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Ecological Momentary Interventions: Incorporating Mobile Technology Into Psychosocial and Health Behavior Treatments

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Abstract

Purpose—Psychosocial and health behavior treatments and therapies can be extended beyond traditional research or clinical settings by using mobile technology to deliver interventions to individuals as they go about their daily lives. These Ecological Momentary Interventions [EMI] are treatments that are provided to people during their everyday lives (i.e., in real time) and in natural settings (i.e., real world). The goal of the present review is to synthesize and critique mobile technology-based EMI aimed at improving health behaviors and psychological and physical symptoms.

Methods—Twenty-seven interventions using palmtop computers or mobile phones to deliver ambulatory treatment for smoking cessation, weight loss, anxiety, diabetes management, eating disorders, alcohol use, and healthy eating and physical activity were identified.

Results—There is evidence that EMI can be successfully delivered, are accepted by patients, and are efficacious for treating a variety of health behaviors and physical and psychological symptoms. Limitations of the existing literature were identified and recommendations and considerations for research design, sample characteristics, measurement, statistical analyses, and clinical implementation are discussed.

Conclusions—Mobile technology-based EMI can be effectively implemented as interventions for a variety of health behaviors and psychological and physical symptoms. Future research should integrate the assessment and intervention capabilities of mobile technology to create dynamically and individually tailored EMI that are ecologically sensitive.

Clinicians have long sought to extend psychotherapy into patients' everyday lives by encouraging activities and skill building between treatment sessions. The use of interventions in patients' natural environments is also being adopted in behavioral health and psychosocial treatment domains more generally. The term Ecological Momentary Intervention [EMI] provides a framework for treatments characterized by the delivery of interventions to people as they go about their daily lives. EMI can take many forms ranging from unstructured clinical recommendations (e.g., requesting a cardiac rehabilitation patient practice relaxation techniques when stressed) to more formalized and structured interventions (e.g., a person participating in a smoking cessation intervention receives a text message on her mobile phone with tips for dealing with cravings during a time when she typically smokes a cigarette). EMI can supplement existing interventions or ongoing treatments (medical or psychological), or could be implemented on their own. The key feature of all EMI is that the treatment is provided to people during their everyday lives (i.e., in real time) and settings (i.e., real world). Therefore, these interventions are *ecologically* valid because they occur in the natural environment, and are provided at specifically identified *moments* in everyday life, allowing EMI to provide real-time support in the real world.

Developments in the sophistication and affordability of mobile technology have created more opportunities for treatments to be available to people during times ("real time") and in places or situations ("real world") when they are most needed. Two commonly used devices are palmtop computers and mobile telephones. Palmtop computers (also referred to as personal digital assistants [PDAs], handheld computers, pocket computers, or PalmPilots) are small electronic devices that present applications (e.g., appointment book, customized programs to administer questionnaire or EMI) on a touch-sensitive screen. Mobile phones typically have the capability to send and receive voice and written text messages (and in some cases, pictures and videos). Mobile technology is ideal for providing EMI because these devices are relatively small and convenient for people to carry on their person as they go about their daily lives.

To date, research evaluating mobile technology-based EMI has occurred with little communication between researchers and clinicians in different disciplines. As a result, the research is not well integrated, limiting our understanding of the common issues, challenges, and opportunities for EMI in psychosocial and health behavior treatments. The aim of this review is to identify methodological features of existing psychosocial EMI and evaluate the efficacy and acceptability of these treatments, in order to highlight limitations of existing interventions and provide recommendations for future clinical and research applications. In the following section a brief history and rationale for employing EMI in psychosocial treatments are discussed. The use of ambulatory assessments is also examined, as this line of research parallels, but has largely been separate from, the intervention literature.

Rationale and Benefits of Ecological Momentary Interventions [EMI]

For decades in psychotherapy, clinicians have encouraged patients to practice skills, participate in activities, and complete assignments between therapy appointments (Kazantzis & L'Abate, 2007). These activities are a form of EMI, although they are generally not labeled as such. Between session assignments are most commonly associated with cognitive and behavior therapies, as these traditions formalized and popularized the idea of giving patients "homework" as a way to practice, generalize, and maintain therapeutic skills (Kazantzis, Deane, & Ronan, 2000). As described previously, this approach is now being extended to include health behavior and psychosocial interventions outside of therapy.

Incorporating EMI into other treatment settings has several benefits. First, EMI extend interventions beyond the standard treatment context by providing support in patients' everyday lives, as compared to being delivered only during discrete times (e.g., office visits). With the additional support provided by EMI, patients may feel better equipped to practice new behaviors and skills (Hay & Kinnier, 1998; Kazantzis & L'Abate, 2007; Newman, Consoli, & Taylor, 1997). Second, because EMI are provided in individuals' natural environments, patients have an opportunity to apply new skills and behaviors to their actual experiences. Even when interventions produce effective skill acquisition when assessed in clinical or research settings, evidence suggests these skills do not necessarily translate to real life (e.g., Kalichman et al., 2002; Malow, West, Corrigan, & Pena, 1994). EMI can reinforce the systematic use of treatment components in real-world settings, thus generalizing the intervention program's impact.

Using mobile technology (e.g., palmtop computer, mobile telephone) to deliver EMI can provide additional advantages for patients and researchers or practitioners. Electronic devices are highly portable, making it possible for the intervention to be available at any time. Information can be presented directly on palmtop computer or mobile phone screens and users can enter information directly on the device. Interactive Voice Response [IVR] systems also allow for users to provide and receive information using mobile phones (e.g., Freedman, Lester, McNamara, Milby, & Schumacher, 2006; Levin & Levin, 2006).[1] Although the use of electronic devices elicits a range of reactions, for some it may increase the sense of privacy,

[1]Related research areas include the use of "landline" telephones to provide teletherapy or access IVR services that provide interventions. These forms of treatment were important precursors to EMI, but they are not ambulatory in the sense that they are available to patients in limited settings (e.g., only at home). As mobile phones become more common these interventions will likely be administered using mobile technology with increasing frequency. For the purpose of this review in order to ensure that the interventions were ambulatory, and thus EMI, we excluded studies using teletherapy or IVR *unless* they were exclusively delivered via mobile technology.

comfort, and acceptance of the intervention (Newman, Consoli et al., 1997). Technology-based systems can also automatically tailor EMI content based on participant characteristics or assessment responses. It has been shown that tailoring the content of health messages based on individual characteristics (e.g., readiness to change, motivation, self-efficacy) can improve message acceptance and willingness to change (e.g., Kreuter, Farrell, Olevitch, & Brennan, 2000; Kreuter, Strecher, & Glassman, 1999). Mobile technology also allow for the timing of messages to be individually tailored by providing EMI at specific times when participants or patients are most in need of additional support. Finally, technology-based interventions can perform basic and repetitious tasks (e.g., practicing relaxation training), allowing clinicians to make more effective use of their time and focus on the complex aspects of care. Based on these benefits there is potential to improve treatment efficiency and decrease overall treatment time, thus greatly reducing the intervention cost.

Despite the benefits of using mobile technology for EMI, several drawbacks should be noted. Using mobile technology and developing EMI can have more “up-front” costs than more traditional methods and requires considerable time for researchers and clinicians to setup the systems and teach patients to use the devices. These challenges for implementing EMI will be discussed in greater detail in following sections. Nonetheless, as these technologies advance, declining prices and user-friendly interfaces (to improve the ease of adoption and use) allow mobile technology to remain a promising tool for providing real-time support in patients' everyday lives.

Ecological Momentary Assessment [EMA]

Approaches to collect data in everyday life have evolved in a variety of disciplines to fulfill specific research needs. The development of real-time data capture techniques runs parallel to the use of EMI, although real-time assessment and intervention procedures have largely remained separate. Periodically signaling people to report on experiences in their daily lives was known early on as the Experience Sampling Method [ESM] (Csikszentmihalyi & Larson, 1987). Before palmtop computers were widely available, researchers gave participants pagers that were programmed to “beep” at random times throughout the day, and participants would report on their subjective experiences on paper diaries they carried with them (Scallon, Kim-Prieto, & Diener, 2003). Today, these methods of using random sampling to capture real-time data have been expanded to include assessment of internal and external cues (e.g., social interaction, situational variables) and are referred to as Ecological Momentary Assessment [EMA]. Stone and colleagues (2007) argue that the EMA framework encompasses diverse ambulatory assessment techniques including paper diaries, behavioral observation, self-monitoring systems, experience sampling, and ambulatory monitoring of physiological information. (Similarly, the term Ecological Momentary Intervention [EMI] is being used to describe a variety of ambulatory treatment strategies that are delivered in people's natural environments.)

The rationale for using EMA rests on three central benefits of these methodologies. First, self-report data are traditionally collected via retrospective assessments, requiring participants to summarize their experiences over some time period. Information recall is affected by heuristics used in memory search and reconstruction, which can systematically bias participant responses (Scallon et al., 2003; Smyth & Stone, 2003; Stone & Shiffman, 1999). For instance, people are more likely to recall salient experiences and tend to remember events according to what they

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currently know about the event or behavior (Hufford, 2007; Smyth & Stone, 2003; Stone & Shiffman, 1994). Retrospective recall (and the associated biases) is greatly reduced with EMA because people report on current or recent states or events. Second, like EMI, EMA occur in natural settings, thus increasing generalizability and ecological validity. Assessments occurring in research or clinical settings (e.g., laboratory, hospital, etc.) cannot reflect all aspects of individuals' lives, making it difficult or impossible to assess important behaviors. Also, relationships identified in research or clinical settings do not necessarily reflect processes occurring in the real world (Smyth & Stone, 2003). For example, there is evidence that some people have high blood pressure only when taken in a medical setting (so-called “white-coat hypertension”; Pickering & Freedman, 1991). Third, multiple assessments occur over time, so temporal relationships among variables can be explored. These data allow more complex and nuanced research and clinical questions about dynamic associations and processes that occur over time to be addressed.

In sum, EMA techniques have remained largely separate from EMI, although they share many of the same advantages over traditional assessment and treatment procedures (e.g., improved ecological validity and real-world generalizability). The merging of ambulatory assessment and intervention is an important area of future research as advances in mobile technology make it feasible for individuals' EMA responses to inform and tailor the content and delivery of EMI; these issues are discussed more fully in later sections of the review.

Review Aims, Methodology and Inclusionary Criteria

This review synthesizes and critiques studies that implement EMI for psychological and physical symptoms and health behaviors using mobile technology. The interventions use mobile electronic devices (i.e., palmtop computers, mobile telephones) to deliver psychosocial EMI to people as they go about their daily lives. The aim of this review is to: (1) examine existing research with respect to the characteristics of the interventions and studies; and (2) evaluate evidence for the feasibility, acceptability, and efficacy of psychosocial and behavioral health EMI in promoting positive outcomes. In the first part of the review, we will focus on the parameters and process of the studies, discussing issues related to the samples, methodological approaches, and intervention features. The second part of the review will examine the feasibility, acceptability, and efficacy of the existing EMI. Recommendations for future applications of mobile technology-based EMI in research and practice are also discussed.

