. Of the 40 studies, 23 included healthy community-dwelling volunteers as their participants. The remaining 17 studies sampled from a variety of clinical populations, with no single clinical population appearing more than twice. Only 6 of the 40 studies targeted samples psychiatric diagnoses or symptoms. These populations included spousally bereaved participants (Brown et al., 1996; Ong et al., 2004), clinically depressed (Chepenik et al., 2006; Kleban et al., 1992), and participants with Parkinson's disease (Richard et al., 2001; Weintraub et al., 2006).

Common exclusionary criteria in these reports were: 1) Significant cognitive impairment detected via a cognitive ability screening test (commonly the Mini-Mental State Examination or MMSE, using a cut-off score of 24 (Folstein et al., 1975); 2) Non-English speaking, 3) Current depressive symptoms and/or history of psychiatric disorders or various other chronic medical conditions (e.g. central nervous system disease, active liver or kidney disease, and insulin dependent diabetes).

Data Capture Method

A majority of the papers used paper-based diary methods (n=34), followed by papers with an electronic signaling device (n=5), and electronic data capture alone (n=1). Most of the reports that used electronic signaling devices employed some form of a beeper or paging device to signal when participants were to make entries in paper diaries.

Two investigations coupled diary data with physiological recordings. Shapiro and Goldstein (1998) used a wrist actigraph to monitor physical activity, and an ambulatory blood pressure monitor to measure blood pressure and heart rate over a 24-hour period. In addition, participants were asked about what physical activities they were engaging in, and every time the ambulatory recorder was activated, participants were instructed to make a diary entry (Shapiro & Goldstein, 1998). Ong & Allaire (2005) monitored affect and blood pressure in daily workbooks, completed twice a day over a 60-day period.

Data Capture Schedules

The most common designs were fixed-schedule designs (n=30), followed by experience sampling (n=6) and event-based designs (n=4). Fixed-schedule designs asked participants to make diary entries at predetermined and consistent intervals. Experience sampling methods (Bolger et al., 2003) randomly sampled participants at varying times of the day. Usually there were a fixed number of diary entries, but the timing was spread out randomly throughout the day, and varied from day to day. Only four studies (Dubbert et al., 2002; Johnson & Bytheway, 2001; McConnell & Copestake, 1999; Safford & Baumel, 1994) used

a purely event-based design. Dubbert et al. (2002) asked the participants to make diary entries only when they walked for a period of at least ten minutes. Therefore, the number of diary entries per participant varied greatly, depending on each individual's walking adherence.

Timing & Duration

Some studies (n=16) asked participants to give responses based on their current state. Others (n=20) asked participants to provide a retrospective report of their state or daily activities, generally during the previous day or week. Four of the studies asked for both immediate and retrospective reports.

The duration of a study ranged from one day to 365 days, with the median being two weeks. Typically, the shorter the duration of the study, the more frequent the diary entries. For example, in their two-day investigation, Shapiro et al. (1998) prompted participants three times per hour during waking hours and once an hour during sleep. The study with the longest duration (Dubbert et al., 2002) asked participants to make weekly diary entries for one year.

Research Questions & Types of Assessments

Some reports incorporated established measures and scales to assess affect, daily activities, physical activities, and social exchanges. For example, Chepenik et al. (2006), in an investigation of late-life depression, asked participants to fill out the Lawton Positive and Negative Affect Rating Scales at the end of each day for two weeks. In contrast, Jacelon and Imperio (2005) seeking to evaluate the different strategies used by people with chronic health problems to maintain their health, dignity, and autonomy employed a more qualitative approach. These investigators presented their subjects with a series of open-ended questions that had been specifically developed for their research.

The most common assessment content solicited ratings on affect (n =15), activities daily living (ADL's) (n = 12), physical activities (n=10), and social exchanges (n = 8). Other studies evaluated general symptoms (e.g., pain), task demand/difficulty, walking, and blood pressure. Many investigators examined within-person variability in certain psychological variables (mood, affect, worry, stress, etc.) and daily activities. For example, Milligan et al. (2005) assessed the links between positive and negative social exchanges and later emotional well-being. Other studies used the diary entries to monitor changing emotional and/or psychological factors over the course of a treatment intervention. Diaries were also used for direct comparisons between pre-specified cohorts over time, as in Skarborn and Nicki (2000). This study sought to compare worry in pre-versus post-retirement individuals over a period of three days.

Rarely, investigators utilized multiple approaches. Thus, Klumb and Baltes (1999) studied the validity of retrospective time-use reports (using the Yesterday Interview) and compared it to the alternate Experience Sampling Method. In terms of timing and duration of episodes, contexts, type of activity and mood ratings, divergent and convergent correlations indicated high levels of agreement between the two approaches.

Compliance

There was wide variability among indicators of compliance and 13 of the studies did not report a measure of compliance. Many studies reported subject attrition, while others reported compliance in the form of missing data or diary entries per participant. Some studies completely excluded participants who did not fully complete all diary entries (Furlan et al., 2004) or less than the minimum number of required diary entries (Ong et al., 2004).

Moreover, compliance in event-based study is challenging because there is no set number of diary entries that participants were required to make.

