Psychological Medicine (2012), **42**, 1119–1129. © Cambridge University Press 2011
doi:10.1017/S0033291711002200

REVIEW ARTICLE

Experience Sampling Methodology studies of depression: the state of the art

C. Telford[1], S. McCarthy-Jones[2,3]*, R. Corcoran[4] and G. Rowse[2]

[1] *Sheffield Asperger Syndrome Service, St George's Community Health Centre, Winter Street, Sheffield S3 7ND, UK*
[2] *Clinical Psychology Unit, University of Sheffield, Western Bank, Sheffield S10 2TN, UK*
[3] *Macquarie Centre for Cognitive Science, Macquarie University, Balaclava Road, North Ryde, NSW 2109, Australia*
[4] *Division of Psychiatry, University of Nottingham, Queen's Medical Centre, Nottingham NG7 2UH, UK*

Background. Experience Sampling Methodology (ESM) is ideally suited to test the predictions, and inform the development of contemporary cognitive models of depression. Yet there has been no systematic examination of ESM in depression research.

Method. A search of databases (PsychARTICLES, PsycINFO, AMED, Ovid Medline and CINAHL) was conducted to identify studies published within the last 25 years investigating major depressive disorder (MDD) using ESM.

Results. Altogether, 19 studies using ESM, or comparable methodologies, with clinically depressed individuals were identified and critically reviewed. The identified studies examined six aspects of MDD: methodological issues; positive and negative affect; cortisol secretion; antidepressant treatment; work performance; genetic risk factors.

Conclusions. Despite some methodological limitations of existing studies, ESM has made a significant contribution to our current understanding of depression by consolidating existing theories, uncovering new and clinically relevant findings and identifying questions for future research. This review concludes by introducing the possibility of using ESM as an intervention tool in clinical practice and proposing that ESM could be useful for furthering knowledge of the causes of MDD.

Received 24 September 2010; Revised 31 August 2011; Accepted 13 September 2011; First published online 19 October 2011

Key words: Depression, depressive disorder, ecological momentary methodology, experience sampling methodology.

Introduction

Preliminary research using Experience Sampling Methodology (ESM) began in the early 1980s to explore subjective reactions to experiences as they occur in the natural environment. ESM provides ecologically valid, real-life characterizations of thinking and behaviour (Hurlbert, 1997) by employing electronic signalling devices to prompt participants to complete self-reports at pre-selected randomized time-points. Thus, information on participants' environment, activities, thoughts, feelings or symptoms can be gathered 'within the context and flow of everyday experience' (de Vries, 2006, p. 8). ESM data collection can be coupled with simultaneous physiological measures, such as changes in levels of stress hormones that accompany experiences. The reliability, validity and feasibility of ESM in clinical samples has been demonstrated by Csikszentmihalyi & Larson (1987, 2006), who showed that ESM data can discriminate between clinical and non-clinical groups, is more reliable than retrospective self-reports, is a stable measure over time, has good individual response consistency and results in satisfactory participant compliance. To date, ESM has been used to investigate conditions including schizophrenia (Myin-Germeys *et al*. 2001), bulimia (Larson & Asmussen, 1992), panic disorder (Dijkman-Caes & de Vries, 1991), personality disorder (Loewenstein *et al*. 1987) and major depressive disorder (MDD) (e.g. Myin-Germeys *et al*. 2003*b*).

However, ESM studies examining the aetiology and impact of depression on everyday functioning are relatively new. ESM is ideally suited to test the predictions and inform the development of contemporary cognitive models of depression. This is not only because it can test theories and models in an ecologically valid way, but also because it offers a way to gain novel insights into the spontaneously occurring thoughts, feelings and physiological changes that accompany depression that would not be detected by retrospective self-report or cross-sectional

* Address for correspondence: Dr S. McCarthy-Jones, Clinical Psychology Unit, Sheffield University, Western Bank, Sheffield S10 2TN, UK.
(Email: s.mccarthyjones@gmail.com)

laboratory-based studies. Although literature reviews of ESM in psychosis research have been conducted previously (Myin-Germeys *et al*. 2003*a*; Oorschot *et al*. 2009) and a recent review paper briefly examined ESM studies of depressed individuals (Myin-Germeys *et al*. 2009), there has been no systematic critique of ESM in depression research. This paper aims to address this gap by reviewing the contribution of ESM in studies of clinical depression and considering how this technique might be used to advance our knowledge of depression and its treatment.

Method

Inclusion criteria were defined as:

(1) Published in English language, peer-reviewed journals.
(2) Published in the last 25 years.
(3) Use of ESM requiring participants to complete daily diaries (electronic or paper) in response to hearing pre-programmed auditory signals from a portable device.
(4) Include participants with a diagnosis of MDD.
(5) Statistical analyses performed using hierarchical or multi-level regression analyses. Hierarchical or multi-level regression analyses are ideally suited to ESM studies because of the nested structure of ESM data, with levels of nesting at 'beep', 'day' and 'person' level (Walls *et al*. 2006), and their ability to acknowledge that observations from the same participant are more similar than observations from different participants.

Search strategy

The studies included in this review were identified by systematically searching, up to July 2009, the following five databases: PsychARTICLES; PsycINFO; AMED (Allied and Contemporary Medicine); Ovid Medline; CINAHL (Cumulative Index to Nursing & Allied Health Literature). To reflect the fact that there exists a range of other techniques with a family resemblance to ESM, such as ecological momentary analysis (EMA) and electronic diary studies, the keywords 'ecological momentary analysis', 'EMA' and 'electronic diary' were also employed in the search. Although there are important differences, as well as similarities, between ESM and EMA (Hektner *et al*. 2007), for the purposes of the present review we treated EMA as a form of ESM. The search string employed in the present study was ('experience sampling' OR 'ESM' OR 'ecological momentary analysis' OR 'EMA' OR 'electronic diary' OR 'momentary assessment') AND ('depression' OR 'depressive disorder').