Studies published in English-language, peer-reviewed journals that evaluated an ambulatory psychosocial intervention were identified via searches in MEDLINE, PsycINFO, PsycARTICLES, and INSPECT (an electronics, computing, and information technology database). Combinations of the following search terms were used: *mobile computing, technology, electronics, ambulatory, health, health behavior, mental health, intervention, treatment, therapy, psychotherapy, pocket computer, handheld computer, personal digital assistant [PDA], palmtop computer, cellular phone, mobile phone, text message, short message system [SMS]*. The resulting reference lists were reviewed to identify additional relevant articles (i.e., back citation) for potential inclusion. Studies were included if: (1) the study's aim was to improve psychological or physical health or health behaviors using a mobile, electronic device to deliver a psychosocial intervention in patients' everyday lives; and (2) the intervention program was evaluated with respect to behavior or symptom change. Twenty-seven interventions meeting these criteria were identified and reviewed. These interventions targeted a variety of psychological, physical, and behavioral health issues including smoking cessation, weight loss, anxiety, diabetes management, eating disorders, alcohol use, and healthy eating and physical activity.

Review and Critique of Intervention Design, Delivery, and Outcomes

Several aspects of intervention development and implementation will be discussed including the participant characteristics, research design, features of the EMI, and treatment efficacy. Table 1 provides an overview of the key characteristics of each study included in the review. This table identifies the target symptom or behavior of the intervention, participant characteristics, if the study was a randomized controlled trial [RCT], the conditions or treatment groups, duration of treatment, and assessment times. Although the goal of this review is to provide a synthesis across studies (rather than a study by study description), two EMI studies – one targeting smoking cessation and the other increasing physical activity – are described in detail to provide a clearer picture of how such studies are designed and carried out.

Examples of Ecological Momentary Interventions [EMI]

Smoking Cessation EMI—Rodgers and colleagues (2005) tested the efficacy of a smoking cessation intervention delivered via mobile phone based text messaging to a large sample (*n*=1705) of young smokers in New Zealand. An interdisciplinary team developed over 1,000 EMI messages with information relevant to quitting (e.g., withdrawal symptoms, motivational support, etc.). For participants receiving EMI, message content was tailored based on individual smoking history and barriers to cessation and the timing of the EMI delivery was tailored to individuals' chosen quit dates; all messages were delivered using an automated system. Participants received five text messages daily on their personal mobile phones at randomly selected times for one week before and four weeks after their quit date, and continued to receive three messages per week for a total of six months. In addition, when experiencing a craving, participants could send a text message to a provided phone number and receive a reply message with tips for coping with cravings. The intervention also encouraged participants to develop social support networks by providing them with a month of free text messaging. Participants in the control condition received a text message every two weeks thanking them for participating and providing reminders about the follow-up assessment.

Results showed that people receiving the EMI were significantly more likely to have quit smoking than control participants, six weeks (28% vs. 13%) and twelve weeks (29% vs. 19%) after beginning the study, but group differences were not maintained at 26 weeks (25% vs. 24%). This study demonstrated a text message EMI can increase smoking cessation rates in the short term and provides an example of an EMI that requires limited individual contact and is completely automated. This method of intervention has potential for being able to reach a large number of people without requiring a great deal of resources (e.g., clinician time, equipment, etc.).

Physical Activity EMI—King and colleagues (2008) developed a palmtop computer-delivered intervention aimed at increasing middle- and older-aged adults' physical activity using a palmtop computer-based EMI. Individuals randomized to receive the EMI (*n*=19) were individually taught to use the palmtop computer and received physical activity education materials. During the following eight weeks, they were signaled to complete a brief EMA questionnaire the palmtop computer two times each day (2pm, 9pm). The assessment requested information regarding contextual variables (e.g., location), physical activities, and behavioral and motivational factors. EMI were delivered on the palmtop computer after the assessment and included daily and weekly individualized goal setting, feedback on progress, and assessments of barriers and enablers of meeting goals. Participants in the control condition (*n*=18) received written physical activity materials and all participants completed assessments of physical activity level and treatment acceptability at the end of the eight weeks.

All of the participants receiving the EMI finished the study and on average completed 68% of the palmtop computer questionnaires and EMI. Participants who received the EMI reported

higher levels of physical activity (based on mean number of minutes active and caloric expenditure), as compared to those who only received psychoeducation materials. Researchers analyzed the data participants provided on the palmtop computers and found they reported a significant increase in the frequency of their use of the pedometer and 64% of the participants reported an increase in pedometer-based steps during the intervention. This study demonstrates that a relatively short-term, low intensity palmtop computer-based EMI can increase middle- and older-aged adults physical activity. More generally, it provides an example of an automated, palmtop-computer based EMI that requires limited clinician time during the intervention.

These samples provide a sense of the design and implementation of EMI studies, and the various forms such interventions can take. The area of technology-based EMI is relatively new, and only a small corpus of studies exists. Given the heterogeneity of samples, research designs, and EMI characteristics, a meta-analysis of this literature (at this time) could produce results that are inconclusive at best or misleading at worse (Cooper, 1998), and we therefore conducted a narrative research synthesis.

Sample Characteristics

Demographic Characteristics—The interventions in this review targeted a variety of psychological and physical symptoms and health behaviors including smoking cessation (*k*=8, 29%; where *k* represents the number of reviewed studies), anxiety (*k*=6, 22%), weight loss (*k*=5, 19%), diabetes management (*k*=3, 11%), eating disorders (*k*=2, 7%), alcohol use (*k*=1, 4%), healthy eating (*k*=1, 4%), physical activity (*k*=1, 4%). Two thirds of studies (*k*=18) were conducted with people in their mid-30s to 60s and the remaining third was with individuals in their teens and 20s (*k*=9). Twelve studies (44%) included samples composed of 70-100% women; this was particularly pronounced for weight loss and eating disorder interventions (where nearly all participants were female). More than half the interventions were conducted in the United States (*k*=17, 63%), and eleven (41%) were implemented in other countries including Australia, New Zealand, Scotland, England, Germany, Norway, and South Korea (two studies were conducted in more than one country; Kenardy et al., 2003; Newman, Kenardy, Herman, & Taylor, 1997).

The degree to which people are open to using technology may be influenced by their age. In general, younger people are more familiar with, and comfortable using, palmtop computers and mobile phones than are older people. Technology is an important part of children's, teenagers', and young adults' lives, so EMI may fit better within their lifestyle than more traditional treatments, potentially making EMI more readily accepted and improving the chances for lasting behavior change (e.g., Franklin, Waller, Pagliari, & Greene, 2006; Obermayer, Riley, Asif, & Jean-Mary, 2004; Weitzel, Bernhardt, Usdan, Mays, & Glanz, 2007). EMI, however, were also effectively implemented and accepted by middle age and older adults (Atienza, King, Oliveria, Ahn, & Gardner, 2008; King et al., 2008). In fact, there is potential for EMI to be especially helpful for the elderly, as they can provide a way for healthcare providers, family, and friends to monitor and maintain contact with the individual (Gandy, Starner, Auxier, & Ashbrook, 2000). For example, ambulatory assessment via automatic means (e.g., physiological monitoring) or self-report (e.g., medication adherence, symptoms, self-care activities) can be used to help document individuals' daily functioning. These assessment tools can also trigger EMI, with reminders or instructions for medication adherence or self-care activities automatically delivered to patients when problematic reports occur. Implementing EMI for older or elderly adults presents unique challenges with respect to intervention development, motivation, and physical limitations (Arning & Ziefle, 2007; Sterns, 2005). When introducing EMI to elderly people, it is important to eliminate fear of new technology and accommodate mobility, vision, and cognitive limitations of older adults by

using different types of hardware and software. In coming years as mobile technology become more accessible it is likely that even older adults will be familiar with and comfortable using these devices.

Technology Literacy—Three studies (11%) reported participants' familiarity with mobile devices, but a wide range of experience was seen. It was reported that 93% (King et al., 2008) and 54% (Atienza et al., 2008) of participants indicated they never used a palmtop computers, and 80% reported not owning one (Weitzel et al., 2007). It is likely that participants are more familiar with mobile phones. In fact, in all but three (Franklin et al., 2006; Lazev, Vidrine, Arduino, & Gritz, 2004; Vidrine, Arduino, Lazev, & Gritz, 2006) of the 15 studies that used mobile phones, participants were required to use their own devices. Familiarity with technology has implications for the level of participant training required to use the devices and intervention systems. Studies using palmtop computer-based EMI will likely require extensive training on the general use and maintenance of the devices and specific instructions for completing study activities. For most participants, mobile phone-based EMI studies (particularly when participants to use their own phone) will need less formal training by the researchers, as was seen in several of the large-scale interventions (Brendryen, Drozd, & Kraft, 2008; Brendryen & Kraft, 2008; Joo & Kim, 2007; Rodgers et al., 2005).

Sampling Bias and Attrition—As with any intervention research, issues of participant self-selection into (or out of) the study can influence the generalizability of findings and have implications for dissemination. Individuals who are uncomfortable using mobile electronic devices may not self-select into EMI studies, an issue that has not yet been well addressed in this literature. Although not a perfect test, one study compared self-reported computer literacy and familiarity for individuals who completed the study to those who dropped out and found no significant differences (Burnett, Taylor, & Agras, 1992). This analysis, however, does not account for individuals who do not respond to advertisements or decline participation because of the involvement of electronic devices. A related concern is regarding attrition, and how individual differences and group assignment may be associated with study dropout. In most studies, not all of the participants who began the study completed it (see Table 1, Participant Characteristics). Four studies reported differences between completers and non-completers on demographic characteristics, outcome measures, or group membership (i.e., treatment vs. control group). In one weight loss intervention, non-completers had higher body mass indices [BMI], higher depression scores, rated the EMI as less credible, and were less likely to recommend the treatment to others at the start of the study (Burnett et al., 1992). Atienza and colleagues (2008) found individuals who did not complete a healthy eating intervention were younger and ate less dietary fiber at the baseline assessment. Differential attrition rates between treatment groups are a particular concern because it can be a threat to the internal and external validity of a study and make comparisons between groups more difficult to interpret. For example, in one smoking cessation intervention, more treatment than control participants completed the assessment 1 month post-cessation, likely inflating the effect size for one month abstinence (no group differences in attrition were seen 3, 6, or 12 months post-cessation; Brendryen et al., 2008). Conversely, Rodgers and colleagues (2005) found participants in the EMI condition dropped out of the follow-up phase at a higher rate than control participants; authors attributed this to control participants receiving compensation after completing the follow-up, while EMI participants were compensated during the intervention. Future research should carefully report attrition rates in treatment and comparison groups and differential attrition should be considered when interpreting results.

A limitation of using technology to deliver EMI is that some patients will not be open to this form of intervention and may resist treatment (Kenardy & Adams, 1993; Marks, 1999). Research identifying person-level characteristics (e.g., age, education, familiarity with technology) that influence the perceived credibility and willingness to participate in EMI

treatments can inform the development of more appropriate approaches to disseminate these interventions. For example, the strategies used to explain the intervention during recruitment and when training participants to use electronic devices could be modified depending on the individual's age, education, and familiarity with technology to make the intervention more acceptable to a wider range of people.