Nevertheless, reported compliance rates appeared to be high, with only four of the 27 studies reporting overall compliance rates lower than 80%. The studies with low compliance rate included one (Johnson & Bytheway, 2001) that required participants to record every time they performed certain activities, whereas another one (Kamarck et al., 2002) required participants to make entries every 45 minutes. These factors might have contributed to the decreased compliance rate. The studies that sampled from clinical (or psychiatric) populations did not appear to be associated with lower compliance than that reported among healthy participants.

Hnatiuk (1991) investigated the acceptability of the experience sampling method in older adults, collecting data on activities, thoughts, and mood over a one-week period. These researchers reported that 79 % of the participants responded either positively or neutrally to the experience. The attrition rate was 25%, and the primary reason for dropping out was attributed to participants not fully understanding what they were supposed to do. Participants who failed to complete the tasks were older and less educated than the completers.

Study Rationale

We identified three categories of rationales for use of EMA within clinical and non-clinical populations: 1) Comparison with global measures (n = 7), 2) As an outcome measure in treatment studies (n = 9), and 3) Hypothesis testing (n = 23).

1) For Comparison with Global Measures—EMA was used in studies to determine whether a global measure provided an accurate portrayal of the frequency of a behavior, such as engagement in physical activity. Alternatively, the validity of the diary itself was assessed in relation to daily living tasks such as taking medications. In an attempt to validate the LASA (Longitudinal Aging Study Amsterdam) physical activity questionnaire, Stel et al. (2004) used a seven-day diary and pedometer. The investigators found a high correlation between the LASA and the diary. Other clinical studies (Jacelon & Imperio, 2005; Johnson & Bytheway, 2001) sought to validate the use of various forms of diaries for use in research with older adults and medication use by identifying contrasts between global self-report and diary based data. Together, EMA can be used as a ‘gold standard’, as in the case of the LASA study, or as a technique to identify discrepancies in participant reporting of everyday phenomena.

2) As an Outcome Measure in Treatment Studies—Several reports included EMA in clinical trials of pharmacotherapy or behavioral interventions. Furlan et al. (2004) examined the impact of SSRIs on daily affect in a sample of healthy older adult volunteers. Participants were asked to record their mood and activities each night. Although affective “blunting” was not identified in relationship to SSRI use, a decrease in negative affect in relationship to negative events was seen compared to placebo. Morales et al. (2006) conducted a randomized clinical trial with elderly volunteers to examine whether the use of simvastatin was related to change in affect. Daily diaries were used to evaluate within-subject changes in affect from day-to-day. The repeated measures over 105 days also served to improve the statistical power for detecting the drug effect of simvastatin. Subtle affective changes were seen in regard to positive affect, as well as interaction between treatment, affect, and life events. In both of these studies, subtle variations in affect not identified by traditional symptom measures were identified, particularly in regard to interactions between affective fluctuation and contextual events. Moreover, increasing the number of assessments over time increased the power to detect these variations.

3) For Hypothesis Testing of Casual Models—A number of studies used EMA for assessing multivariate hypotheses capitalizing on temporally rich data to develop or assess causal models. For example, Ong and Allaire (2005) examined intra-individual association between daily affect and blood pressure variation in relationship to the subject's social connectedness. Similarly, Chepenik et al. (2006) used daily diaries to identify substantial day-to-day variability in negative affect among those with depression, and concluded that the daily diary data revealed a greater degree of intra-individual variability in affect than would be identified with traditional clinical ratings. These same relationships might have been identified in laboratory studies, yet their identification in community-based settings lends evidence for ecological validity.

Discussion

Our systematic literature review identified a total of 40 studies using EMA methods in older adults since 1990. There was a wide variety of uses for these methods, and a considerable range in methods of implementation, although. Use of these methods among older samples with psychiatric disabilities was limited to six studies. Most studies employed fixed schedule reporting, which was related to the low use of electronic methods of data collection. Compliance with these methods was inconsistently reported; nevertheless, for the 27 studies that did report compliance, 23 had rates that exceeded 80%. The specific utilities of EMA approaches over traditional measures in aging research were in validating global measures, assessing hypotheses about intra-individual variability, and discovering subtle treatment effects. As we discuss below, enhancements to the functionality of these measures may increase their breadth of application and ease of use in aging research.

There are several limitations to our review. We attempted to conduct an exhaustive literature search, but it is possible that we may have omitted studies. The diverse nature of these articles limited our ability to conduct a quantitative review. In particular, we were not able to estimate a mean level of compliance with EMA methods, as the kinds of compliance reported were inconsistent across studies. Therefore, the lack of consistency in compliance reporting limits the ability to define the demographic and clinical characteristics of those older adults who would not be good candidates for EMA studies.

Nevertheless, with the 1990 review by Ujimoto (1990) as a frame of reference, there has been a broad range of samples and uses of EMA methods in aging research over the past two decades. About half of the samples were from non-clinical populations, whereas the other half involved a variety of clinical samples. There was also great diversity in the manner in which EMA methods were implemented, with studies lasting for several days or up to a year. The modal study obtained a modest sized sample of non-cognitively impaired older adults, and followed them for about two weeks, most commonly asking questions about physical and daily living activities along with mood. In regard to broad measures of compliance, there was no observable trend in regard to differences in study structure or compliance between clinical and non-clinical population, and measures of compliance were generally reported as indicating high levels of compliance and participant retention (~80 % across studies). In previous reviews assessing EM A in younger populations, mostly with electronic data collection, similarly high levels of compliance were observed (Burton et, 2007). Therefore, our review suggests EMA is generally feasible in older adults.