Results

Studies that sampled the participants' experience only once per day (e.g. Stetler & Miller, 2005; Cohen *et al*. 2008) were deemed not to sample the ambulatory nature of participant's states in sufficient detail to be comparable with the majority of other studies identified by our search and were hence excluded. Other studies (e.g. Putnam & McSweeney 2008; Silk *et al*. 2007; Forbes *et al*. 2009) that only sampled experience in order to create an ecologically valid measure of a given construct (e.g. affect) were also excluded. ESM studies that failed to use hierarchical or multi-level regression analyses (Barge-Schaapveld *et al*. 1995; Conrad *et al*. 2008) in addressing topics that later studies subsequently addressed using such analyses were also excluded from this review. However, the study of Whalen *et al*. (2008), which failed to employ hierarchical or multi-level regression analyses (instead using a mixed method analysis of variance), was included as it made a contribution to the field by assessing a novel variable (caffeine use) not reported on by other studies. After this process, 19 published articles were selected for inclusion in this review. Table 1 provides details of the characteristics and main findings of these studies.

Aspects of MDD as explored using ESM

Although all 19 studies reviewed collected data within the 'flow of everyday experience' (de Vries, 2006, p. 8), six broad themes were identified.

Theme 1: Methodological issues

Husky *et al*. (2010) examined acceptance rates, compliance rates, fatigue effects and reactivity to ESM techniques in individuals with MDD in order to establish the feasibility of this methodology in this population. All patients with MDD who were invited to enter the ESM study agreed to participate. Altogether, 95% completed at least 50% of the assessments and 70% completed 95% of the assessments. A practice effect was found, with MDD patients completing assessments more quickly as the study proceeded. The authors concluded that the results supported the feasibility and validity of this methodology in patients with MDD. However, it should be noted that Husky *et al*. used a lower frequency of sampling (five beeps per day) than most of the other studies (10 beeps per day) reviewed here. This may mean their compliance rates are not generalizable to the other studies reviewed in this paper.

Two studies examined how data collected by ESM compared with data obtained from retrospective reports. A first study examined data collected by these

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

two methodologies on levels of positive affect (PA) and negative affect (NA). Ben-Zeev *et al*. (2009) found that levels of PA and NA, reported by both MDD patients and healthy controls during an ESM study, differed from their retrospective reports. Both groups' retrospective reports overestimated the level of PA and NA that they reported in the ESM stage of the study. MDD patients were more inaccurate at recalling levels of NA (but not PA) than healthy controls. It was also found that, whereas controls recalled more PA than NA, MDD patients did not show this bias, but neither did they recall more NA than PA. In a later study, Ben-Zeev & Young (2010) examined this effect for specific symptoms of depression. Patients with MDD were found to have a greater negative retrospective bias (i.e. they claimed in retrospect to have experienced higher levels of such symptoms than they actually reported in the ESM phase) than healthy controls for anhedonia, suicidality, sadness and confusion. Healthy controls were found to have positive retrospective biases (i.e. they claimed in retrospect to have experienced lower levels of such symptoms than they actually reported in the ESM phase) for detachment, helplessness, self-control and anhedonia, which patients with MDD did not display.

The three methodological studies of ESM with patients with MDD indicate that the method is tolerable, provides data that appear to better represent their internal states than retrospective methodologies and provides additional information in terms of the nature of their retrospective biases.

Theme 2: PA, NA and stress

All studies that reported data on absolute levels of PA and NA found that individuals with MDD reported higher levels of NA and lower levels of PA than healthy controls (Barge-Schaapveld *et al*. 1999; Myin-Germeys *et al*. 2003*b*; Peeters *et al*. 2003*c*, 2006; Bower *et al*. 2010). By comparing the diurnal mood variation of PA and NA in adults with MDD and healthy controls, Peeters *et al*. (2006) found that moment-to-moment variability of mood state was more pronounced in those with more severe depression. Depressed participants' PA levels increased more during the course of the day, peaked later and showed reduced inter-individual variation. Their NA levels showed increased diurnal variation with decreasing NA levels during the course of the day, greater inter-individual and more moment-to-moment variation than healthy controls.

Peeters *et al*. (2003*c*) found that individuals with MDD reported similar frequencies of negative daily events compared with healthy controls, but that they appraised these events as being more stressful, unpleasant and important. Yet despite making such appraisals, MDD patients showed significantly smaller ('blunted') NA increases in response to negative daily events than healthy controls. However, negative daily events had a more persistent effect on NA levels for MDD participants. A later study by the same group (Peeters *et al*. 2010) found that diminished emotional reactivity to everyday life events predicted relatively higher depression severity levels after 1 month of a pharmacotherapy and psychotherapy intervention. Furthermore, individuals who exhibited reduced NA reactivity to negative daily events were also less likely to have recovered 18 months later.

Myin-Germeys *et al*. (2003*b*) also examined perceived stress and affect in patients with MDD. They found that MDD patients reported more stress due to ongoing activities and their social environment than did controls. They also found, in seeming contradiction to Peeters *et al*. (2003*c*), that the MDD group had a greater increase of NA in response to stress resulting from ongoing activities (but not social context) than healthy controls. Myin-Germeys and colleagues proposed that their results differed to Peeters and colleagues due to the different operationalizations of stress (activity-related stress *versus* negative daily events respectively). However, Wichers *et al*. (2009*a*), in a study reported in more detail in Theme 6, found (using a negative daily events definition of stress) that MDD was associated with greater levels of NA in response to negative daily events. Hence, the difference between event- and activity-related stress cannot fully explain the incongruence of the results of Myin-Germeys *et al*. (2003*b*) with those of Peeters *et al*. (2003*c*). This highlights the need for clear, comparable operationalizations of affect and stressor types in ESM studies.

