Bringing experience-sampling technology to family medicine

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Feasibility, usability and lessons-learned

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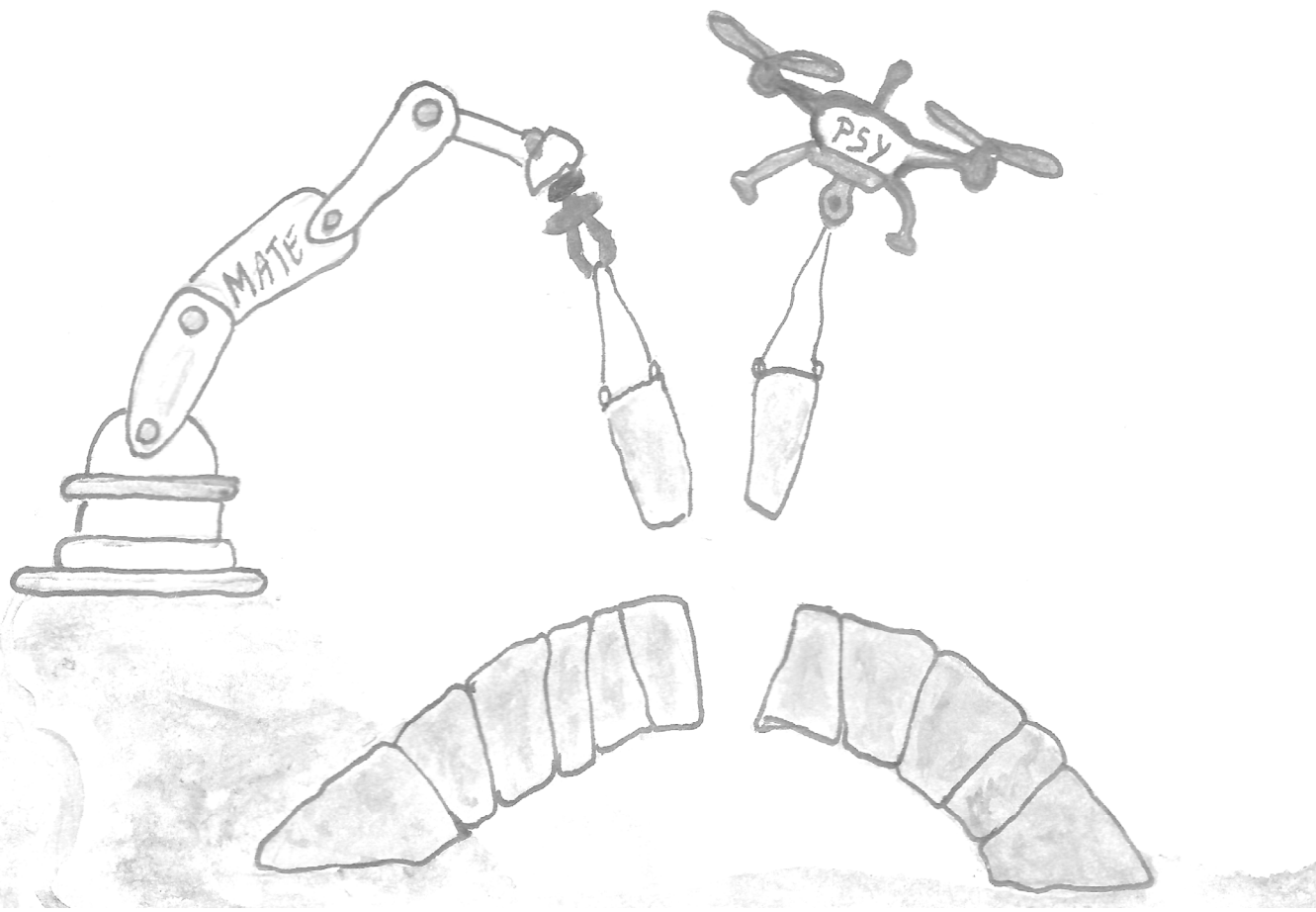
Chapter 1