Our review also identified several areas where EMA utilization may be enhanced. Although clinical populations were sampled (e.g., older people with depression or Parkinson's disease), one common trend in regard to in the inclusion/exclusion criteria was the exclusion of participants with cognitive deficits (e.g., exclusion of participants with scores less than 24 on the Mini-Mental State Examination (MMSE; Folstein et al., 1975). One approach to enhancing compliance in cognitively impaired people could be a combination of daily diary

and experience sampling methods. Paging participants to remind them to make diary entries can minimize forgetfulness and other recall issues. Experience sampling methods can reduce the strain on prospective memory to complete daily diaries and thus may limit the time needed to complete diaries. Other possible adaptations include simplified diary entries and rating scales or the option of dictating responses to a caregiver.

Another potential improvement is the adaptation of electronic data capture methods for older adults. Despite the availability of electronic diaries, is the great majority of studies included paper diaries, with all but six studies using this method. Use of electronic data capture would allow researchers to expand beyond fixed schedule formats, as electronic devices are generally necessary to solicit responses at unpredictable intervals. In addition, entries are date- and time- stamped, which can eliminate the problem of entries completed after the stated time. Stone et al. (2002) attached photosensors to paper diary binders to record when the binder was open and closed. The authors measured actual compliance (diary entries tracked by photosensors or electronic diaries) and reported compliance (diary entries reported by participants) separately. The investigators found that electronic diaries resulted in a 94% actual compliance rate, as opposed to only an 11% actual compliance rate for the paper diaries.

The limited use of electronic methods likely stems from the general concern that elderly subjects may be unfamiliar, unable or unwilling to use such devices (Namazi citation); however, one study suggested that older subjects were no more likely than younger adults to prefer paper diaries over electronic. (Shiffman et al., 2008). The one study in our review that did use electronic forms reported that the measure was well accepted by participants (Kamarck et al., 2002). Specific adaptations of electronic methods for older adults may include interfaces or instructions that take into account sensory or motor deficits among older people (e.g., touch screens, larger font or clearly labeled push buttons)

Finally, the content assessed in these studies was typically restricted to daily activities or emotional ratings. Psychological variables (e.g., perceived control) were rarely incorporated but could be utilized (Kamarck et al., 2002). Many of the assessments did not use established or validated measures, and the psychometric characteristics of these 'homemade' scales should be reported. The potential for coupling EMA methods with other continuous monitoring domains, such as physiological recordings, seems to be a particularly promising avenue of research. Two studies we reviewed displayed the potential for combining actigraphy and/or blood pressure data with affective fluctuation (Ong & Allaire, 2005; Shapiro & Goldstein, 1998). Again, the addition of electronic means of inputting behavioral/ affective responses could be coupled with these health monitoring devices.

In conclusion, our review identified an array of samples, implementation strategies, and purposes for incorporating EMA into aging research. A great majority of studies that reported compliance had rates greater than 80%. These studies displayed some advantages over data obtained with traditional global self-report measures, including the detection of subtle fluctuating effects of treatments or modeling intra-individual variability on cognitive, emotional, and physiological measures. However, use of these methods in psychiatric research, as well as adaptations of EMA for use in cognitively impaired populations was limited. Greater utilization of available technology with electronic data capture methods may increase ease of implementation and concurrent physiological measures could provide compelling new data. With adaptations made for aging people, EMA approaches may enhance researcher capacity to shed new light on aging and mental health.

Acknowledgments

This work was supported, in part, by National Institute of Mental Health grants K23MH077225 and P30MH066248, by the Sam and Rose Stein Institute for Research on Aging, and by the Department of Veterans Affairs.

Role of the Funding Sources: This work was supported, in part, by the National Institute of Mental Health grants K23MH077225 and P30MH066248, by the Sam and Rose Stein Institute for Research on Aging, and by the Department of Veterans Affairs. These funding sources had had no further role in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