Another ESM study examined factors that predicted levels of NA and PA in MDD patients. Using ESM, Bower *et al*. (2010) found that sleep quality predicted levels of PA in both healthy controls and patients with MDD, but did not predict levels of NA in either of these groups once diagnostic status had been controlled for. Going beyond simple measures of affect, Barge-Schaapveld *et al*.'s (1999) ESM study attempted to look at a more general measure of well-being, quality of life and, in particular, 'moment-to-moment quality of life' (mQoL) as assessed by the question: 'In general, how is it going with you right now?'. The authors found that, compared with healthy controls, depressed participants had more frequent and severe physical complaints, lower levels of mQoL and less activity enjoyment. Although there were no group differences in time spent in social, leisure or maintenance activities, depressed participants were more likely than controls to be doing nothing and less likely

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

Table 1. *Summary of Experience Sampling Methodology (ESM) studies of depression*

Study	Location, sample (*n*)	ESM design	Main findings
Barge-Schaapveld *et al.* (1999)	Netherlands: 63 primary care MDD patients and 22 healthy controls	Wristwatch signals 10 × daily for 6 days	PA and activity enjoyment were linked to mQoL levels. MQoL was more variable in depressed adults
Barge-Schaapveld *et al.* (2002)	Netherlands: primary care MDD patients receiving imipramine ($n=32$) or placebo treatment ($n=31$) and 22 healthy controls	Wristwatch signals 10 × daily for 6 days in baseline week, 3 days of 1st treatment week, 6 days of 6th week and 6 days of 18th week	Treatment related increases in side-effect severity were associated with lowered mQoL. Treatment appeared to stabilize mQoL fluctuation and lead to reduced inactivity. MQoL was observed to take longer to normalize than retrospective global QoL measures suggest
Ben-Zeev *et al.* (2009)	USA: 26 community patients with MDD, 25 healthy controls	Personal digital assistant signals 9 × daily for 'a week'	Both groups recalled more PA and NA than reported during ESM stage. MDD patients more inaccurate at recalling levels of NA. Controls recalled more PA than NA. MMD patients did not show this pattern, but nor did they recall more NA than PA
Ben-Zeev & Young (2010)	USA: 26 hospitalized patients with MDD, 25 healthy controls	Pager signals between 6 or 7 × daily for 'a week'	Patients with MDD retrospective reports exaggerated six of 13 forms of NA compared with healthy controls
Bower *et al.* (2010)	USA: 35 community patients with MDD, 25 with minor depression and 36 healthy controls	Personal digital assistant signals 10 × daily for 3 days	Poor sleep quality associated with reduced PA in all groups, but not NA (once diagnostic group was controlled for)
Husky *et al.* (2010)	USA: 20 out-patients with MDD, 21 with bipolar disorder	Personal digital assistant signals 5 × daily for 3 days	This methodology is feasible and valid with patients with MDD
Myin-Germeys *et al.* (2003*b*)	Netherlands: 38 BD, 46 MDD and 42 NAP patients, plus 49 healthy controls	Wristwatch signals 10 × daily for 6 days	Changes in negative and PA associated with subjectively stressful situations differed among the three clinical groups. NAP patients were more vulnerable to the effects of daily life stress *vis-à-vis* BD and MDD patients
Peeters *et al.* (2003*c*)	Netherlands: 44 MDD out-patients and 37 healthy controls	Wristwatch signals 10 × daily for 6 days	Compared with healthy controls, MDD negative and PA responses were blunted in response to minor negative events, but enhanced following positive events
Peeters *et al.* (2003*a*)	Netherlands: 45 MDD out-patients and 39 healthy controls	Wristwatch signals 10 × daily for 6 days (plus saliva samples)	*Vis-à-vis* healthy controls, cortisol responsivity to negative daily events was blunted in MDD patients (particularly males and participants with a family history of mood disorder)
Peeters *et al.* (2003*b*)	Netherlands: 47 MDD out-patients and 39 healthy controls	Wristwatch signals 10 × daily for 6 days (plus saliva samples)	ESM highlighted cortisol abnormalities in MDD involve dysregulation, not hyperactivity
Peeters *et al.* (2006)	Netherlands: 46 MDD out-patients and 39 healthy controls	Wristwatch signals 10 × daily for 6 days	ESM highlighted distinct diurnal disturbances of positive and NA in MDD participants compared with healthy controls
Peeters *et al.* (2010)	Netherlands: 46 out-patients with MDD	Wristwatch signals 10 × daily for 6 days	Greater emotional reactivity during ESM sampling predicted greater depression levels at 1 month follow-up. Those who showed less emotional reactivity to negative events were less likely to have recovered at 18 month follow-up

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

Table 1. (*cont.*)

Study	Location, sample (*n*)	ESM design	Main findings
Stetler *et al.* (2004)	USA: 47 individuals diagnosed with major or minor depression and 50 healthy controls recruited via community adverts	Handheld computers signalling 4 × daily at 1, 4, 9 and 11 h after participants' pre-reported waking time for four non-consecutive days. Saliva samples collected	Unlike the healthy control participants, cortisol secretion among depressed participants was unrelated to regular activities (especially social activities) – consistent with the hypothesis that activities are less able to entrain the diurnal rhythms of depressed adults
Wang *et al.* (2004)	USA: 286 employees with chronic medical conditions or a diagnosis of MDD (group *n* not reported)	Electronic pagers randomly signalling 5 × daily for 7 days. Work performance reported	MDD was significantly related to decrements in work performance and the findings advocated better accessibility to treatments for depression
Whalen *et al.* (2008)	USA: 30 adolescents and children, aged 7–17 years with MDD, 23 healthy controls	Answer only mobile phone, 12 × a weekend for 8 weekends	MDD group consumed more caffeine. Caffeine use decreased in MDD group as their treatment continued. Daily caffeine use was positively associated with daily nervousness for youth with MDD, but not controls
Wichers *et al.* (2007*a*)	Belgium: 259 female twin pairs (89 with a depressed co-twin)	Wristwatch signals 10 × daily for 5 days	Probands with a depressed co-twin showed a mood bias to stress – showing genetic risk of depression is related to heightened NA in response to daily stress
Wichers *et al.* (2007*b*)	Belgium: 268 female twin pairs (72 with a depressed co-twin)	Wristwatch signals 10 × daily for 5 days	PA was found to reduce the interaction between proband appraisal of stress and co-twin depression. Results indicated that PA buffers against negative reactivity and genetic risk of depression
Wichers *et al.* (2009*a*)	Netherlands: 279 female twin pairs (88 with a depressed co-twin)	Wristwatch signals 10 × daily for 5 days	Subjects at high genetic risk of depression developed higher levels of daily life stress-sensitivity after exposure to prenatal (birth weight) and post-natal (childhood adversity and adult recent negative life events) stress exposures than those at low genetic risk
Wichers *et al.* (2009*b*)	Netherlands: 83 out-patients with MDD, 22 healthy controls	Wristwatch signals 10 × daily for 6 days	Treatment with imipramine decreased stress-sensitivity and increased reward experience