Research Design Issues

Study Design—This literature includes a variety of experimental design approaches ranging from case studies to large randomized controlled trials [RCTs]; individual study designs can be found in Table 1. Nearly 60% of the interventions (*k*=16) included at least one control or comparison group. Of these RCTs eight used a usual care (typically psychoeducation) or waitlist control condition (30%), five used CBT (31%), two used psychoeducation (7%), one used EMA (without EMI) as a comparison group (4%), and one intervention compared three variations of EMI (4%; note percentages add to more than 100% because some studies used multiple comparison groups). Of the remaining studies, seven (26%) were uncontrolled trials and four (36%) were qualitative case studies describing an EMI treatment used in a clinical setting with one to four patients. To establish the utility of EMI, it is important to document that individuals benefit from these treatments beyond what would be expected from receiving no treatment or standard care. It is less clear, however, what the most suitable control or comparison conditions are in such trials. Comparing novel treatments such as EMI to a no treatment control group is quite liberal, whereas when comparing EMI to established interventions the added value (in terms of efficacy, cost effectiveness, etc.) can be more clearly established. For example, several studies aimed at smoking cessation (Brendryen et al., 2008;Brendryen & Kraft, 2008;Vidrine et al., 2006), weight loss (Agras, Taylor, Feldman, Losch, & Burnett, 1990;Burnett, Taylor, & Agras, 1985;1992), and reducing anxiety symptoms (Gruber, Moran, Roth, & Taylor, 2001;Kenardy et al., 2003;Newman, Kenardy et al., 1997) compared previously validated interventions (i.e., CBT, psychoeducation) to treatments supplemented with EMI, providing a more stringent test of the efficacy of EMI. Future RCTs should, when possible, compare novel EMI treatments to existing empirically supported interventions or to standard care.

Despite the need for additional, well-controlled, RCTs in this literature, this approach can neglect important qualitative feedback from participants regarding the intervention (see Fisher, 2008). Feedback can take many forms, including formal questionnaires, focus groups, and unstructured interviews, with all allowing participants to identify issues that could interfere with ease of use, acceptability, and perceived usefulness. Qualitative methods are especially important during the early stages of intervention development so that deficiencies in the systems can be identified and corrected before controlled trials are conducted. In the present review, although more than half of the studies included information regarding participant's feedback on the intervention, these data were largely collected post-intervention. With few exceptions where formative research was described (Patrick et al., 2009; Whittaker et al., 2008), it is unclear if participant feedback informed intervention design or implementation. Although it is possible authors used such methods but did not report it (e.g., due to space limitations), future work developing EMI would benefit from eliciting qualitative feedback regarding the usability and acceptability of EMI in pilot testing and utilizing such information prior to implementing controlled trials (and reporting it when possible).

Assessment of Outcomes—Nearly all of the studies (*k*=25, 93%) used a pre-post assessment design (see Table 1, Assessment Times for information regarding specific studies). The other two studies collected data during a follow-up assessment (Vidrine et al., 2006), and weekly during the intervention (Bauer, Percevic, Okon, Meermann, & Kordy, 2003). Follow-up assessments were conducted for eight of the interventions (30%), and occurred from three

to 12 months after the intervention (mode=6 months). Limited follow-up data is particularly problematic for EMI studies because part of the rationale for using ambulatory interventions is they allow individuals to more easily incorporate skills into everyday life, thus increasing the likelihood of lasting behavior change. With few exceptions (Agras et al., 1990;Burnett, Taylor, & Agras, 1985), assessments more than six months after the intervention were not conducted, making determinations regarding longer lasting behavior changes difficult. Future research examining the efficacy of EMI should include longer follow-up periods to more clearly establish the efficacy of this treatment approach.

The interventions reviewed focused almost solely on behavior and symptom changes measured using paper assessments before and after treatment. Many of the interventions collected self-report EMA data during the intervention, yielding data that could address more specific questions regarding participants' daily experience with EMI. Seven of these studies reported results from these data (Baer, Minichiello, Jenike, & Holland, 1988; Bauer et al., 2003; Burnett et al., 1985; King et al., 2008; Newman, Consoli, & Taylor, 1999; Przeworski & Newman, 2004; Weitzel et al., 2007). Real-time momentary data collected via participants' self-reports (i.e., EMA) or automatically recorded data regarding intervention use (e.g., frequency, time, and duration of EMI use) create complex and rich datasets. In order to more fully understand the factors that influence EMI efficacy, future research should use EMA data to address more nuanced research questions regarding EMI implementation and efficacy. This has been done in two articles (Dow et al., 2007a; 2007b), which identified predictors and moderators of treatment outcome (e.g., anxiety severity, duration of diagnosis) for the anxiety EMI intervention described by Kenardy and colleagues (2003). In addition, questions regarding how EMI use (e.g., frequency, duration) may be influenced by person-level characteristics (e.g., familiarity with technology, age) or daily experiences (e.g., mood, stress, location), and in turn, impact treatment efficacy can be addressed with EMA data. It is important to recognize EMA data present unique challenges for traditional statistical modeling techniques because of their hierarchical organization (i.e., multiple assessments are nested within days, days are nested within people) and potentially large amounts of missing data (due to the intensity of the sampling protocol, often multiple times per day). These issues require multilevel modeling (or other sophisticated statistical methods) to adequately account for autocorrelation effects associated with the nested structure, and the quantity of missing data. Although coverage of this issue is beyond the scope of this review, several reviews discuss statistical procedures that can be applied to EMA data (see Schwartz & Stone, 1998; 2007).

Ecological Momentary Intervention [EMI] Features

The following section is devoted to describing qualities of the EMI included in this review. Table 2 presents the EMI features for individual studies and the discussion below provides a synthesis of this information. This table identifies the type of mobile technology used, the extent to which the EMI delivery system was automated or automatic, and treatment components (in addition to EMI) that were included as part of the intervention. The next three columns describe the frequency of EMI, amount of time over which EMI were provided, and a description of the content of the EMI. The final three columns identify the events or situations that trigger or initiate an EMI to be delivered to a participant, and whether the EMI timing and content are individually tailored.

Delivery Methods—The studies in this review used a variety of types of technology and protocols to deliver EMI to participants (see Table 2, Type of Technology). The EMI were delivered using palmtop computers (*k*=12, 44%), mobile phone voice capacities (*k*=4, 15%), and mobile phone text messaging (or Short Messaging Service [SMS]; *k*=13, 48%; note some studies used both voice and SMS). All of the studies using palmtop computers provided participants with devices during the study, but as was discussed previously, 80% of the studies

using cell phones required participants use their own phone. Overall, the electronic devices were well received by participants, who reported minimal difficulties remembering to carry the palmtop computers or mobile phones (King et al., 2008;Newman et al., 1999), suggested the devices were easy to use (Newman et al., 1999;Obermayer et al., 2004), and were comfortable responding in social situation (King et al., 2008).

The studies included in this review were conducted over a span of nearly 25 years, during which time technology advanced dramatically. In the l980s and 90s when the first EMI studies took place, the sophistication and capacity of available technology was significantly more limited than it is today. Participants were most likely unfamiliar with mobile technology and participation would require the researcher to provide both the devices and extensive training teaching them to use the devices and programs. Moreover, the capacity of the devices in terms of sophisticated data capture and intervention components were very limited (e.g., to simple alarm reminders). More recently, however, studies utilize devices common in daily life. Many studies, for example, allow participants to use their own mobile devices, which requires less formal training to use the EMI program (e.g., Brendryen et al., 2008; Brendryen & Kraft, 2008; Joo & Kim, 2007; Rodgers et al., 2005). As technology continues to advance the formats in which EMI are delivered will also change. To date, studies have primarily relied on text or voice messaging, but as mobile devices with Internet capabilities become more widespread, web-based interventions will also be usable in real time.

The majority of studies (*k*=19, 70%) used an algorithm-based automated system to deliver the EMI, but one quarter (*k*=7) required a person to review participant data, select and send appropriate messages, or have a conversation with participants, and one study used a system including both automated and manual EMI deliver (see Table 2, Automated EMI Delivery). EMI requiring someone to select appropriate EMI messages or initiate delivery is undesirable in many settings where it would be difficult to find healthcare practitioners willing (or with time) to engage in such activities. Automated systems can be more complex to develop, but are desirable because they require little ongoing involvement by researchers or clinicians as the EMI are delivered.

The frequency with which EMI were delivered varied greatly, ranging from once per week to five times per day (see Table 2, EMI Frequency). The time period over which EMI were delivered (i.e., intervention duration) also differed across studies ranging from 2 weeks to nearly 2 years (mode=12 weeks; see Table 2, EMI Duration). Although it may seem desirable to provide frequent EMI for extended periods of time, if the time and effort required for participation is too great, it could deter people from taking part in studies or receiving treatment. In general, the interventions with more frequent EMI (at least daily) were shorter in duration (2-12 weeks), whereas less frequent interventions were used in longer studies (6-12 months). Interventions lasting six to 12 months (Brendryen et al., 2008;Brendryen & Kraft, 2008;Franklin et al., 2006;Rodgers et al., 2005) also tended to decrease the EMI frequency as the study progressed. Four studies reported feedback from participants regarding intervention length and EMI frequency; three found interventions lasting eight weeks (2 EMI/day; King et al., 2008), twelve weeks (1 EMI/week; Joo & Kim, 2007), and 1 year (1 EMI/day; Franklin et al., 2006) were acceptable, but Weitzel and colleagues (2007) reported the majority of college student participants thought random daily messages for two weeks was too frequent. It is difficult to draw strong conclusions at this time regarding the ideal intervention duration and EMI frequency based on these few studies that reported participant feedback. When designing studies researchers can use the relative frequency of the symptom or behavior being targeted (e.g., anxiety, smoking, drinking alcohol) to help determine how often EMI should be delivered. Symptoms or behaviors that occur multiple times per day (e.g., smoking) may require several daily EMI, while less frequent behaviors (e.g., alcohol drinking episode, binge eating) might use less intense EMI protocols. Researchers need to more regularly elicit

feedback from participants regarding the relative balance between study duration and intervention frequency (preferably during the design phase) and adjust EMI protocols accordingly.

Intervention Components—The majority of the studies reviewed provided EMI as only one component in a treatment protocol (*k*=23, 85%; see Table 2, Additional Treatment Components). Of these, many used EMI to supplement group or individual cognitive-behavioral therapy [CBT] (*k*=9, 39%), eight (35%) incorporated an interactive website (where participants could access psychoeducational material, seek social support, and track treatment progress), four included psychoeducation (15%), and two used a support group in addition to the EMI (7%). In two studies (7%) the EMI involved individual brief counseling sessions on mobile phones, and thus provided some personal contact (Lazev et al., 2004;Vidrine et al., 2006) and only two interventions (7%) provided EMI without any additional treatment support (Weitzel et al., 2007;Whittaker et al., 2008).

To date, research primarily demonstrates EMI can elicit symptom and behavior change when implemented as one of several treatment approaches within a larger treatment protocol; there is more limited evidence demonstrating the efficacy of EMI alone. Three studies in this review demonstrated EMI can be effectively implemented alone without additional treatment support (Agras et al., 1990; Weitzel et al., 2007; Whittaker et al., 2008), while another showed EMI in combination with a support group was more cost-effective than EMI alone (Burnett et al., 1992). Researchers and practitioners alike have expressed concern that incorporating electronic devices into treatment will limit patients-clinicians interactions or even replace clinicians all together (Boland, 2007; Kenardy & Adams, 1993; Marks, 1999). This concern in part reflects the belief that non-specific treatment factors, such as the patient-provider relationship, play an important role in symptom and behavior change. However, some people may be unable or unwilling to get treatment in person (due to cost, distance, stigma, etc.), and these individuals may want or need EMI alone. Future research should systematically investigate the efficacy of EMI administered with minimal additional treatment and identify for whom such EMI may be most (or least) beneficial.