References

- Beal DJ, Weiss HM. Methods of Ecological Momentary Assessment in Organizational Research. *Organizational Research Methods*. 2003; 6:440–464.
- Bolger N, Davis A, Rafaeli E. Diary methods: capturing life as it is lived. *Annual Review of Psychology*. 2003; 54:579.
- Brown LF, Reynolds CF, Monk TH, Prigerson HG. Social rhythm stability following late-life spousal bereavement: Associations with depression and sleep impairment. *Psychiatry research*. 1996; 62:161. [PubMed: 8771613]
- Burton C, Weller D, Sharpe M. Are electronic diaries useful for symptoms research? A systematic review. *Journal of psychosomatic research*. 2007; 62:553. [PubMed: 17467410]
- Carstensen LL, Pasupathi M, Mayr U, Nesselroade JR. Emotional experience in everyday life across the adult life span. *Journal of Personality and Social Psychology*. 2000; 79:644–655. [PubMed: 11045744]
- Chepenik LG, Have TT, Oslin D, Datto C, Zubritsky C, Katz IR. A Daily Diary Study of Late-Life Depression. *American Journal of Geriatric Psychiatry*. 2006; 14:270. [PubMed: 16505132]
- Dubbert PM, Cooper KM, Kirchner KA, Meydrecht EF, Bilbrew D. Effects of nurse counseling on walking for exercise in elderly primary care patients. *Journals of Gerontology: Series A: Biological Sciences and Medical Sciences*. 2002; 57:M733.
- Folstein M, Folstein S, McHugh P. “Mini-Mental/state”: a practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*. 1975; 12:189–98. [PubMed: 1202204]
- Furlan PM, Kallan MJ, Have TT, Lucki I, Katz I. SSRIs do not cause affective blunting in healthy elderly volunteers. *The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry*. 2004; 12:323. [PubMed: 15126234]
- Principles of geriatric medicine and gerontology. New York: McGraw-Hill Professional; 2003.
- Hnatiuk SH. Experience sampling with elderly persons: an exploration of the method. *International journal of aging & human development*. 1991; 33:45. [PubMed: 1917118]
- Jacelon CS, Imperio K. Participant Diaries as a Source of Data in Research With Older Adults. *Qualitative health research*. 2005; 15:991. [PubMed: 16093375]
- Johnson J, Bytheway B. An evaluation of the use of diaries in a study of medication in later life. *International Journal of Social Research Methodology*. 2001; 4:183–204.
- Kamarck TW, Janicki DL, Shiffman S, Polk DE, Muldoon MF, Liebenauer LL, Schwartz JE. Psychosocial demands and ambulatory blood pressure: a field assessment approach. *Physiology & Behavior*. 2002; 77:699. [PubMed: 12527022]
- Kleban MH, Lawton MP, Nesselroade JR, Parmelee P. The Structure of Variation in Affect Among Depressed and Nondepressed Elders. *Journal of Gerontology: Psychological Sciences*. 1992; 47:190–198.
- Klumb PL, Baltes MM. Validity of Retrospective Time-Use Reports in Old Age. *Applied Cognitive Psychology*. 1999:527–539.
- McConnell AK, Copestake AJ. Maximum static respiratory pressures in healthy elderly men and women: issues of reproducibility and interpretation. *Respiration; international review of thoracic diseases*. 1999; 66:251.

- Milligan C, Bingley A, Gatrell A. Digging deep: Using diary techniques to explore the place of health and well-being amongst older people. *Social science & medicine*. 2005; 61:1882. [PubMed: 15913863]
- Mollenkopf H, Marcellini F, Ruoppila I, Flaschenträger P. Outdoor mobility and social relationships of elderly people. *Archives of Gerontology and Geriatrics*. 1997; 24:295. [PubMed: 15374117]