MDD, Major depressive disorder; PA, positive affect; NA, negative affect; mQoL, momentary quality of life; BD, bipolar disorder; NAP, non-affective psychosis.

All participants were aged >18 years unless stated otherwise.

to be engaged in work (despite similar employment rates in both groups). Analyses showed that PA and activity enjoyment were associated with higher mQoL, whereas NA and physical complaints were associated with lower mQoL in both groups. Among depressed participants there was more moment-to-moment, day-to-day and inter-individual variability in mQoL.

Finally, Whalen *et al.* (2008) used EMA to investigate interrelations between affect and caffeine use in youths with MDD. Their study found that at baseline youths with MDD used more caffeine than healthy controls. Over 8 weeks of cognitive behavioural therapy (CBT) and/or psychopharmacology, MDD patients experienced a four-fold decrease in caffeine consumption across treatment, even though they were not explicitly told to abstain from caffeine. The authors suggest that youths with MDD may use caffeine to help treat symptoms of depression. The authors also examined the relationship between caffeine consumption and NA. The daily level of caffeine consumption predicted levels of all four types of NA on the same day (sadness, anger, nervousness and upset). Additionally, an interaction was found between caffeine consumption and diagnostic group in predicting

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

nervousness, with daily caffeine use being positively associated with daily nervousness for youths with MDD, but not for healthy individuals.

In summary, it appears that altered diurnal mood variation and emotional reactivity, lower PA and higher NA, alongside more moment-to-moment variability in levels of affect are characteristic of depression. In addition to producing findings specifically pertaining to NA and PA, these studies also show how ESM can be used to assess other variables (e.g. quality of life, nutritional intake and levels of specific forms of stress) that are likely to prove of relevance to our understanding of MDD.

Theme 3: Cortisol secretion

Hormones secreted from the hypothalamic-pituitary-adrenal axis play a role in the aetiology of mood disorders (e.g. Holsboer, 2001) and it is understood that cortisol helps restore homeostasis following stress. ESM has been used to assess such moment-to-moment physiological changes and concurrent affect.

Participants in Peeters *et al*.'s (2003*a*) study collected salivary cortisol at the same time as making ESM self-reports. Participants with MDD, unlike healthy controls, showed no significant increase in cortisol following negative events. Subanalyses showed that cortisol responses to negative events were significantly lower in men with MDD (compared with women with MDD) and also lower in MDD participants with a family history of mood disorder. Although participants in this study with MDD did not differ from healthy controls in their diurnal pattern of cortisol levels, in a more detailed examination of cortisol levels and variability over the course of the day by Peeters *et al*. (2003*b*) analysis of within-person variability among MDD patients revealed a more erratic pattern of cortisol secretion throughout the day, particularly in patients with more severe or recurrent episodes. Yet, although small elevations in cortisol secretion were associated with more severe depressive symptoms, there was no evidence of hypercortisolism in MDD patients, compared with healthy controls.

Stetler *et al*.'s (2004) study examined the relationship between cortisol secretion and 'social zeitgebers' among clinically depressed individuals and healthy controls. A 'zeitgeber' is any external cue that entrains (i.e. modifies in order to align with external environmental cues) the internal time-keeping systems of organisms. Contrary to expectation, there were no significant group differences in diurnal cortisol secretion or regular activities (social or non-social). However, analyses revealed an uncoupling of the relationship between regular activity and diurnal cortisol patterns in the depressed group. Whereas regular activities (especially those of a social nature) were important in entraining cortisol secretion among healthy controls, this was not found for depressed participants.

Summarizing the findings from these studies examining cortisol secretion in MDD using ESM is difficult. However, it is clear that ESM has established an altered pattern of cortisol reactivity in MDD, with subtle differences in the relationship between cortical secretion and stressful or social events in depression compared with that seen in non-depressed adults.

Theme 4: Antidepressant treatment

Antidepressant medication remains the most common treatment for depression in the UK (Hollinghurst *et al*. 2005), despite the ready accessibility and efficacy of alternative treatments and concerns over the dangers of antidepressants. Barge-Schaapveld & Nicolson (2002) utilized ESM in a clinical drug trial. Participants diagnosed with MDD were given an antidepressant or placebo treatment, and a healthy control group was employed. Treatment-related increases in frequency and severity of side-effects were associated with lowered mQoL, as assessed by ESM, especially among treatment drop-outs. Despite greater clinical improvement in depression at week six, participants receiving antidepressant treatment did not report greater increases in mean mQoL ratings *vis-à-vis* placebo participants. However, drug treatment did stabilize mQoL fluctuation and led to increased activity. Participants' decisions to prolong treatment depended on clinical improvement, mQoL changes and some specific early side-effects. By week 18, although remitted participants' global QoL normalized (as measured by retrospective questionnaires), mQoL differed from that of healthy controls. These results suggest that everyday quality of life takes longer to return to normal than retrospective measures suggest.