EMI Content—A variety of intervention strategies were utilized in the EMI treatments (see Table 2, Intervention Content). The overarching goal of these interventions was to help participants reduce negative psychological symptoms or modify unhealthy behaviors by encouraging self-regulation and goal setting to improve individuals' self-efficacy in making lifestyle changes.[2] Not surprisingly, all the interventions used some behavioral approaches, including teaching strategies for coping with unpleasant emotional states (e.g., anxiety, cigarette craving, desire to binge), using behavioral substitution (i.e., substituting healthier behaviors), and setting short- and long-term goals. Cognitive treatment strategies, such as challenging distorted thinking and cognitive reframing, were used particularly in anxiety interventions. Several studies included a psychoeducational component within the EMI to provide information about symptoms and what participants could expect as they begin to make behavior changes. For example, smoking cessation EMI provided information about withdrawal symptoms and typical barriers to quitting, and weight loss EMI included general nutritional and caloric information on various foods participants ate. Individual feedback, notifying participants of their progress towards their goals, was provided in one-third of the interventions (*k*=9). Motivational messages were used in two-thirds of the studies (*k*=18), urging participants to continue focusing on making behavior changes. These messages varied

[2]There is an emerging trend for mobile technology, particularly text messaging via mobile phones, to be used in healthcare settings as a way for providers to deliver reminders or recommendations to patients (e.g., medication dose, appointments). Although conceptually related to the studies in the present review, they do not include psychosocial interventions aimed at eliciting long-term behavior change (such as those described in this section), and thus were not included for review.

in their level of detail, ranging from brief statements (e.g., “Keep up the good work!”) to more detailed testimonials from people who were successful in making behavior changes. Studies dismantling intervention content would be useful for identifying the important qualities of effective ambulatory treatments, which likely depend upon the sample and condition being treated. The relative contribution of each of these intervention strategies remains to be determined and is an important area for future research.

EMI Tailoring—There is an emerging trend in health research to tailor behavior change interventions for individuals based on key variables or personal characteristics. Tailored messages are designed for specific individuals, which is in contrast to targeted interventions created for a subgroup of people who share one or more demographic characteristic (e.g., smokers, overweight Latinos; Kreuter et al., 1999). Several approaches for tailoring health messages have been suggested (Kreuter et al., 2000; Kreuter et al., 1999; Rakowski, 1999), but the overarching rationale for using tailored versus generic messages is tailored information is more personally relevant, increasing the likelihood of thoughtful consideration an helping to enact behavior change (Kreuter et al., 2000).

EMI can be tailored to participants in two ways. First, the content of the EMI can be specifically designed based on information individuals provide during pre-intervention assessments or momentary assessments (i.e., EMA). About two-thirds of the studies (k=19) used EMI with tailored content, three (11%) include a combination of tailored and generic messages, and five (19%) used only generic messages (Table 2, EMI Content Tailored). The tailored EMI included interactive CBT activities (e.g., relaxation, problem solving, goal setting), feedback based on concurrent EMA, individual counseling, or messages based on pre-intervention behavior patterns. The generic content EMI were generally motivational statements or reminders to practice learned skills (e.g., CBT).

A second method of tailoring EMI involves delivering the interventions at specific moments when individuals are especially in need of additional support. In order to provide time tailored EMI, the events or circumstances that trigger or initiate the delivery of the intervention must be clearly defined. A variety of delivery protocols were utilized that included user initiated, fixed prompt times, random prompted times, and tailored dates and/or times (see Table 2, EMI Triggers). EMI that were user initiated relied on participants to initiate contact with the electronic device when specific events occurred (e.g., ate a meal, exercised, experienced anxiety, craved a cigarette). Fixed and random prompt times involved the palmtop computer or mobile phone providing an auditory alarm signaling the receipt of an EMI at either specific pre-arranged times when participants were notified they would receive messages, or at seemingly random times (i.e., participants did not know when they would receive the EMI).

Of the interventions reviewed, eight (30%) used only EMI that were administered during individually tailored times, 11 (40%) administered a combination of EMI that were and were not time tailored, and eight (30%) did not use time tailored interventions (see Table 2, EMI Timing Tailored). All of the studies that used at least some time-tailored EMI provided them upon request by the participant (e.g., when experiencing anxiety, before/after a meal, when craving a cigarette). In addition, six provided the EMI during days or times when participants had previously indicated they would be especially in need of support (i.e., during typical smoking times; Obermayer et al., 2004;Riley, Obermayer, & Jean-Mary, 2008), when the reported needing support via EMA (i.e., high current anxiety ratings measured via EMA; Newman et al., 1999;Przeworski & Newman, 2004), or at times they previously chose to receive EMI (Patrick et al., 2009;Whittaker et al., 2008).

There is reason to believe that some level of tailoring is important. Several interventions that did not tailor EMI content received feedback suggesting the EMI messages were not as well

accepted. For instance, one-third of participants receiving standard, non-tailored EMI text messages were dissatisfied with the content of the messages (Joo & Kim, 2007). Participants in three other studies indicated EMI were repetitive and suggested using a more diverse pool of feedback (Franklin et al., 2006; Newman et al., 1999; Weitzel et al., 2007). EMI that were not time-tailored drew criticism from participants in one study who complained about receiving EMI at the same time each day (Newman et al., 1999). Although there is evidence from several studies suggesting standardized, non-tailored EMI may not be well received by participants, no clear pattern emerged regarding the relationship between EMI tailoring and treatment efficacy. Future research investigating the effect of content- and time-tailoring on participant acceptance and efficacy of EMI treatments is necessary (and opens up other questions, such as the potential mediating role of adherence). Studies experimentally manipulating the tailoring of EMI content and timing and measuring the acceptability and efficacy of treatment would be highly informative.

Another potential approach to EMI tailoring is the use of ambulatory assessment to provide information about the most appropriate content and timing of EMI. Momentary assessments, such as self-report EMA, ambulatory physiological measures (e.g., heart rate, galvanic skin response; Asada, Shaltis, Reisner, Rhee, & Hutchinson, 2003; Ebner-Priemer & Kubiak, 2007; Fahrenberg, 1996), or environmental sensors information (e.g., location in the home, presence of others; Gandy et al., 2000; Intille, 2007), are additional sources of information from which interventions can be tailored. Several studies in this review requested participants periodically complete EMA regarding their current affect (e.g., anxiety level) or behavior (e.g., calories consumed) and immediately provided tailored EMI based on the concurrent assessments (Agras et al., 1990; Burnett et al., 1985; [1992]; Newman et al., 1999; Newman, Kenardy et al., 1997). Similar strategies could also be employed using mobile devices to monitor physiological states such as heart rate, blood pressure, or blood glucose. Morris and colleagues have developed technology that monitors health status in everyday contexts and translates it into personalized feedback delivered in real time (Morris, Digital Health Group, & Intel Corporation, 2007). For instance, a mobile oximetry device designed to monitor cardiovascular stress in patients with congestive heart failure, provided patients with real-time feedback regarding current physical exertion and long-term fitness goals on mobile telephones. These intervention systems have yet to be evaluated, but as technology continues to become more sophisticated, using concurrent assessments of physiological or environmental cues to tailor momentary behavioral health messages becomes a possibility.

Treatment Efficacy

EMI Feasibility

Intervention compliance: One of the benefits of using technology such as palmtop computers and mobile phones is they can automatically track participants' EMI use. More than half (*k*=16) of the studies reported participants' EMI compliance and demonstrated they were able to adequately adhere to the treatment protocol (Agras et al., 1990; Atienza et al., 2008; Baer et al., 1988; Brendryen et al., 2008; Brendryen & Kraft, 2008; Burnett et al., 1992; Gruber et al., 2001; King et al., 2008; Kwon et al., 2004; Lazev et al., 2004; Newman et al., 1999; Patrick et al., 2009; Przeworski & Newman, 2004; Riley et al., 2008; Robinson et al., 2006; Weitzel et al., 2007). Six interventions found participants were more adherent to the study protocol at the start of the study than they were 8-12 weeks later (Agras et al., 1990; Atienza et al., 2008; Baer et al., 1988; Newman et al., 1999; Patrick et al., 2009; Przeworski & Newman, 2004). Some authors interpreted this trend as evidence that participants implemented treatment strategies on their own at the end of the intervention and did not become dependent on the electronic devices. Although plausible, evidence demonstrating (either via self-report or behavioral observation) that participants begin to use intervention skills without the assistance of EMI is necessary to fully justify this claim (e.g., Przeworski & Newman, 2004). Clinicians

and researchers have expressed concern that patients, particularly those with anxiety disorders, will become overly reliant on the electronic devices and symptoms will worsen when treatment ends (Anderson, Jacobs, & Rothbaum, 2004; Newman, Consoli et al., 1997). This issue can be examined indirectly by demonstrating that participants continue to maintain treatment gains after the mobile device is taken away, as was seen in several studies (Burnett et al., 1985; Gruber et al., 2001; Kenardy et al., 2003; Newman, Kenardy et al., 1997). Nonetheless, research investigating participants' EMI compliance during the course of treatment and reactions to treatment ending is still warranted to evaluate these concerns.

Researchers and clinicians are often interested in tracking treatment compliance because it is expected that individuals who adhere to treatment will experience greater therapeutic gains. One EMI study addressed this issue by relating EMI compliance to patients' weight loss and found that participants who used the palmtop computer at least once per day, periodically reviewed motivational statements and feedback, and reported on eating and exercise on the palmtop computer lost more weight than those who were less compliant with the intervention (Burnett et al., 1992). Future research corroborating these findings could suggest the importance of developing strategies to encourage patient compliance. The specific strategies used will vary greatly depending on the level of contact participants have with research staff but may include education regarding the importance of compliance or rewards for obtaining a certain level of compliance.

Intervention credibility and satisfaction: More than half the interventions (*k*=19) reported participants' satisfaction with and/or the credibility of the EMI treatment program either through formal evaluations or anecdotal reports. The seven studies measuring treatment credibility found that the EMI intervention was perceived to be credible (Agras et al., 1990; Burnett et al., 1985; [1992]; Gruber et al., 2001; Kenardy et al., 2003; Newman et al., 1999; Newman, Kenardy et al., 1997) and there were no differences in ratings of treatment credibility for individuals receiving EMI versus those in comparison conditions (Burnett et al., 1985; 1992; Gruber et al., 2001; Newman, Kenardy et al., 1997). For the most part participants reported favorable reactions to the EMI and were satisfied with the treatment program (Atienza et al., 2008; Brendryen et al., 2008; Brendryen & Kraft, 2008; Franklin et al., 2006; Gruber et al., 2001; Joo & Kim, 2007; Kenardy et al., 2003; King et al., 2008; Kwon et al., 2004; Newman et al., 1999; Newman, Kenardy et al., 1997; Obermayer et al., 2004; Patrick et al., 2009; Przeworski & Newman, 2004; Riley et al., 2008; Whittaker et al., 2008), although in two studies many participants disliked the frequency (Weitzel et al., 2007) or generic nature (Robinson et al., 2006) of the EMI. Overall, these findings provide evidence that EMI delivered via palmtop computers and mobile phones are perceived as credible and generally acceptable to participants.