- Mollenkopf H, Marcellini F, Ruoppila I, Szeman Z, Tacken M, Wahl HW. Social and behavioural science perspectives on out-of-home mobility in later life: Findings from the European project MOBILATE. *European Journal of Ageing*. 2004; 1:45.
- Morales K, Wittink M, Datto C, DiFilippo S, Cary M, TenHave T, Katz IR. Simvastatin causes changes in affective processes in elderly volunteers. *Journal of the American Geriatrics Society*. 2006; 54:70. [PubMed: 16420200]
- Moskowitz DS, Young SN. Ecological momentary assessment: what it is and why it is a method of the future in clinical psychopharmacology. *Journal of psychiatry & neuroscience: JPN*. 2006; 31:13.
- Namazi K, McClintic M. Computer use among elderly person in long-term care facilities. *Educational Gerontology*. 2003; 29:535–550.
- Ong AD, Allaire JC. Cardiovascular intraindividual variability in later life: the influence of social connectedness and positive emotions. *Psychology and aging*. 2005; 20:476. [PubMed: 16248706]
- Ong AD, Bergeman CS, Bisconti TL. The Role of Daily Positive Emotions During Bereavement. *Journal of Gerontology: Psychological Sciences*. 2004; 59B:168–176.
- Richard IH, Justus AW, Kurlan R. Relationship Between Mood and Motor Fluctuations in Parkinson's Disease. *Journal of Neuropsychiatry Clinical Neuroscience*. 2001; 13:35–41.
- Safford F, Baumeister B. Testing the effects of dietary lecithin on memory in the elderly: An example of social work/medical research collaboration. *Research on Social Work Practice*. 1994; 4:349.
- Schaie, K.; Carstensen, L. Social Structures, Aging and Self Regulation in the Elderly. Can Self-Regulation Explain Age Differences in Daily, Weekly, and Monthly Reports of Psychological Distress?. Almeida, D.; Mroczek, D.; Neiss, M., editors. Springer Publishing Company, Inc; 2006.
- Schwarz, N. Retrospective and Concurrent Self-Reports: The Rationale for Real-Time Data Capture. In: Stone, A.; Shiffman, SS.; Atienza, A.; Nebeling, L., editors. *The science of real-time data capture: Self-reports in health research*. New York: Oxford University Press; 2007.
- Shapiro D, Goldstein I. Wrist actigraph measures of physical activity level and ambulatory blood pressure in healthy elderly persons. *Psychophysiology*. 1998; 35:305. [PubMed: 9564750]
- Shiffman S, Stone A, Hufford MR. Ecological Momentary Assessment. *Annual Review of Clinical Psychology*. 2008; 4:1–32.
- Skarborn M, Nicki R. Worry in pre- and post-retirement persons. *International journal of aging & human development*. 2000; 50:61. [PubMed: 10735182]
- Stel VS, Smit JH, Pluijm SM, Visser M, Deeg DJ, Lips P. Comparison of the LASA Physical Activity Questionnaire with a 7-day diary and pedometer. *Journal of clinical epidemiology*. 2004; 57:252. [PubMed: 15066685]
- Stone AA, Schwartz JE, Broderick JE, Hufford MR. Patient non-compliance with paper diaries. *BMJ*. 2002; 324:1193–1194. [PubMed: 12016186]
- Stone, A.; Shiffman, S.; Atienza, A.; Nebeling, L. Historical Roots and Rationale of Ecological Momentary Assessment (EMA). In: Stone, A.; Shiffman, S.; Atienza, A.; Nebeling, L., editors. *The Science of Real-Time Data Capture*. New York: Oxford University Press; 2007. p. 3-10.
- Ujjimoto KV. Time-budget methodology for research on aging. *Social Indicators Research*. 1990; 23:381–393.
- Weintraub D, Cary MS, Stern MB, Taraborelli D, Katz IR. Daily Affect in Parkinson Disease Is Responsive to Life Events and Motor Symptoms. *American Journal of Geriatric Psychiatry*. 2006; 14:161–168. [PubMed: 16473981]