More recently, Wichers *et al*. (2009*b*) performed a randomized controlled trial in which MDD patients received either imipramine or placebo for 6 weeks. At baseline, patients with MDD were found, using ESM, to have higher levels of activity-related stress and lower levels of activity-related reward than controls. Emotional reactivity to such events also differed, with patients displaying an increased NA response to activity-related stress as compared with controls (replicating Myin-Germeys *et al*. 2003*b*). After treatment it was found that stress-sensitivity (responding with NA to negative stimuli) decreased more and reward experience (responding with PA to pleasant stimuli) increased more in the treatment group than the placebo group. The authors also reported the

notable finding that 'increases in Reward Experience discriminated between treatment responders and non-responders, independently from changes in appraisal and thus appeared to be a necessary condition for response to treatment, in contrast to changes in Stress-Sensitivity' (p. 928).

ESM studies evaluating the effects of antidepressant treatment have hence demonstrated the utility of using ESM to better understand the diverse and complex effects of pharmacological agents on internal states and behaviour.

Theme 5: Work performance

Depression is associated with absenteeism and reduced productivity at work as well as redundancy (Adler *et al*. 2006). Wang *et al*. (2004) used ESM to examine the impact of MDD on work performance in service workers. MDD was found to be related to decrements in task focus and productivity at work. Wang and colleagues argued that the impact of depression on job performance was greater than the impact of depression on absenteeism and subsequently estimated that the costs of lost productivity exceed those of effective treatment. A major impact of this study is the economic evidence it provides for improving treatment provision for depressed employees.

Theme 6: Genetic risk factors

Levinson's (2006) review of the role of genetics in depression describes MDD as moderately heritable and notes an overlapping genetic susceptibility with the personality trait neuroticism. It is recognized that the tendency to develop NA in response to stress is closely related to neuroticism (Kendler *et al*. 2004). This is sometimes referred to as a 'mood bias towards NA' (Erickson *et al*. 2005). Wichers *et al*.'s (2007*a*) ESM examined the contribution of genetics in mood bias towards NA in response to stress. Non-depressed twins with a co-twin diagnosed with MDD exhibited greater NA toward daily life stress than individuals with a healthy co-twin, suggesting that genetic liability to depression may, in part, be expressed by a heightened negative affective response to everyday stress. Wichers *et al*. (2007*b*) later re-analysed some of the data collected during this study and found some evidence that PA acts as a protective factor in NA reactivity. Furthermore, their findings indicated that shared genetic vulnerability to depression matters less among individuals who experience more day-to-day PA.

A later study by Wichers *et al*. (2009*a*) attempted to determine the mechanism through which genes had an effect on the increased affective reaction to stress by examining if there was a differential effect of earlier stressful events on the stress-reactivity of those at high and low genetic risk of depression. Non-depressed twins at high genetic risk of depression (i.e. with a co-twin with a history of depression) developed higher levels of daily life stress-sensitivity after exposure to prenatal (birth weight) and post-natal (childhood adversity and adult recent negative life events) stress than those at low genetic risk. The authors argued that genes associated with depression may act by accelerating the process of stress-sensitization following stress exposure over the life course.

The findings of Wichers and colleagues' studies on ESM and genetic risk have indicated that a genetic liability to depression may, in part, operate through a heightened negative affective response to everyday stress and an accelerated process of stress-sensitization. Furthermore, using ESM has highlighted that PA may have a protective effect in those with such a genetic liability. However, we note that Wichers and colleagues' all-female samples meant the findings are not directly generalizable to male populations.

Discussion

In total, 19 ESM studies examining MDD were found and six research foci identified: methodology; positive affect, negative affect, and stress; cortisol secretion abnormalities; the side-effects and benefits of antidepressant treatment; work performance; and genetic risk factors in depression. The results of this review show that ESM studies of depression have already made important contributions to our understanding of MDD.

Support for existing theories

ESM has contributed to MDD research by supporting and adding strength to existing theories. The results of Peeters *et al*. (2003*a*, *b*), for example, corroborate the dysregulation hypothesis of cortisol abnormalities in MDD (Siever & Davis, 1985). In addition, the work of Wichers *et al*. (2007*b*) supports the 'broaden-and-build theory' of the protective function of PA in depression (Fredrickson, 2001). In view of these findings, one of ESM's strengths within MDD research is its ability to strengthen existing theory with ecologically valid evidence.

New findings from ESM

A number of new insights into MDD have been generated by ESM studies. The work of Peeters and colleagues and other groups using ESM has captured characteristic details of the profile and persistence of NA and PA that retrospective designs would be incapable of revealing. For example, Peeters *et al*.'s (2003*c*) finding that individuals with MDD do not

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

report more frequent negative events, but do report fewer positive events, contradicted much of the previous research in this area, gathered using retrospective designs (e.g. Ravindran *et al*. 1995). Furthermore, Peeters and colleagues also found that although individuals with MDD may react with less NA to daily negative events they recover more slowly, prolonging the impact of negative events in such individuals. The importance of this result was supported by the results of their later ESM work (Peeters *et al*. 2010) showing that individuals with MDD with diminished reactivity to negative everyday life events were less likely to have recovered 18 months later.

The mechanisms through which a genetic component to depression may operate has also benefited from the use of ESM methodologies. For example, Wichers *et al*. (2009*a*) have found that a genetic predisposition to depression may operate through the development of higher levels of daily life stress-sensitivity. This offers the potential for the advancement of a more integrated biopsychosocial model of depression and has clinical implications for psychological interventions aimed at preventing the onset of depression among individuals where there is a significant familial or genetic risk of onset (see below).