Symptoms and Health Behavior Outcome

Smoking cessation: Eight of the reviewed interventions attempted to help interested individuals quit smoking. Half of these studies included a control condition and each found that participants in the EMI conditions were more likely to self-report abstinence after the intervention (Brendryen et al., 2008; Brendryen & Kraft, 2008; Rodgers et al., 2005; Vidrine et al., 2006). Group differences in abstinence were biochemically confirmed in one intervention (Vidrine et al., 2006), but not another (Rodgers et al., 2005). In all the controlled studies, participants receiving EMI reported greater self-efficacy for remaining abstinent (Brendryen et al., 2008; Brendryen & Kraft, 2008; Rodgers et al., 2005; Vidrine et al., 2006). Obermayer, Riley, and colleagues conducted two studies using the same intervention and (based on biochemical testing) found 28-42% quit smoking at the end of the 6-week intervention (Obermayer et al., 2004; Riley et al., 2008). Similar positive results were demonstrated in two

other small studies, with 69% (Whittaker et al., 2008) and 75% (Lazev et al., 2004) of participants self-reporting abstinence after receiving EMI.

This research suggests mobile phone-based EMI can be used to help participants successfully quit smoking, improve self-efficacy for remaining smoke free, and are more efficacious than standard smoking cessation interventions alone (e.g., psychoeducation, nicotine replacement therapies). There is less evidence evaluating the efficacy of EMI using objective, biochemical outcome measures of nicotine exposure (e.g., salivary cotinine levels). Additional research using objective outcome measures of smoking cessation is necessary to demonstrate these treatment effects can be attributed to the intervention and not experimental demand (an issue discussed in greater detail in a following section).

Weight loss: The goal of five of the reviewed interventions was to help people lose weight, often by decreasing caloric intake and increasing physical activity. Joo and Kim (2007) provided participants with a weekly text message EMI encouraging healthy eating and exercise, and found that participants lost an average of 3.3 pounds and reduced their waist circumference by 1.7 inches over three months. This was an uncontrolled study, however, making strong conclusions regarding efficacy difficult. The remaining four weight loss EMI studies provided more systematic and controlled evaluations of treatment efficacy. Two of these weight loss interventions were RCTs comparing an empirically supported CBT treatment for weight loss to palmtop computer-based EMI for overweight women. In one study participants receiving the CBT and EMI lost more weight than those receiving CBT alone immediately post treatment (8 vs. 3 pounds), and at 24 weeks (16 vs. 4 pounds) and 40 weeks (18 vs. 2 pounds) after the intervention (Burnett et al., 1985), suggesting EMI may enhance treatment gains of CBT. Agras and colleagues (1990) found no group differences between group CBT, EMI, and EMI plus a support group; all participants lost about 5 pounds. In a recent study, at the end of 4 months, participants receiving EMI lost more weight than those receiving psychoeducation materials (6 vs. 2 pounds; Patrick et al., 2009). These studies provide some evidence that EMI, requiring minimal therapist time and effort, can be used either as an alternative to, or to enhance, CBT or psychoeducation. Burnett and colleagues (1992) also tested a palmtop computer-based EMI for overweight women, but varied the number of days on which participants were told to use the interventions. Women who received EMI 7 days per week and those who received EMI 4 days per week and participated in a support group lost more weight than women who only received EMI 4 days per week. Thus participants encouraged to use EMI more frequently may experience larger treatment gains, and including additional treatment support (e.g., via a support group) may improve weight loss outcomes further.

Empirical evidence suggests EMI can produce similar weigh loss in overweight women to a validated CBT intervention and that adding EMI to CBT or psychoeducation can enhance treatment efficacy. Conclusions regarding the efficacy of a low intensity EMI treatment (e.g., Joo & Kim, 2007) are premature because the lack of studies with experimental research designs. It is important to note that all of these studies were conducted with samples of 80-100% women, limiting conclusions regarding the efficacy of EMI for weight loss in men.

Anxiety symptoms: EMI have been used for the treatment of a variety of anxiety disorders including obsessive-compulsive disorder [OCD], generalized anxiety disorder [GAD], panic disorder, and social phobia. The three controlled studies of EMI for anxiety disorders compared a standard 12-session CBT treatment to an abbreviated course of CBT (4-8 sessions) supplemented with EMI. In general, they found individuals receiving brief CBT and EMI experienced similar treatment gains in fewer sessions, as compared to people receiving standard CBT. In other words, incorporating EMI into treatment allowed the number of therapy sessions to be reduced by about half, while maintaining similar treatment efficacy. In particular, Newman and colleagues (1997) found that participants with panic disorder who received four

brief individual CBT sessions supplemented with eight weeks of EMI showed similar improvements on self-reported anxiety symptoms as those who received 12 individual CBT sessions; both treatments eliminated panic attacks in 67% of participants. In another sample of patients with panic disorder, researchers compared a 12-session CBT treatment, brief 6-session CBT, and the brief CBT supplemented with palmtop computer-based EMI. All treatment groups showed statistical and clinical improvements in self-report measures of anxiety as compared to a waitlist-control group. Participants receiving the 12-sessions of CBT experienced significantly greater treatment gains than 6 sessions, and the group receiving 6 sessions and EMI fell between the two but was not statistically different from either (Kenardy et al., 2003). Gruber and colleagues (2001) also found patients receiving a standard group CBT treatment course (12 sessions) and abbreviated treatment (8 sessions) with palmtop computer-based EMI experienced improvements in behavioral assessments of social phobia. In addition, the group receiving the EMI had greater treatment gains on cognitive measures of anxiety. In general, these three studies suggest that by including EMI as part of a CBT treatment program, the number of therapy sessions can be reduced by about half while maintaining similar (or in some cases superior) treatment benefits. Three case reports describing the anxiety disorder treatment also suggested treatments incorporating EMI were effective at reducing patients' anxiety symptoms. In these reports, patients experienced initial treatment gains, with a reduction in compulsive behaviors (e.g., checking; Baer et al., 1988), GAD symptoms (Newman et al., 1999), and social anxiety (Przeworski & Newman, 2004). These case reports demonstrate that EMI can be effectively implemented in clinical settings and clinically meaningful changes in anxiety symptoms were seen.

In sum, empirical evidence and clinical case reports suggest EMI can be effectively implemented to reduce anxiety symptoms. The existing controlled trials demonstrated that abbreviated courses of CBT treatment supplemented with EMI can produce similar (and in some cases superior) statistical results to standard CBT interventions for panic disorder and social phobia, suggesting EMI may provide a cost-effective alternative to current anxiety treatments. Although cost-effectiveness is an important aspect of treatment to consider, future research should examine whether EMI can be used to create anxiety treatments that are superior to existing therapies.

Diabetes self-management: Managing diabetes is difficult for many patients because it requires frequent and regular attention to medical regimens (e.g., blood glucose testing) and lifestyle modification (diet, exercise) and EMI could provide a useful tool to help patients manage these tasks. Three studies used mobile phones to provide EMI to encouraging healthy eating, exercise, and routine medical care for patients with diabetes. In two studies, using a specially designed and secure website, patients regularly recorded their blood glucose and provided information regarding their lifestyle (e.g., diet, exercise). The website could be accessed by their healthcare providers and patients were sent an individualized message once a week by the research team. In an uncontrolled trial of this intervention, Kwon and colleagues (2004) found statistically and clinically significant improvements in blood glucose control for patients receiving EMI during a 3 month period. In a more rigorous test of intervention efficacy, Yoon and Kim (2008) tested a similar intervention in an RCT and found patients receiving EMI saw a statistically and clinically meaningful decline in their blood glucose levels at the end of the 12-month intervention (baseline HbA1c=8.1%, 12 month HbA1c=6.8%), while patients receiving usual care during this time saw a slight (but not statistically significant) increase (baseline HbA1c=7.6%, 12 month HbA1c=8.4%). This intervention did require considerable effort by the practitioners, who needed to review patients' information, and develop and send individual text messages to each patient, but there was evidence that such an intervention improved diabetes management over usual care. In another study, an intervention for children and teenagers with type 1 diabetes was tested by comparing patients receiving standard insulin therapy, standard insulin therapy and EMI, and intensive insulin therapy and

EMI (Franklin et al., 2006). The patients receiving standard insulin therapy experienced no changes in blood glucose control (measured via HbA1c) regardless of whether they received EMI, but those receiving intensive therapy and EMI experienced a significant decrease in HbA1c levels. Due to this study's unbalanced design (i.e., no intensive insulin without EMI condition), it is premature to conclude that EMI can be useful in this format for children with diabetes. Given the complexity of managing diabetes and the chronic nature of the disease, however, EMI could be a promising tool for assisting patients and healthcare providers in managing diabetes and future research in this area is encouraged.

Eating disorder symptoms: Two non-controlled pilot studies examined the efficacy of an "after care" text messaging intervention for patients completing treatment for bulimia nervosa, and showed mixed results. Robinson and colleagues (2006) found that after CBT but before beginning the EMI intervention, 38% of patients experienced subclinical symptoms and 10% were symptom free, and this shifted to 18% and 29% respectively after the 6-month intervention. The percentage of patients with clinical symptoms did not change before (52%) and after (53%) the EMI. These findings are again difficult to confidently interpret because of the uncontrolled research design. In a similar "after care" text messaging intervention, some improvements in self-reported binging and compensatory behaviors (e.g., vomiting) were reported for two patients, but both continued to experience "dysfunctional" levels of body dissatisfaction (Bauer et al., 2003). Although promising, these findings require replication in controlled trials or using superior within subject designs.

Other health behaviors: Three studies described EMI addressing health behaviors that do not fall into the categories outlined above. Weitzel and colleagues (2007) designed an EMI for college student alcohol drinkers aimed at reducing negative consequences of alcohol consumption (e.g., missing class, legal problems, etc.). They found students receiving one daily EMI for two weeks reported consuming alcoholic drinks on fewer days than their peers who only completed EMA. In another intervention, a palmtop computer-based EMI aimed at increasing participants' vegetable and whole grain intake over an 8-week period was tested. Results showed that participants receiving EMI subsequently increased vegetable intake and there was a statistical trend for an increase in dietary fiber as compared to individuals who received standard nutritional psychoeducation (Atienza et al., 2008). In another study (described previously), the goal was to increase middle- and older-aged adults' physical activity using a palmtop computer-based EMI. King and colleagues (2008) found participants receiving the EMI reported higher levels of physical activity (based on mean number of minutes, caloric expenditure and pedometer use), as compared to individuals who only received psychoeducation regarding the benefits of physical activity.

These findings suggest EMI can be designed to change a variety of health behaviors, with varying levels of success. EMI could be especially effective for the treatment of symptoms and health behaviors with discrete antecedent states (e.g., cravings or urges prior to [over]eating, substance use, risky sexual activity, self-harm behavior) or events (e.g., anxiety provoking situation, stressors, mealtimes), as these can serve as triggers for the delivery of EMI. Future research should expand beyond the reliance on broad heuristics for identifying antecedents and use EMA techniques to identify individualized sets of triggers to be used to further tailor EMI content and delivery.

Summary of EMI Feasibility and Efficacy—It is clearly feasible to implement EMI using mobile technology; participants demonstrated adequate compliance to the treatment protocol and identified EMI as credible and acceptable forms of treatment. Empirical evidence suggests EMI can be effective at encouraging smoking cessation, improving weight loss in overweight women, and reducing anxiety symptoms. Several anxiety and weight loss intervention trials demonstrated EMI can produce similar treatment outcome to more time intensive CBT

interventions, and there is some indication that combining CBT and EMI may enhance treatment effects. There are more limited studies examining the efficacy of other psychological and health behavior interventions and further research is clearly warranted.