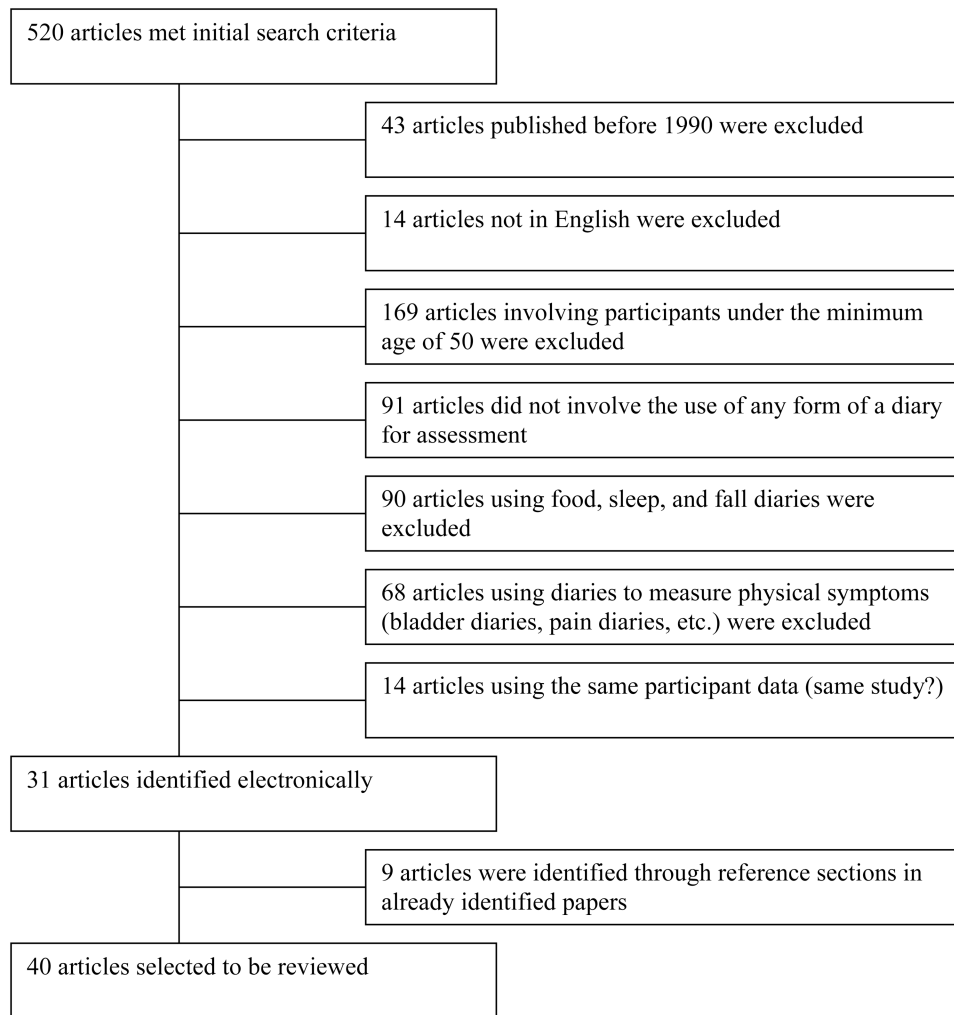


Figure 1. Flowchart showing the detailed search strategy used

Table 1

Ecological Momentary Assessment Studies in Older Adults

Author/year	N	Sample Populations	MeanAge/AgeRange	Timing	# of Days	Format	Compliance	Research Questions						
								Daily Activities	Physical Activities	Affect	Social Exchange	Other		
Instrument Validation Studies: Non-clinical Populations														
(Carmel & Moon, 1992)	34	Older community-dwelling adult volunteers	R = 59-83	Daily	4 days	p [*]	Not reported	X						
(Reuben, Wong, Walsh, & Hays, 1995)	24	Older community-dwelling adult volunteers	M = 75.4	Weekly	84 days	p [*]	97 % of possible entries							X
(Pols, Peeters, Kemper, & Collette, 1996)	33	Elderly women volunteers	R = 51-71	Daily	12 days	p [*]	Not reported		X					
(Klumb & Baltes, 1999)	83	Healthy volunteers	M = 80 R = 72-97	5 times per day	1 day	pe ^{**}	Not reported	X			X			X
(Stel et al., 2004)	439	Community-based population of older men and women	R = 69-92	Daily	7 days	p [*]	91 % possible entries		X					
Instrument Validation Studies: Clinical Populations														
(Johnson & Bytheway, 2001)	77	Older adults currently maintaining a consistent medication regimen	Not reported	Throughout the day	14 days	p ^{***}	73 % complete diaries	X						X
(Jacion & Imperio, 2005)	10	Community-dwelling older adults living with chronic health problems	Not reported	Daily	14 days	p [*]	Not reported	X						X
Hypothesis Testing: Non-clinical Populations														
(Baltes, Wahl, & Schmid-Furstoss, 1990)	60	Mobile and independently living elderly people	M = 72.7	Daily	168 days	p [*]	81.6 % completed the study	X			X			X
(Stoller, 1993)	669	Older community-dwelling adult volunteers	M = 74.1	Daily	21 days	p [*]	94 % of possible entries							X
(Visser, van der Horst, de Groot, Deurenberg, & van Staveren, 1995)	12	Older community-dwelling adult volunteers in good health	R = 69-82	Daily	2 days	p [*]	Not reported		X					
(H. Mollenkopf et al., 1997)	1400	Community dwelling volunteers	Not reported	Daily	3 days	p [*]	Not reported		X		X			
(Shapiro & Goldstein, 1998)	119	Older community-dwelling adult volunteers in good health	M = 67 R = 55-79	3 times per hour (waking hours) 1 times per hour (sleep hours)	2 days	pe ^{**}	87.4 % had complete data		X		X			X
(Musil et al., 1998)	64	Older community-dwelling adult volunteers	M = 75.5	Daily	28 days	p [*]	94 % completed the study							X
(McConnell & Copestake, 1999)	10	Older community-dwelling adult volunteers	R = 59-84	Throughout the day	28 days	p ^{***}	Not reported				X			
(Fricke & Unsworth, 2001)	33	Older community-dwelling adult volunteers	M = 78.4 R = 66-95	Throughout the Day	1 day	p [*]	Not reported	X						
(Klumb, 2001)	83	Healthy community dwelling volunteers	M = 80 R = 73-97	5 times per day	6 days	pe ^{**}	87 % average entries completed	X				X		X
(Kumarek et al., 2002)	464	Healthy older adults	R = 50-70	Every 45-minutes	6 days	p ^e	73 % completed both sessions and at least 30 entries				X		X	X