General introduction



Miss Jacobs frequently visits the family physician with varying somatic symptoms (gastrointestinal complaints, neck pain, headaches, shoulder pain), without a clear somatic cause. She is referred to the psychological assistant. Besides the somatic symptoms, she feels continuously tense and experiences a high level of irritability. Furthermore, she has sleeping problems, experiences difficulties concentrating and worries a lot. She cannot relax anymore. Miss Jacobs tells the psychological assistant that these symptoms increased since an incident at work. She tells that her partner confirms the tension, the fact that she cannot relax anymore and that she experiences difficulties of letting things go. She wants to know what is going on. The psychological assistant proposes keeping a daily diary to get insight into the causes and consequences of her vulnerabilities, but also her strengths. However, she forgets completing the diary four times during the week and backfills it at the parking lot just before her treatment session starts. Consequently, the diary does not provide insight into the moments that she experiences anxiety or, in contrast, feels well. Recently, an mHealth tool based on the Experience Sampling Method was introduced as an alternative to written diaries. This technology enables mapping the patient's thoughts, feelings, experiences and behavior, and gaining insight into the patient's daily life functioning. The psychological assistant is a novice to the method. She is wondering how and when she can use this experience-sampling technology to deepen the problem explorations during patient consultations.

From vulnerabilities to strengths and resilience

Family physicians have an increasing role in the care for people with mental health vulnerabilities[1]. Patients consult often for relatively undifferentiated problems such as pain, depression or worries about cognitive decline. It is often difficult to substantialize the actual occurrence and patterns over time, making it difficult to understand how problems will evolve. Patients may report, for example, that they spend the whole day ruminating, while everything else is neglected. In reality, they might also have experienced moments without rumination. Healthcare professionals want to explore the daily life reality to better understand the patients' narrative. This requires an explorative process to place these experiences into context.

In mental health, no miracle solutions exist. Even a simple intervention as taking (antidepressant) medication requires a daily action. Most strategies, for instance being aware of intrusive automatic thoughts resulting in mood swings,

require continuous active monitoring. This is not different from healthy lifestyle interventions as dietary routines, improving exercise or stop drinking in somatic medicine. The truth is that all strategies to improve mental health require motivation and user involvement[2,3]. Individuals are difficult to motivate by external examples – a friend who is able to relax or disregard intrusive thoughts does not have my (depressive) brain. But, information about situations where the persons themselves were able to stick with healthy lifestyle routines or relax undisturbed by intrusive thoughts is important because it reflects someone's own potential[4–6]. Most assessment strategies focus on symptoms and problematic situations (the individual's vulnerabilities), but optimal treatment strategies also require information on non-occurrence of symptoms, potentially reflecting resilience[7–12]. Peoples' coping abilities in all health domains are of growing importance in our society. The development towards self-reliance is partly driven by shrinking government expenditure; helping more patients with fewer healthcare professionals and resources[13]. But most importantly, it reduces the dependency of individuals from their healthcare professionals, and improves autonomy and self-determination[14–16]. Over the past years, the change in focus of care from disease or disorder to the patient's functioning and resilience was emphasized again[10,11,17–19]. This requires an active role of patients in their treatment, and a recasting of treatment to promote the patient's autonomy and empowerment[20,21].

Standard self-report assessments

But, mapping the patient's unique living conditions in order to place the patient's vulnerabilities and strengths in the context remains often uncharted. Targeted assessments and adequate casting can improve insight into the patient's wishes and needs, and actively involve them in their own care processes[7]. The use of monitoring tools can contribute to better communication between healthcare professionals and their patients, especially when self-reports or Patient Reported Outcome Measures (PROMs) are used and the results are discussed[22–25]. Questionnaires and diaries are examples of PROMs, which enable patients to collect subjective information about their symptoms, daily life functioning, participation and quality of life[23,26]. Questionnaires were developed to assess the incidence, prevalence or frequency of certain complaints or disorders, and to evaluate the effectiveness of treatments[27]. They are relatively inexpensive and provide global indicators of the patient's