Although many studies showed treatment gains immediately or shortly after the intervention, there is conflicting evidence regarding the maintenance of effects. Some studies found a decline in treatment gains over time (e.g., Baer et al., 1988; Rodgers et al., 2005; Vidrine et al., 2006), whereas others saw maintenance (Kenardy et al., 2003) or continued improvement after treatment ended (Burnett et al., 1985; Gruber et al., 2001; Newman, Kenardy et al., 1997; Przeworski & Newman, 2004). In cases where treatment effects are lost over time, EMI may also have the potential to be used as an easy, cost-effective way of delivering "booster" treatments over extended periods of time, although this has yet to be formally examined. Interventions that allow people to receive additional support beyond the initial treatment period may help encourage long-term behavior change. For example, patients who benefit from an initial course of treatment (such as CBT) could help to sustain treatment gains and solidify behavior changes by receiving EMI for brief periods of time (days or weeks) periodically over the following months or years. Developing effective methods for implementing booster interventions via mobile technology could improve the efficacy and cost effectiveness of a variety of psychological and behavioral interventions.

Additional Methodological and Statistical Issues

Research Design Considerations

Measurement Reactivity—It is feasible that frequent real-time assessment or treatment contact may change people's natural environment by introducing cues that could alter social, psychological, and behavioral aspects of their lives (i.e., reactivity), and thus not necessarily accurately reflect real-world processes. Empirical examination of this issue, however, provide little evidence for measurement reactivity to EMA protocols (e.g., Cruise, Broderick, Porter, Kaell, & Stone, 1996; le Grange, Gorin, Dymek, & Stone, 2002). One outstanding issue regarding reactivity is that most studies suggesting EMA is not reactive have examined experiences or processes of which participants are commonly aware (e.g., pain, body image). Thus, it may be the case that intensive measurement of a construct that is not normally salient for participants in their everyday lives may produce greater reactivity. When designing EMI protocol, researchers should consider if the frequency of momentary assessments is similar what participants might normally experience in everyday life to reduce concerns regarding reactivity.

Demand Characteristics—Demand characteristics are cues in the experimental manipulation (e.g., intervention) that provide information about the study's expected outcome, causing participants to change their behavior (Kazdin, 2003). This issue is a concern with all psychosocial interventions, as demand characteristics can differentially influence favorable responding on self-report assessments. It is reasonable that individuals receiving EMI may be motivated to respond as they are "supposed to" when asked about symptoms or behavior change. Concerns regarding demand characteristics can be reduced by including objective outcome measures (i.e., not self-report), such as physiological or behavioral assessments. For example, Gruber and colleagues (2001) assessed social anxiety using behavioral ratings during a simulated dinner party, and several smoking cessation interventions have measured salivary cotinine levels to assess for recent tobacco use (Obermayer et al., 2004; Rodgers et al., 2005; Vidrine et al., 2006). Rodgers and colleagues (2005) reported evidence that could suggest experimental demand influenced reported outcomes. In this smoking cessation trial, at the end of 6 weeks, the EMI group showed a greater discrepancy between self-reported and objective indicators of abstinence than did the control group. Due to the large sample size (n=1705),

objective measures were only conducted on 10% of the participants, making strong statements about the role of demand characteristics difficult. Demand characteristics were not discussed in the reviewed interventions and future research should carefully consider their potential influence. Studies should also employ research designs that include objective outcome measures when available and more carefully match levels of demand across treatment conditions in an effort to minimize these concerns.

Data Analysis Issues

Cost-Effectiveness Analyses—One of the benefits of using technology to deliver EMI is that they may provide a cost effective treatment strategy. Cost evaluation analyses are economic analyses that weigh the relative costs and outcomes of two or more treatment strategies by measuring intervention costs, benefits, and effectiveness. A variety of analytic approaches have been suggested for psychological and behavioral health research, with the overall goal of facilitating decisions regarding how healthcare dollars are best spent (Kaplan & Groessl, 2002; Yates & Taub, 2003). Several studies reported the cost of treatment (Gruber et al., 2001; Kenardy et al., 2003; Newman, Kenardy et al., 1997; Przeworski & Newman, 2004), but Agras and colleagues (1990) provided the most complete estimate of treatment costs by measuring the expenses associated with CBT for weight loss (including provider payment and overhead costs), and the cost of palmtop computers and the EMI treatment. The costs were totaled for each of the three treatment groups (palmtop computer-based EMI only, support group and EMI, group CBT only; see Table 1) and the amount of weight lost for each $100 spent on the intervention was calculated for each group. Results showed that per kilogram lost the treatment including the support group and EMI was half the cost of the other treatments, and thus, the most cost effective. Future studies should consider conducting cost effectiveness analyses as they can allow researchers, clinicians, patients, and policy makers to arrive at more informed decisions about the most appropriate allocation of resources.

Analyses of Clinical Significance—Although most of the interventions in this review reported the statistical significance of findings, less than half reported outcomes that convey information regarding practically or clinically relevant changes. Some domains of study reported clinical significance more thoroughly than others. For example, several studies reported on the number of participants who were free or nearly free of anxiety (Baer et al., 1988; Kenardy et al., 2003; Newman et al., 1999; Newman, Kenardy et al., 1997; Przeworski & Newman, 2004) or eating disorder symptoms (Bauer et al., 2003; Robinson et al., 2006), and all of the smoking cessation interventions indicated the percentage of participants who had successfully quit smoking. Given the variety of treatment outcomes assessed in this review, the specific types of clinically significant outcomes will vary, but future research on EMI should assess and report the practical importance of treatment outcomes in addition to statistical significance to provide a more appropriate interpretation of study results.

Intent-to-Treat Analyses—Intent-to-treat analyses are another useful way to convey information regarding the practical significance of the intervention results. The rationale for conducting these analyses is to more accurately account for the effects of participant non-compliance during treatment or follow-up. For example, participants who were unwilling to use mobile electronic devices, or who were not experiencing treatment gains could prematurely terminate study participation, thus biasing the follow-up data. Intent-to-treat analyses include all randomized participants in the group to which they were assigned (regardless of treatment or follow-up adherence), thus providing a more conservative estimate of treatment effects (Lachin, 2000). In the present review, all but one smoking cessation interventions reported intent-to-treat analyses (Whittaker et al., 2008), while most of the remaining studies with missing treatment or follow-up did not conduct or report these analyses. Although some

research domains (i.e., smoking cessation) commonly report these results, there is a need for future work to regularly include intent-to-treat analyses.

Clinical Implementation of EMI

Delivering Interventions to "Hard to Reach" Populations—Mobile electronic devices have unique potential to administer interventions to individuals who may be unable or unwilling to participate in traditional psychotherapy or behavioral interventions. For example, palmtop computers and mobile phones can be used to deliver interventions to people living in rural areas or are home-bound and do not have regular access to behavioral health practitioners. Behavioral telehealth, the use of communication technologies (e.g., videoconferencing) to provide behavioral health care over long distances, is growing in popularity as it can provide assessment, diagnostic, and treatment services to people who may otherwise go without (Boland, 2007; Nickelson, 1996). Mobile technology could be an effective behavioral and health intervention tool in developing countries where the healthcare infrastructure to deliver traditional interventions is less available (Lester, Gelmon, & Plummer, 2006), or for individuals who engage in behaviors that are not conducive for participation in traditional intervention studies (e.g., current drug use, homelessness; Freedman et al., 2006). Using EMI in these settings and populations presents additional challenges, such as concerns about cost of supporting mobile telephones in developing countries or the need to replace mobile devices that are not returned by participants. These limitations are important to note, however, it remains to be seen how the cost of creating and implementing EMI in developing and rural settings or with more challenging populations compares to the construction of infrastructure required to provide more traditional care.

Practical Issues Related to EMI Dissemination—Some have argued that ambulatory assessment and intervention can and should be disseminated for use in everyday clinical practice (Marks, 1999; Newman, Consoli et al., 1997), but there are several practical considerations that must be addressed before widespread dissemination is considered. First, hardware and software must be available to meet specific treatment needs (e.g., motivational program for smoking cessation, CBT for panic disorder), a task that can be accomplished if EMI treatments are manualized and marketed to practitioners (Newman, Consoli et al., 1997). Second, cost considerations must also be acknowledged, as the price of setting up and implementing EMI must be outweighed by the benefits of such a system. Clinicians must consider costs associated with purchasing treatment software, hardware (i.e., computers, mobile devices), and the time required to setup and implement the EMI system. One way to offset hardware costs is to allow or require patients to use their own mobile devices (as was done in most of these studies that used mobile phones). In smaller clinical practices, the cost of setting up an EMI system may exceed potential gains, but for larger practices clinicians may ultimately save time and money. Although outside the scope of this review, for those interested in using mobile technology to implement EMI, hardware and software options and considerations have been described elsewhere (Ebner-Priemer & Kubiak, 2007; Hufford, 2007; Shiffman, 2007; Shiffman, Stone, & Hufford, 2008). Incorporating mobile technology into behavioral health treatments is promising, but the barriers to adoption should be carefully considered. Future research aimed at making ambulatory treatments more accessible and reasonable to implement with respect to cost and time could have important implications for disseminating EMI treatments.

Ethical Considerations Regarding EMI in Research and Practice—Ethical issues related to the use of technology must also be considered in both research and practice. Patient confidentiality is an area of particular concern because of the involvement of computerized records. Clinicians and researchers alike must take precautions to protect patient confidentiality, a task that is made more difficult by the mobile nature of the intervention. One

way patients and research participants' personal information can be protected is by ensuring that access to confidential information on mobile devices is limited by requiring passwords or using a coding system (Newman, Consoli et al., 1997; Schulenberg & Yutrzenka, 2004). Similarly, special care should be taken when storing confidential electronic files that are removed from the mobile devices; these issues become especially important when the technology needs to be serviced by technicians (Schulenberg & Yutrzenka, 2004). As the sophistication of technology continues to improve, it is becoming possible to collect large amounts of information automatically, perhaps even without people's knowledge (e.g., physiological measures, environmental sensors; Gandy et al., 2000; Intille, 2007), raising novel privacy and confidentiality concerns.

Overall Conclusions and Recommendations for Research and Practice

The development of portable electronic devices, such as palmtop computers and mobile telephones, allows for researchers and clinicians to assess, support, and interact with participants and patients in their daily lives. Ecological Momentary Intervention [EMI] studies provide a very promising evidence base for acceptability and efficacy of ambulatory interventions across a variety of physical and mental health conditions and for health behavior change. Despite such promise, a number of methodological, statistical, practical, and ethical concerns remain to be addressed. Table 3 contains a summary of key conclusions and limitations and provides recommendations for future research and clinical practice.

To date, EMI have been used with diverse populations of people to address a variety of physical and mental health conditions and to promote health behavior change. It is still unclear how person-level characteristics (e.g., age, education, familiarity with technology) may influence people's willingness to receive EMI treatment, and additional research addressing this issue is needed. Additionally, more careful attention must be paid to research design in studies testing the efficacy of EMI, including the incorporation of qualitative methods (e.g., patient feedback during intervention development), and the use of EMA/EMI data to examine the real-world use of ambulatory interventions. As this review demonstrates, EMI can take many forms, and have been used as a treatment in and of itself or (more commonly) as a supplement to other psychological or medical treatments. One particularly appealing aspect of EMI is that the content and timing of the intervention can be ideographically tailored to patients. By integrating the assessment and intervention capacities of mobile technology (e.g., palmtop computers, mobile phones, physiological equipment), EMI can be developed that are sensitive to participants' internal states (e.g., mood, cravings, physiological responses) and external cues and contexts (e.g., social interaction, location). Future research should expand beyond the reliance on broad heuristics for identifying potential antecedents and use EMA techniques to identify individualized sets of triggers to be used to further tailor EMI content and delivery.