Limitations of ESM in depressed populations and of existing ESM studies

A number of potential limitations to using ESM to collect data in specifically depressed populations still remain to be considered. For example, depression is known to be associated with ruminative thinking (e.g. Kim *et al*. 2011) as well as high trait levels of self-focused attention (Dunn *et al*. 2007). It is plausible that participation in ESM studies may further exacerbate such thinking/attention patterns, which, in addition to the ethical issues this raises, may result in artefacts in the data collected. However, as we note below, this potential impact of ESM may actually be used to aid the therapeutic process. Furthermore, as CBT for depression includes helping patients correctly identify their emotions (e.g. anger, anxiety, sadness, shame, etc.), the stage of therapy a patient is at may impact upon the type of affective states or cognitions they report, introducing further artefacts into data collected through ESM.

A number of limitations of existing ESM studies of MDD are also apparent. First, they could be improved by employing a greater range of outcome measures, going beyond the currently predominant affective (e.g. NA and PA) and physiological (e.g. cortisol) measures, to more fully understand MDD. Studies such as Barge-Schaapveld *et al*. (1999), which assessed mQoL, and Whalen *et al*. (2008), which assessed the relationship between affect and caffeine use, have already indicated the utility of a diverse range of measures.

A second shortfall of existing ESM studies is their failure to assess the specific cognitions that are central to cognitive theories of depression. For example, at the heart of Beck's (1976) model of depression is the cognitive triad of negative automatic thoughts, systematic logical errors and depressogenic schemas. All items in this triad could potentially be assessed using ESM to tap into ongoing examples of these and their relationship to affect and depressive symptomatology. It is hence imperative that future ESM studies attempt to test the hypothesis that negative automatic thoughts precede negative mood. In order to address other causal questions, it would also be interesting to use ESM to examine specific cognitions and behaviours pretreatment, as well as change following psychological interventions such as CBT. Such studies could usefully investigate whether these therapies are actually working as expected in terms of the changing relationship between thought and emotion.

Another area requiring future development results from the fact that ESM studies are currently limited by existing statistical analysis methods. The rich time-series data generated by ESM has so far been analysed in fairly rudimentary ways. Analysis of unevenly spaced observations within a multi-level modelling framework will require new statistical techniques that are still being developed.

Treatment

It has been argued that current treatment guidelines for depression are inadequately informed by recent research findings (Luyten *et al*. 2006) and the findings of ESM studies of MDD can be seen to be one area that has yet to be fully developed in terms of their treatment potential. Indeed, the ESM studies reviewed here have a number of implications for the treatment of MDD.

ESM studies of NA and PA patterns in MDD (e.g. Peeters *et al*. 2003*a*) have clear implications for treatment. For example, psychological interventions for MDD should focus on stress management training (particularly in those at high genetic risk of developing MDD), as well as behavioural activation and increasing exposure to pleasant events. This conclusion is reinforced by genetic studies of MDD employing ESM. For example, studies (e.g. Wichers *et al*. 2007*b*) showing that PA may act as a protective factor against a genetic predisposition to MDD also suggest that behavioural activation and increasing exposure to pleasant events may play an important role in preventing the development of MDD. ESM studies of

https://doi.org/10.1017/S0033291711002200 Published online by Cambridge University Press

response to antidepressant treatment, which show response to be associated with an increase in reward experience (e.g. Wichers *et al*. 2009*b*), also support this proposal. It can also be seen that ESM studies showing that MDD patients' retrospective reports of their NA and PA are more inaccurate than those of healthy controls (Ben-Zeev *et al*. 2009; Ben-Zeev & Young, 2010) highlight the importance of tools utilized in CBT, such as mood and thought records (e.g. Greenberger & Padesky, 1995), in allowing patients and clinicians to form an accurate historical representation of the patient's cognitive and affective states.

Importantly, future research should examine the feasibility of using ESM itself as a clinical intervention in MDD. Indeed, several studies have already described therapeutic approaches using ESM. For example, Newman *et al*. (1997) gave patients with panic disorder palm top computers and at random intervals through the day they prompted participants to complete a breathing retraining exercise or a programme to help them alter their thinking and remain in the present situation, resulting in clinically significant improvements.

None of the ESM studies reported here considered the impact of prolonged self-reporting on participants' awareness, knowledge and experience of internal phenomenon. As ESM prompts individuals to think about their thoughts and feelings as they go about their day-to-day life, it is plausible that it could be used to develop individuals' awareness of cognitive and emotional processes. In this respect, ESM could potentially be used as an intervention tool by helping patients with MDD become more mindful of physical symptoms, unhelpful thinking patterns and external triggers. In particular, ESM appears ideally suited to use with mindfulness-based cognitive therapy for MDD (Segal *et al*. 2002), which employs mindfulness techniques to create awareness of negative thinking patterns and disengagement from ruminative depressive cycles. Furthermore, the potential of ESM to encourage an awareness of moments that are temporally limited and contextual, which may reduce a maladaptive tendency to have overgeneralized autobiographical memory in depressed individuals (Williams & Scott, 1988), may also be a fruitful area for research.

Conclusions

ESM studies have made a significant contribution to our understanding of depression, consolidating existing theories, uncovering new, clinically relevant information and identifying questions requiring further exploration. A number of key ways in which ESM could be used to further increase our understanding of MDD have been suggested here. Importantly, this review also suggests that future studies should investigate the feasibility of ESM as a clinical tool in psychological therapies.

Declaration of Interest

None.

References

Adler DA, McLaughlin TJ, Rogers WH (2006). Job performance deficits due to depression. *American Journal of Psychiatry* **163**, 1569–1576.

Barge-Schaapveld DQCM, Nicolson NA (2002). Effects of anti-depressant treatment on the quality of daily life: an experience sampling study. *Journal of Clinical Psychiatry* **63**, 477–485.