Author/year	N	Sample Populations	Mean/Age/AgeRange	Timing	# of Days	Format	Compliance	Research Questions					
								Daily Activities	Physical Activities	Affect	Social Exchange	Other	
(Bouisson & Swendsen, 2003)	47	Convenience sample from the community	M = 80.89	4 times per day	4 days	see footnote p ^{**}	80 % of possible entries		X				
(Heidrun Mollenkopf et al., 2004)	3950	Healthy volunteers	R = 55-74	Daily	2 days	p [*]	55%	X					
(Milligan, Bingley, & Garell, 2005)	79	Healthy volunteers	R = 65-91	Weekly	210 days	p [*]	87 % SSS data used; 81% possible entries	X					X
(Ong & Allaire, 2005)	33	Healthy normotensive men and women	M = 74 R = 60-87	Twice a day	60 days	p [*]	97 % days of complete data		X	X			X
(Neupert, Almeida, Mroczek, & Spiro, 2006)	374	Taken from VA Normative study	M = 73.27	Daily	8 days	p [*]	99 % completed the study						X
Hypothesis Testing: Clinical Populations													
(Hnatuk, 1991)	50	Elderly widows	M = 76 R = 69-94	5 times per day	7 days	pe ^{**}	** Unclear	X		X	X		X
(Kiehan, Lawton, Nesselroade, & Parmelee, 1992)	78	Depressed and non-depressed older residents of a long-term care facility	M = 82.8	Daily (workdays)	42 days (30 entries)	p [*]	Approximately 80 % completed the study		X				
(Brown et al., 1996)	139	Spousally bereaved elderly	R = 55-85	Daily	14 days	p [*]	Not reported	X				X	
(Skarhorn & Nicki, 2000)	96	Elderly persons who were retired and older persons who were not retired	M = 61 R = 50-78	Daily	3 days	p [*]	Not reported						X
(Richard, Justus, & Kurlan, 2001)	18	Patients with Parkinson's disease and motor fluctuations	M = 62	1 time per hour	7 days	p [*]	89 % of SSSs completed study		X				X
(Ong, Bergeman, & Bisconti, 2004)	39	Recently bereaved older adult widows	M = 71.94 R = 61-83	Daily	198 days	p [*]	87.2 % had useable diary data		X				X
(Chepenik et al., 2006)	128	Primary care patients with major depression and other depressive disorders	M = 72.65	Daily	14 days	p [*]	Not reported	X					X
(Weintraub, Cory, Stern, Taraborelli, & Katz, 2006)	47	Non-depressed males with Parkinson's disease	M = 72.46	Daily	28 days	p [*]	All SSSs completed 25 days within 31 days						X
Treatment Studies: Non-clinical Populations													
(Safford & Baumel, 1994)	89	Healthy older adults	R = 50-80	Throughout the Day	14 days	p ^{***}	89 % completed the study						X
(Leaf & Reuben, 1996)	20	Community dwelling sedentary volunteers	Not Reported	Daily	112 days	p [*]	95 % completed the study		X				
(Furlan, Kallan, Have, Lucki, & Katz, 2004)	54	Community-dwelling healthy older adult volunteers	M = 72.14 R = 65-84	Daily	28 days	p [*]	90.7% completed entire study	X					X
(Katz et al., 2005)	105	Healthy volunteers	M = 70.9	Daily	35 days	p [*]	95.1 % completion rate; 85 % had complete data on 90% of the days					X	
Treatment Studies: Clinical Populations													
(Dabbert, Cooper, Kirchner, Meyruech, & Bilbrew, 2002)	212	Primary Care Patients	M = 68.7 R = 60-80	Throughout the day	365 days	p ^{***}	85.4% completed the study			X			
(Focht, Ewing, Gauvin, & Rejeski, 2002)	32	Older, overweight, or obese adults with knee osteoarthritis (OA)	M = 69.1	6 times per day	6 days	pe ^{**}	91.2% of possible entries						X

Author/year	N	Sample Populations	Mean/Age/AgeRange	Timing	# of Days	Format	Compliance	Research Questions					
								Daily Activities	Physical Activities	Affect	Social Exchange	Other	
(Morales et al., 2006)	80	Older volunteers with high normal/mildly elevated serum cholesterol	M = 70	Daily	105 days	see footnote p [*]	80% completed whole study				X		
(Basler, Bertalanffy, Quint, Wilke, & Wolf, 2007)	170	Older adults with chronic low back pain	M = 70.3 R = 65-84	At each assessment	3 assessments	see footnote p [*]	89% completed the study	X					

p = paper diary

pe = paper + some form of electronic data capture

e= electronic

* = fixed-schedule

** = experience sampling

*** = event based

Table 2
Study Rationale and Major Findings

Instrument Validation Studies		
Non-clinical populations		
(Cartmel & Moon, 1992)		Validation of two physical activity measures with a diary measure. Strenuous activity was over-reported, and mild/moderate activity underreported.
(Reuben, Wong, Walsh, & Hays, 1995)		High rate of return using postcard diary system. Validity of postcards in corresponding to actual health care utilization was high.
(Pols, Peeters, Kemper, & Collette, 1996)		Validation of two physical activity questionnaires with diary measure as gold standard.
(Klumb & Baltes, 1999)		Compared ESM and “yesterday interview” approaches and found considerable agreement. Self-care activities were better suited for frequencies, and other activities better captured by duration.
(Stel et al., 2004)		The LAPAQ, a physical activity questionnaire, showed acceptable correspondence with a 7-day diary measure of activity, supporting its validity
Clinical populations		
(Johnson & Bytheway, 2001)	Older adults consistently maintaining a medication regime	Diaries difficult for some pts, producing sampling biases. Attenuation of diary entry detail over the course of study.
(Jacelon & Imperio, 2005)	Community dwelling older adults living with chronic health problems	Diaries designed to collect qualitative data on daily health activities, and respondents could choose audio taped, telephone, or written diaries.
Hypothesis Testing		
Non-clinical populations		
(Baltes, Wahl, & Schmid-Furstoss, 1990)		Older adults time use most characterized by obligatory activities, performed in the mornings, and afternoons and evenings were mostly spent with leisure activities. Activity profiles identified which related to significant differences in functional health and personal control.
(Stoller, 1993)		Larger number of symptoms reported in a diary measure related to more negative interpretation of symptoms, and the majority of the sample reported interference with desired activities.
(Visser, van der Horst, de Groot, Deurenberg, & van Staveren, 1995)		Physical activity monitored in experimental respiration chamber – greater activity did not correspond to greater energy cost.
(H. Mollenkopf et al., 1997)		Social network density predicted greater mobility outside of the house, and those living at home and with no kids were at risk for low frequency of outdoor mobility.
(Shapiro & Goldstein, 1998)		Participants described their activities/social context at random intervals corresponding with blood pressure data collection. BP higher among strangers than family, controlling for activity level.
(Musil et al., 1998)		Total of 61% of a larger sample agreed to participate. Analysis of health problems reported indicated that most problems were not illnesses.
(McConnell & Copestake, 1999)		Physical activities tracked through diaries correlated with respiratory muscle strength, controlling age and physical characteristics.
(Fricke & Unsworth, 2001)		Older community dwelling sample spent most of time at home and alone, and tasks rated most important were IADLs.
(Klumb, 2001)		Intra-individual variability in engagement in everyday activities predicted by self-efficacy, and productive activities perceived as more difficult.