Perhaps the foremost challenge remaining is that EMI are not yet widely accepted, let alone adopted, in clinical settings, as many practical and ethical concerns remain to be resolved before widespread dissemination can or should occur. Future research should investigate factors that influence clinician's willingness to incorporate technology-based ambulatory interventions, such as lack of technical knowledge, cost and time investment, role adjustment, and skepticism of the value of technology. Better understanding and addressing these barriers, coupled with future research demonstrating the clinical significance and cost-effectiveness of EMI, appears the next step towards successful dissemination and acceptance of ambulatory interventions.

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Table 1

Characteristics of EMI studies for psychosocial and health behavior treatments.

Reference	Treatment Goal	Participant Characteristics (number completing study)	RCT	Study Conditions	Intervention Duration	Assessment Times
Obermayer, Riley, Asif, & Jean-Mary (2004)	Smoking cessation	*n*=46 (31) college student smokers; mean age=20 (age range 18-25); 72% White, 15% Asian, 7% Black, 7% Other; 46% female; United States	No	E: EMI C: None	EMI: 6 weeks	Pre, 3 week, post
Lazev, Vidrine, Arduino, & Gritz (2004)	Smoking cessation	*n*=20 (19) HIV+ smokers; mean age=41; 80% Black, 20% White; 20% female; United States	No	E: EMI C: None	EMI: 2 weeks	Pre, post
Rodgers, Corbett, Bramley, Riddell, Wills, Lin, & Jones (2005)	Smoking cessation	*n*=1705 (1265) smokers; mean age=25; 63% European; 58% female; New Zealand	Yes	E: EMI C: No treatment	EMI: 20 weeks	Pre, 6 week, 12 week, post
Vidrine, Arduino, Lazev, & Gritz (2006)	Smoking cessation	*n*=95 (77) HIV+ smokers; mean age=43; 72% Black, 19% White, 8% Hispanic; 22% female; United States	Yes	E: EMI C: Usual care	EMI: 2 months Usual care: 1 PE counseling session	Pre, 3 month
Brendryen & Kraft (2008)	Smoking cessation	*n*=396 (296) smokers; mean age=36; 50% female; Norway	Yes	E: EMI C: Usual care	EMI: 12 months Usual care: cessation PE information mailed	Pre, 1, 3, 6 month, post
Brendryen, Drozd, & Kraft (2008)	Smoking cessation	*n*=296 (175) smokers; mean age=40; 50% female; Norway	Yes	E: EMI C: Usual care	EMI: 12 months Usual care: cessation PE information mailed	Pre, 1, 3, 6 month, post
Riley, Obermayer, & Jean-Mary (2008)	Smoking cessation	*n*=31 (27) college student smokers; age range 18-24; 65% White, 24% Asian, 5% Black, 3% Hispanic; 53% female; United States	No	E: EMI C: None	EMI: 6 weeks	Pre, post
Whittaker, Maddison, McRobbie, Bullen, Denny, et al. (2008)	Smoking cessation	*n*=17 (13) smokers; age range=16-35+; 35% Maori, 24% Pacific Islander, 18% European, 12% Indian,	No	E: EMI C: None	EMI: 4 weeks	Pre, post

Reference	Treatment Goal	Participant Characteristics (number completing study)	RCT	Study Conditions	Intervention Duration	Assessment Times
		12% Other; 65% female; New Zealand				
Burnett, Taylor, & Agras (1985)	Weight loss	*n*=12 (12), overweight, mean age=42, females; United States	Yes	E: CBT, EMI C: CBT	CBT: 8 weeks (2.5 hours) EMI: 6 weeks	Pre, post, 4 month, 8 month, EMA
Agras, Taylor, Feldman, Losch, & Burnett (1990)	Weight loss	*n*=90, overweight, mean age=45, mean BMI=29.7, mean weight= 171.6 lbs, females; United States	Yes	E1: EMI E2: support group, EMA/EMI C: Group CBT	EMI: 12 weeks Group PE: 4 weeks (session length NR) Group CBT: 12 weeks (session length NR)	Pre, post, 6 month, 12 month, EMA
Burnett, Taylor, & Agras (1992)	Weight loss	*n*=40 (23), overweight, mean age=38, females; United States	Yes	E1: brief EMI E2: brief EMI, support group E3: EMI C: None	Brief EMI: 4 days/week, 10 weeks EMI: 7 days/week, 10 weeks Support group: 10 weeks (5 hours)	Pre, post, EMA
Joo & Kim (2007)	Weight loss	*n*=927 (433), age range 30-60, mean BMI=25.7, 89% female; South Korea	No	E: PE, EMI C: None	PE: 2 sessions (length NR) EMI: 3 months	Pre, post
Patrick, Raab, Adams, Dillon, Zabinski et al. (2009)	Weight loss	*n*=65 (52), mean age=45; 75% Caucasian, 17% Black; 80% female; United States	Yes	E : EMI, brief phone calls C : Usual care	EMI: 4 months Calls: 1/month, 5-15 minutes Usual care: mailed PE materials monthly (4 months)	Pre, 2 month, post
Baer, Minichiello, Jenike, & Holland (1988)	Reduce anxiety symptoms	*n*=1, OCD diagnosis, female, age 58, treatment resistant; United States	No	E: CBT, EMI C: None	As needed for ~2 years	Pre, post, EMA
Newman, Kenardy, Herman, & Taylor (1997)	Reduce anxiety symptoms	*n*=20 (18), panic disorder diagnosis; mean age=38; 83% female, race NR; United States and Australia	Yes	E: Brief CBT, EMI C: CBT	Brief CBT: 4 weeks (6 hours) EMI: 12 weeks CBT: 12 weeks (12 hours)	Pre, post, 6 month, EMA
Newman, Consoli, & Taylor (1999)	Reduce anxiety symptoms	*n*=4 (3), GAD diagnosis; 40-year-old White female, 31-year-old Asian American male, 55-year-old White male; United States	No	E: Group CBT, EMI C: None	Group CBT: 8 weeks (12 hours) EMI: 12 weeks	Pre, post, 6 month, EMA
Gruber, Moran, Roth, & Taylor (2001)	Reduce anxiety symptoms	*n*=54 (39), social phobia diagnosis, mean age=42, 52% female, race NR; United States	Yes	E1: Brief group CBT, EMI C1: Group CBT C2: WLC	Brief CBT: 12 weeks (20 hours) CBT: 12 weeks (30 hours) EMI: 12 weeks	Pre, post, 6 month

Reference	Treatment Goal	Participant Characteristics (number completing study)	RCT	Study Conditions	Intervention Duration	Assessment Times
Kenardy, Dow, Johnson, Newman, Thomson, & Taylor (2003)	Reduce anxiety symptoms	*n*=163 (93), panic disorder diagnosis, mean age=37, 76% female, race NR; Australia and Scotland	Yes	E1: Brief CBT, EMI C1: Brief CBT C2: CBT C3: WLC	Brief CBT: 6 weeks (6 hours) CBT: 12 weeks (12 hours) EMI: 12 weeks	Pre, post, 6 month
Przeworski & Newman (2004)	Reduce anxiety symptoms	*n*=1, social phobia diagnosis, 24-year-old White female; United States	No	E: Group CBT, EMI C: None	Group CBT: 8 weeks (12 hours) EMI: 12 weeks	Pre, post, 6 month, EMA
Kwon, Cho, Kim, Lee, Song, et al. (2004)	Improve diabetes self-care	*n*=185, Type 1 2 diabetes, mean age=42 29% female; South Korea	No	E: EMI C: None	EMI: 3 months	Pre, post, EMA
Franklin, Waller, Pagliari, & Greene (2006)	Improve diabetes self-care	*n*=92 (90), Type 1 diabetes, median age 12-14, 97% Caucasian, 46% female; Scotland	Yes	E1: EMI, insulin E2: EMI, intense insulin C: Insulin	EMI: 12 months Insulin: 12 months	Pre, post
Yoon & Kim (2008)	Improve diabetes self-care	*n*=100 (51), diabetes, mean age=47, 57% female; South Korea	Yes	E: EMI C: Usual care	EMI: 12 months Usual care: medical care	Pre, 3, 6, 9 month, post
Bauer, Percevic, Okon, Meermann, & Kordy (2003)	Reduce eating disorder symptoms	*n*=2, bulimia nervosa diagnosis, 21-year-old female, 20-year-old female, race NR; Germany	No	E: EMI C: None	EMI: 12-14 weeks	EMA
Robinson, Perkins, Bauer, Hammond, Treasure, & Schmidt (2006)	Reduce eating disorder symptoms	*n*=21(9), bulimia nervosa diagnosis, median age=26, 95% female; England	No	E: EMI C: None	EMI: 6 months	Pre, post, EMA
Weitzel, Bernhardt, Usdan, Mays, & Glanz (2007)	Reduce alcohol use	*n*=40 (39) college student drinkers, mean age=19, 75% White, 55% female; United States	Yes	E: EMI C: EMA	EMI: 2 weeks EMA: 2 weeks	Pre, post, EMA
Atienza, King, Oliveria, Ahn, & Gardner (2008)	Improve dietary intake	*n*=36 (27), mean age=58-63, 89% White, 70% female; United States	Yes	E: Paper PE, EMI C: Paper PE	Paper PE: 1 session (length NR) EMI: 8 weeks	Pre, post, EMA
King, Ahn, Oliveria, Atienza, Castro, & Gardner (2008)	Increase physical activity	*n*=37 (37), mean age=60; 74-83% White, 42-44% female; United States	Yes	E: Paper PE, EMI C: Paper PE	Paper PE: 1 session (length NR) EMI: 8 weeks	Pre, post, EMA

Note. BMI=body mass index, C=control condition, CBT=cognitive behavior therapy, E=experimental condition, EMA=ecological momentary assessment, EMI=ecological momentary intervention, GAD=generalized anxiety disorder, NR=not reported, OCD=obsessive-compulsive disorder, PE=psychoeducation, post=post-intervention assessment, pre=pre-intervention assessment, RCT=randomized controlled trial, WLC=waitlist control.