Barge-Schaapveld DQCM, Nicolson NA, Berkhof J, DeVries M (1999). Quality of life in depression: daily life determinants and variability. *Psychiatry Research* **88**, 173–189.

Barge-Schaapveld DQCM, Nicholson NA, van der Hoop RG, DeVries MW (1995). Changes in daily life experience associated with clinical improvement in depression. *Journal of Affective Disorders* **34**, 139–154.

Beck AT (1976). *Cognitive Therapy and the Emotional Disorders*. International Universities Press: New York.

Ben-Zeev D, Young MA (2010). Accuracy of hospitalized depressed patients' and healthy controls' retrospective symptom reports. *Journal of Nervous and Mental Disease* **198**, 280–285.

Ben-Zeev D, Young MA, Madsen JW (2009). Retrospective recall of affect in clinically depressed individuals and controls. *Cognition & Emotion* **23**, 1021–1040.

Bower B, Bylsma LM, Morris BH, Rottenberg J (2010). Poor reported sleep quality predicts low positive affect in daily life among healthy and mood-disordered persons. *Journal of Sleep Research* **19**, 323–332.

Cohen LH, Gunthert KC, Butler AC, Parrish BP, Wenze SJ, Beck JS (2008), Negative affect spillover from daily events predicts early response to cognitive therapy for depression. *Journal of Consulting and Clinical Psychology* **76**, 955–965.

Conrad A, Wilhelm FH, Roth WT, Spiegel D, Taylor CB (2008). Circadian affective, cardiopulmonary, and cortisol variability in depressed and nondepressed individuals at risk for cardiovascular disease. *Journal of Psychiatric Research* **42**, 769–777.

Csikszentmihalyi M, Larson R (1987). Validity and reliability of the Experience-Sampling Method. *Journal of Nervous and Mental Disease* **175**, 526–536.

Csikszentmihalyi M, Larson R (2006). Validity and reliability of the Experience-Sampling Method. In *The Experience of Psychopathology: Investigating Mental Disorders in their Natural Settings* (ed. M. de Vries), pp. 43–57. Cambridge University Press: Cambridge.

de Vries M (2006). The experience of psychopathology in natural settings: introduction and illustration variables. In *The Experience of Psychopathology: Investigating Mental*

Disorders in their Natural Settings (ed. M. de Vries), pp. 3–26. Cambridge University Press: Cambridge.

Dijkman-Caes CIM, de Vries MW (1991). Daily life situations and anxiety in panic disorder and agoraphobia. *Journal of Anxiety Disorder* **5**, 343–357.

Dunn BD, Dalgleish T, Lawrence AD, Ogilvie AD (2007). The accuracy of self-monitoring and its relationship to self-focused attention in dysphoria and clinical depression. *Journal of Abnormal Psychology* **116**, 1–15.

Erickson K, Drevets WC, Clark L (2005). Mood-congruent bias in affective go/no-go performance of unmedicated patients with major depressive disorder. *American Journal of Psychiatry* **162**, 2171–2173.

Forbes EE, Hariri AR, Martin SL, Silk JS, Moyles DL, Fisher PM, Brown SM, Ryan ND, Birmaher B, Axelson DA, Dahl RE (2009). Altered striatal activation predicting real-world positive affect in adolescent major depressive disorder. *American Journal of Psychiatry* **166**, 64–73.

Fredrickson BL (2001). The role of positive emotions in positive psychology. The broaden-and-build theory of positive emotions. *American Psychologist* **56**, 218–226.

Greenberger D, Padesky CA (1995). *Mind over Mood: Change How You Feel by Changing the Way You Think*. The Guilford Press: New York.

Hektner JM, Schmidt JA, Csikszentmihalyi M (2007). *Experience Sampling Method: Measuring the Quality of Everyday Life*. Sage: Thousand Oaks, CA.

Hollinghurst S, Kessler D, Peters TJ, Gunnell D (2005). Opportunity cost of anti-depressant prescribing in England: analysis of routine data. *British Medical Journal* **330**, 999–1000.

Holsboer F (2001). Stress, hypercortisolism and corticosteroid receptors in depression: implications for therapy. *Journal of Affect Disorders* **62**, 77–91.

Hurlbert RT (1997). Randomly sampling thinking in the natural environment. *Journal of Consulting and Clinical Psychology* **65**, 941–949.

Husky MM, Gindre C, Mazure CM, Brebant C, Nolen-Hoeksema S, Sanacora G, Swendsen J (2010). Computerized ambulatory monitoring in mood disorders: feasibility, compliance, and reactivity. *Psychiatry Research* **178**, 440–442.

Kendler KS, Kuhn J, Prescott CA (2004). The interrelationship of neuroticism, sex, and stressful life events in the prediction of episodes of major depression. *American Journal of Psychiatry* **161**, 631–636.

Kim S, Yu BH, Lee DS, Kim J-H (2011). Ruminative response in clinical patients with major depressive disorder, bipolar disorder, and anxiety disorders. *Journal of Affective Disorders*. Published online: 3 August 2011. doi:10.1016/j.jad.2011.06.034.

Larson R, Asmussen L (1992). Bulimia in daily life. In *The Experience of Psychopathology: Investigating Mental Disorders on their Natural Settings* (ed. M. W. de Vries), pp. 167–179. Cambridge University Press: Cambridge.

Levinson DF (2006). The genetics of depression: a review. *Journal of Biological Psychiatry* **60**, 84–92.

Loewenstein RJ, Hamilton J, Alagna S, Reid N, de Vries MW (1987). Experiential sampling in the study of multiple personality disorder. *American Journal of Psychiatry* **144**, 19–24.

Luyten P, Blatt SJ, van Houdenhove B, Corveleyn J (2006). Depression research and treatment: are we skating to where the puck is going to be? *Clinical Psychology Review* **26**, 985–999.

Myin-Germeys I, Delespaul P, van Os J (2003*a*). The experience sampling method in psychosis research. *Current Opinion in Psychiatry* **16**, 33–38.