Instrument Validation Studies

Non-clinical populations

(Kamarck et al., 2002)		Within-subjects variability in negative affect, social conflict, and decisional control were associated with cardiovascular activation.
(Bouisson & Swendsen, 2003)		Time-lag analyses indicate greater routine corresponded with decreasing positive affect and increased negative affect, in contrast to previous study.
(Heidrun Mollenkopf et al., 2004)		Environmental/structural conditions predict mobility out of house in a large sample of European seniors.
(Milligan, Bingley, & Gatrell, 2005)		Diaries included mixed-methods approach to assess health status and health-related activities. No gender effects in participation or quantify of information obtained.
(Ong & Allaire, 2005)		Moderational impact of positive emotion on the link between negative emotion and subsequent cardiovascular activation. Social connectedness a major contributor to positive emotion.
(Neupert, Almeida, Mroczek, & Spiro, 2006)		Extension of laboratory-based assessment of stressors and memory to naturalistic setting. Days with stressful events corresponded to occurrence of memory failures.

Clinical populations

(Hnatiuk, 1991)	Elderly widows	The daily lives of a sample of elderly widows measured using experience sampling method were found to be a valid and reliable method.
(Brown et al., 1996)	Spousally bereaved elderly,	Low social rhythm stability and activity level not present in bereaved generally, except among those experiencing a major depressive episode.
(Skarborn & Nicki, 2000)	Elderly persons who were retired and older persons who were not retired	Used worry diary to validate global self-report worry scale. With longitudinal follow up., post-retirement, older people worry less than pre retirement.
(Richard, Justus, & Kurlan, 2001)	Patients with Parkinson's disease and motor fluctuations	No consistent relationship between mood and motor fluctuation, in contrast to prior studies using alternate methodology
(Ong, Bergeman, & Bisconti, 2004)	Recently bereaved older adult widows	Daily positive emotions after bereavement reduced the relationship between stress and depression.
(Chepenik et al., 2006)	Primary care patients with major depression and other depressive disorders	Greater intra-individual variability in dysphoria in major depression than expected and attenuated impact of positive events on positive affect in depressed but not comparison subjects.
(Weintraub, Cary, Stern, Taraborelli, & Katz, 2006)	Non-depressed males with Parkinson's Disease	Lower baseline positive affect in PD, decreasing positive, and an adverse impact of PD symptoms on positive and negative affect. However, patients with PD do not demonstrate anhedonia in response to positive life events.
(Kleban, Lawton, Nesselroade, & Parmelee, 1992)	Depressed and non-depressed old adults in a long-term care facility	Total absence of negative affect was more common than continuous presence of negative affect, total absence of positive affect, or continuous presence of positive affect among residents in a long term care facility.

Treatment Studies

Non-clinical populations

(Safford & Baumel, 1994)		Diary of memory lapses assessed pre and post-intervention, checklist of memory lapses developed through preliminary study.
(Leaf & Reuben, 1996)		Daily walking activity used as outcome measure to assess adherence to lifestyle intervention; 95% of subjects were adherent.
(Furlan, Kallan, Have, Lucki, & Katz, 2004)		Healthy elderly volunteers did not demonstrate affective blunting or intra-individual variability in affect associated with SSRIs

Instrument Validation Studies

Non-clinical populations

(Katz et al., 2005)	Compared diaries to telephone assessments and found consistency. Metoclopramide and Naproxen differed in their impact on the relationship between events and affect
---------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------

Clinical Populations

(Dubbert, Cooper, Kirchner, Meydrech, & Bilbrew, 2002)	Primary care patients	Adherence to walking program assess with diaries. Compliance with diaries was inconsistent due to subject burden.
(Focht, Ewing, Gauvin, & Rejeski, 2002)	Older, overweight, or obese adults with knee osteoarthritis (OA)	Diurnal variation in pain characterized as gradually increased throughout the day, peaking in the afternoon and thereafter decreasing. Acute exercise resulted in an increase in pain when compared with reports occurring at a similar time of the day on a non-exercise day and with reports with equivalent medication use and stress.
(Andersson, Porsaeus, Wiklund, Kaldo, & Larsen, 2005)	Elderly people with tinnitus	Diaries administered pre- and post-treatment to assess effect of behavioral intervention. Diaries showed more change than global measure
(Morales et al., 2006)	Older volunteers with high normal/ mildly elevated serum cholesterol	Assessment of the effects on emotional experiencing of Simvastatin. Greater emotional sensitivity to negative events suggested an effect which diminished over the course of study.
(Basler, Bertalanffy, Quint, Wilke, & Wolf, 2007)	Older adults with chronic low back pain	RCT with diary-based measure of time spent in physical activity and functional activity measured as outcome, showing no effect of motivational program