Table 2

Key features of the Ecological Momentary Intervention [EMI] treatment component

Reference	Type of Technology	Additional Treatment Components	Automated EMI Delivery	EMI Frequency	EMI Duration	Intervention Content	EMI Trigger(s)	EMI Timing Tailored	EMI Content Tailored
Obermayer, Riley, Asif, & Jean-Mary (2004)	Mobile phone: SMS	Interactive website	Yes	Minimum 2/day	6 weeks	BT, PE, FB	User initiated, fixed time, tailored dates and times	Mixed	No
Lazev, Vidrine, Arduino, & Gritz (2004)	Mobile phone: voice	None	No	6 calls (2 weeks)	2 weeks	BT, CT, MT	User initiated, tailored dates, times NR	Yes	Yes
Rodgers, Corbett, Bramley, Riddell, Wills, Lin, & Jones (2005)	Mobile phone: SMS	Interactive website	Yes	5/day (5 weeks) 3/week (6 months)	6 months	BT, PE, MT	User initiated, tailored dates, random time	Mixed	Yes
Vidrine, Arduino, Lazev, & Gritz (2006)	Mobile phone: voice	None	No	8 calls (2 months)	8 weeks	BT, CT, MT	User initiated, tailored dates, times NR	Yes	Yes
Brendryen & Kraft (2008)	Mobile phone: voice and SMS	Interactive website	Yes	1-4/day	1 year	BT, PE, MT	User initiated, random time, fixed time	Mixed	Yes
Brendryen, Drozd, & Kraft (2008)	Mobile phone: voice and SMS	Interactive website	Yes	1-4/day	1 year	BT, PE, MT	User initiated, random time, fixed time	Mixed	Yes
Riley, Obermayer, & Jean-Mary (2008)	Mobile phone: SMS	Interactive website	Yes	1-3/day	6 weeks	BT, PE, FB	User initiated, fixed time, tailored dates and times	Mixed	No
Whittaker, Maddison, McRobbie, Bullen, Denny, et al. (2008)	Mobile phone: SMS video, text	None	Yes	2/day	4 weeks	BT, PE, MT	User initiated, user selected timeframe (random within timeframe)	Mixed	No
Burnett, Taylor, & Agras (1985)	Palmtop computer	Individual CBT	Yes	Minimum 4/day	6 weeks	BT, FB, MT	User initiated, fixed times	Mixed	Yes
Agras, Taylor, Feldman, Losch, & Burnett (1990)	Palmtop computer	None, support group	Yes	Variable	12 weeks	BT, FB, MT	User initiated	Yes	Yes
Burnett, Taylor, & Agras (1992)	Palmtop computer	None, support group	Yes	Variable	10 weeks	BT, FB, MT	User initiated	Yes	Yes
Joo & Kim (2007)	Mobile phone: SMS	Mailed PE material weekly	Yes	1/week	12 weeks	BT, PE, MT	Random times	No	No
Patrick, Raab, Adams, Dillon, Zabinski et al. (2009)	Mobile phone: SMS	PE materials and phone call monthly	Yes	2-5/day	4 months	BT, PE, MT	User selected times	Yes	No
Baer, Minichiello, Jenike, & Holland (1988)	Palmtop computer	Individual CBT	Yes	Variable	2 years	BT, CT, FB	User initiated	Yes	Yes
Newman, Kenardy, Herman, & Taylor (1997)	Palmtop computer	Individual CBT	Yes	Minimum 4/day	12 weeks	BT, CT	User initiated, 30 minutes after user initiated, fixed times	Mixed	Mixed
Newman, Consoli, & Taylor (1999)	Palmtop computer	Group CBT	Yes	Minimum 4/day	12 weeks	BT, CT, MT	User initiated, when anxiety reported (via EMA)	Yes	Yes
Gruber, Moran, Roth, & Taylor (2001)	Palmtop computer	Group CBT	Yes	Minimum 1/day	12 weeks	BT, CT, MT	User initiated, 2 hour after user initiated, fixed times	Mixed	Mixed
Kenardy, Dow, Johnson, Newman, Thomson, & Taylor (2003)	Palmtop computer	Individual CBT	Yes	5/day	12 weeks	BT, CT	User initiated, fixed times	Mixed	Mixed
Przeworski & Newman (2004)	Palmtop computer	Group CBT	Yes	Minimum 5/day	12 weeks	BT, CT, MT	User initiated, when anxiety reported (via EMA)	Yes	Yes

Reference	Type of Technology	Additional Treatment Components	Automated EMI Delivery	EMI Frequency	EMI Duration	Intervention Content	EMI Trigger(s)	EMI Timing Tailored	EMI Content Tailored
Kwon, Cho, Kim, Lee, Song, et al. (2004)	Mobile phone: SMS	Interactive website	No	NR	12 weeks	BT, MT	Random times	No	Yes
Franklin, Waller, Pagliari, & Greene (2006)	Mobile phone: SMS	Interactive website	Mixed	1-2/day	1 year	BT, PE	User initiated, random times	Mixed	Yes
Yoon & Kim (2008)	Mobile phone: SMS	Interactive website	No	1/week	1 year	BT, MT	Random times	No	Yes
Bauer, Percevic, Okon, Meermann, & Kordy (2003)	Mobile phone: SMS	Post-CBT	No	1/week	12-14 weeks	BT, CT, MT	Random times	No	Yes
Robinson, Perkins, Bauer, Hammond, Treasure, & Schmidt (2006)	Mobile phone: SMS	Post-CBT	No	1/week	6 months	BT, CT, MT	Random times	No	Yes
Weitzel, Bernhardt, Usdan, Mays, & Glanz (2007)	Palmtop computer	None	No	1 message/day	2 weeks	BT, FB	Random times	No	Yes
Atienza, King, Oliveria, Ahn, & Gardner (2008)	Palmtop computer	Nutrition PE	Yes	2/day	8 weeks	BT, FB	Fixed times	No	Yes
King, Ahn, Oliveria, Atienza, Castro, & Gardner (2008)	Palmtop computer	Individual exercise PE	Yes	2/day	8 weeks	BT, FB	Fixed times	No	Yes

Note. BT=general behavioral treatment (goal setting, behavior modification, self-regulation), CBT=cognitive behavior therapy, CT=general cognitive treatment (challenging distorted thinking, cognitive reframing), EMA=ecological momentary assessment, EMI=ecological momentary intervention, FB=feedback, Mixed=combination of methods, MT=motivational, NR=not reported, PE=psychoeducation, SMS=short message service (i.e., text messaging).

Table 3

Key conclusions and limitations of the reviewed interventions and recommendations for future research and practice.

	Key Conclusions and Limitations	Research and Practice Recommendations
Participant Characteristics	**Demographic Characteristics** • EMI can be used to treat various psychological and physical symptoms and health behaviors • EMI successfully implemented with men and women from teens to 60s	• Older adults and individuals unfamiliar with mobile technology may require additional training to use electronic devices
	Technology Literacy • EMI can be implemented with people who have varying levels of familiarity with technology	• Most participants need extensive training to use palmtop computer-based EMI; mobile phone EMI studies require less training for most people (especially when using their own mobile phone)
	Sampling Bias • People uncomfortable using mobile electronic devices may self-select out of EMI studies, an issue not empirically addressed in any studies	• Research identifying person-level characteristics (e.g., age, education, familiarity with technology) that influence willingness to participate in EMI studies is needed, so appropriate dissemination methods can be developed
Research Design Issues	**Study Design** • A variety of designs were used including case reports, uncontrolled trials, and RCTs	• More RCTs are needed and comparison conditions should be selected to test EMI against existing treatments • Elicit participant feedback during intervention development to improve treatment design and delivery

	Key Conclusions and Limitations	Research and Practice Recommendations
	Assessment Times	
	• Most studies use relatively short treatment follow-up periods (less than 6 months) • Results from EMA data are not often reported	• Longer-term follow-up evaluations are needed to establish the efficacy and utility of EMI • EMA data collected during the intervention can address more nuanced research questions regarding EMI implementation and efficacy
	Additional Design Considerations	
	• Previous research shows limited evidence for measurement reactivity to EMA • Demand characteristics are not discussed; results of one study suggest demand may account for treatment outcome	• Limit reactivity by designing protocols using EMI with similar frequency and duration to the exposure participants might encounter in everyday life • Reduce demand characteristics by using objective outcome measures (if possible) and matching demand across conditions
	Delivery Methods	
	• Automated EMI delivery systems require little ongoing involvement by researchers or clinicians • Ideal intervention duration and EMI frequency depend on study sample and treatment objectives	• Need feedback from participants regarding the balance between study duration and EMI frequency (preferably during the design phase of the intervention so the EMI protocol can be adjusted as needed)
EMI Features	**Intervention Components**	
	• EMI elicit symptom and behavior changes when implemented with other interventions (e.g., CBT, psychoeducation, support group) • Few studies test the efficacy of EMI provided without any additional treatment or intervention	• Investigations of the efficacy of EMI administered with minimal additional treatment support are necessary to identify for whom such EMI may be most (or least) beneficial
	EMI Content	

	Key Conclusions and Limitations	Research and Practice Recommendations
	• EMI included a variety of treatment approaches (psychoeducation, motivational techniques, behavioral interventions, cognitive restructuring)	• Relative contribution of EMI content (i.e., psychoeducation, motivation, behavioral, cognitive) remains to be determined
	EMI Tailoring	
	• Content and timing of EMI can be individually tailored based on pre-intervention evaluations or momentary assessment data (i.e., EMA) • Non-tailored (standard) EMI may not be well received by participants • No clear pattern emerged regarding the relationship between EMI tailoring and treatment efficacy	• Consider tailoring EMI content and timing based on data from momentary assessments (e.g., EMA, ambulatory physiological measures, environmental sensors) • Need studies experimentally manipulating the extent to which EMI content and timing are tailored to determine how tailoring influences treatment acceptability and efficacy
	Feasibility and Acceptability	
	• Adequate compliance with EMI procedures was seen • EMI treatments were perceived as credible and acceptable by participants	• Need research examining the relationship between EMI compliance and treatment efficacy
Intervention Efficacy	**Symptom and Health Behavior Outcomes**	
	• Several studies demonstrate EMI can be effectively implemented as part of smoking cessation, weight loss, and anxiety interventions • There is more limited (but promising) evidence for the use of EMI in diabetes management • Other health behaviors including healthy eating, physical activity, and alcohol use have been effectively targeted using EMI • Study design limitations prevent conclusions regarding treatment efficacy	• Research should move beyond only developing more cost effective treatments; use EMI to develop interventions with superior efficacy to existing therapies • Conclusions regarding the efficacy of weight loss EMI are limited to overweight women and additional research with men is necessary • RCTs or studies using superior within subject designs are needed to test the efficacy of EMI (particularly for

	Key Conclusions and Limitations	Research and Practice Recommendations
	EMI for eating disorder symptoms	eating disorder symptoms and diabetes management) • Future research using mobile technology to deliver EMI as "booster" treatments may provide a cost effective method for improving the long-term efficacy of psychosocial interventions
Data Analysis Issues	• Few studies estimated the cost-effectiveness of EMI • Less than half the studies reported the clinical significance of outcomes • Some research domains (e.g., smoking cessation) conduct intent-to-treat analyses, but most others do not	• More cost-effectiveness analyses are need to help researchers, clinicians, patients, and third-party payers make more well-informed treatment decisions • Need to conduct clinical significance and intent-to-treat analyses so researchers and clinicians can better anticipate treatment outcomes in clinical settings
Clinical Implementation	• Mobile technology could be used to deliver EMI to people without access to behavioral healthcare (e.g., in developing countries or rural areas, home-bound) • Before EMI are disseminated for clinical use, treatment programs must be developed and marketed and clinicians' cost concerns addressed • Unique ethical concerns (practitioner competence, patient confidentiality) arise with mobile technology use	• Research is need to determine if EMI are a cost-effective alternative to developing infrastructure for traditional medical and psychological interventions in developing countries and rural settings • Manualized EMI treatment programs must be developed before EMI can be widely used in clinical settings

Note. CBT=cognitive behavior therapy, EMA=Ecological Momentary Assessment, EMI=Ecological Momentary Intervention, RCT=randomized control trial.