Myin-Germeys I, Nicolson NA, Delespaul P (2001). The context of delusional experiences in the daily life of patients with schizophrenia. *Psychological Medicine* **31**, 489–498.

Myin-Germeys I, Oorschot M, Collip D, Lataster J, Delespaul P, van Os J (2009). Experience sampling research in psychopathology: opening the black box of daily life. *Psychological Medicine* **39**, 1533–1547.

Myin-Germeys I, Peeters F, Havermans R, Nicolson NA, de Vries MW, Delespaul P, van Os J (2003*b*). Emotional reactivity to daily life stress in psychosis and affective disorder: an experience sampling study. *Acta Psychiatrica Scandinavica* **107**, 124–131.

Newman MG, Kenardy J, Herman S, Barr TC (1997). Comparison of palmtop-computer-assisted brief cognitive – behavioral treatment to cognitive – behavioral treatment for panic disorder. *Journal of Consulting and Clinical Psychology* **65**, 178–183.

Oorschot M, Kwapil T, Delespaul P, Myin-Germeys I (2009). Momentary assessment research in psychosis. *Psychological Assessment* **21**, 498–505.

Peeters F, Berkhof J, Delespaul P, Rottenberg J, Nicolson NA (2006). Diurnal mood variation in major depressive disorder. *Emotion* **6**, 383–391.

Peeters F, Berkhof J, Rottenberg J, Nicolson NA (2010). Ambulatory emotional reactivity to negative daily life events predicts remission from major depressive disorder. *Behaviour Research and Therapy* **48**, 754–760.

Peeters F, Nicolson NA, Berkhof J (2003*a*). Cortisol responses to daily events in major depressive disorder. *Psychosomatic Medicine* **65**, 836–841.

Peeters F, Nicolson NA, Berkhof J (2003*b*). Levels of variability of daily life cortisol secretion in major depression. *Psychiatry Research* **126**, 1–13.

Peeters F, Nicolson NA, Delespaul P, deVries M, Berkhof J (2003*c*). Effects of daily events on mood states in major depressive disorder. *Journal of Abnormal Psychology* **112**, 203–211.

Putnam KA, McSweeney LB (2008). Depressive symptoms and baseline prefrontal EEG alpha activity: a study utilizing Ecological Momentary Assessment. *Biological Psychology* **77**, 237–240.

Ravindran AV, Griffiths J, Waddell C, Anisman H (1995). Stressful life events and coping styles in relation to dysthymia and major depressive disorder: variations associated with alleviation of symptoms following pharmacotherapy. *Progress in Neuro-Psychopharmacology & Biological Psychiatry* **19**, 637–653.

Segal ZV, Williams JMG, Teasdale JD (2002). *Mindfulness-Based Cognitive Therapy for Depression:*

A New Approach to Preventing Relapse. Guilford Press: New York.

Siever LJ, Davis KL (1985). Overview: toward a dysregulation hypothesis of depression. *American Journal of Psychiatry* **142**, 1017–1031.

Silk JS, Dahl RE, Ryan ND, Forbes EE, Axelson DA, Birmaher B, Siegle GJ (2007). Pupillary reactivity to emotional information in child and adolescent depression: links to clinical and ecological measures. *American Journal of Psychiatry* **164**, 1873–1880.

Stetler C, Dickersin SS, Miller GE (2004). Uncoupling of social zeitgebers and diurnal cortisol secretion in clinical depression. *Psychoneuroendocrinology* **29**, 1250–1259.

Stetler C, Miller GE (2005). Blunted cortisol response to awakening in mild to moderate depression: regulatory influences of sleep patterns and social contacts. *Journal of Abnormal Psychology* **114**, 697–705.

Walls TA, Jung H, Schwartz JE (2006). Multilevel models for intensive longitudinal data. In *Models for Intensive Longitudinal Data* (ed. T. A. Walls and J. L. Schafer) pp. 3–37. Oxford University Press: Oxford.

Wang PS, Beck AL, Berglund P, McKenas DK, Pronk NP, Simon GE, Kessler RC (2004). Effects of major depression on moment-in-time work performance. *American Journal of Psychiatry* **161**, 1885–1891.

Whalen DJ, Silk JS, Semel M, Forbes EE, Ryan ND, Axelson DA, Birmaher B, Dahl RE (2008). Caffeine consumption, sleep, and affect in the natural environments of depressed youth and healthy controls. *Journal of Pediatric Psychology* **33**, 358–367.

Wichers M, Myin-Germeys I, Jacobs N, Peeters F, Kenis G, Derom C, Vlietinck R, Delespaul P, van Os J (2007*a*). Genetic risk of depression and stress-induced negative affect in daily life. *British Journal of Psychiatry* **191**, 218–223.

Wichers M, Myin-Germeys I, Jacobs N, Peeters F, Kenis G, Derom C, Vlietinck R, Delespaul P, van Os J (2007*b*). Evidence that moment-to-moment variation in positive emotions buffer genetic risk for depression: a momentary assessment twin study. *Acta Psychiatrica Scandinavica* **115**, 451–457.

Wichers M, Schrijvers D, Geschwind N, Jacobs N, Myin-Germeys E, Thiery C, Derom C, Sabbe B, Peeters F, Delespaul P, van Os J (2009*a*). Mechanisms of gene–environment interactions in depression: evidence that genes potentiate multiple sources of adversity. *Psychological Medicine* **39**, 1077–1086.

Wichers MC, Barge-Schaapveld DQCM, Nicolson NA, Peeters F, de Vries M, Mengelers R, van Os J (2009*b*). Reduced stress-sensitivity or increased reward experience: the psychological mechanism of response to antidepressant medication. *Neuropsychopharmacology* **34**, 923–931.

Williams JMG, Scott J (1988). Autobiographical memory in depression. *Psychological Medicine* **18**, 689–695.