improvement and the service outcome. They allow comparing individual scores with a specific group, but often miss the individual nuances that characterize specific patients[27]. At best, questionnaires are administered with limited frequency (e.g., before and after treatment) and are of limited use to iteratively update treatment strategies. Also, when the patient is asked how (s)he felt during the past days or weeks, this can result in the loss of nuance due to recall bias[28]. There is increasing awareness that experiences are dynamic and strongly determined by context[29]. But due to recall bias, retrospective questionnaires provide little insight into the patient's daily life functioning and the variation over time reflecting contextual influences (e.g., someone feels more anxious in the company of colleagues compared to being alone). Compared to questionnaires, diaries are an improvement because individuals typically write down feelings, thoughts, perceptions and activities repeatedly at regular time intervals. The time window is often limited (e.g., one day) and the reporting process requires less retrospection. This allows some insight into contextual variation and yields more reliable data. However, diaries are often experienced as burdensome and patients forget to complete them[28,30–32].

Experience Sampling Method

Recent technological advancements, such as electronic health (eHealth), the use of information and communication technologies to promote health and the healthcare system[33], and mobile health (mHealth), interventions via smartphones and tablets, may offer possibilities to deal with the drawbacks of questionnaires and diaries. Innovative solutions can bridge the gap between the therapeutic setting and the patient's daily life. As an alternative, the Experience Sampling Method (ESM), also called Ecological Momentary Assessment (EMA), is a diary technique to obtain momentary self-reports concerning the individual's mood, cognition, perception, and behavior in context[34]. Beeps signal individuals (semi-) randomly during waking hours of a normal day to complete some questionnaires[34]. The method was pioneered in the seventies of the past century and originally used paper and pencil data collection with semaphones or electronic signal watches as beepers. The application was flexible and customizing questionnaires was easy. However, there was no control on the actual reporting moment and participants misreport or select entry times, potentially leading to certain conditions being over- or under-represented[34]. Assessment using smartphones is a better way to collect ESM data. It provides

better control on the actual moment reports are filed and the data collection logistics by automatically storing entries in a central database[35]. Furthermore, the user can access online feedback on the data. This is motivating and increases the completion rate[35]. Smartphone supported assessments are experienced as less burdensome due to the high-sampling frequency[35]. Irrespective of its apparent ecological validity, validation of ESM procedures remains crucial, overall adoption should not be taken for granted, and software development costs are high[35].

ESM has already been extensively used in patient-related research as well as in clinical settings both in mental and somatic health, across various psychological disorders (e.g., depressive disorders, schizophrenia spectrum disorders, anxiety disorders and eating disorders) and age ranges[36–43]. Previous research has, for example, demonstrated that the use of ESM with feedback leads to a reduction in depressive symptoms compared to pharmacological treatment[36]. Moreover, fluctuations in mood (i.e., anxiety symptoms) and the context (i.e., social withdrawal, engaging in work activities, doing nothing and passive leisure activities) influence hallucinations[38].

The PsyMate™

One example of an ESM mHealth tool is the PsyMate™ Suite: a smartphone application (Android and iOS), a cloud-based data storage and a web-based reporting tool. This mHealth tool was developed by the department of Psychiatry and Neuropsychology of Maastricht University Medical Center (MUMC+) and Maastricht University. The PsyMate™ app momentarily assesses affect, cognition, perception, and behavior in daily life. It, thereby, provides insight into the individual's daily life functioning, assessing both vulnerabilities and strengths. The PsyMate™ app typically signals users ten times a day to complete a short questionnaire (max. 2 minutes). Mood (i.e., positive and negative feelings), perception of physical status (i.e., hunger, fatigue and pain), behavior (i.e., activities) and context (i.e., location, time and persons present) are assessed. In addition to repeated within-day beep questionnaires, users are also asked to complete a morning and evening questionnaire to assess respectively sleep quality and overall appraisal of the day. Users get feedback by means of graphs and diagrams via the web-based reporting tool. This allows users to make connections between mood, perception of physical status, activities, and context, and provide insight into, for example, how the

environment influences mood (problem explorations). Although the feasibility and usability of ESM have been demonstrated in mental health research, studies assessing ESM use in daily clinical practice in general and family medicine in particular are lacking[39,44–47]. Furthermore, cognition assessments are underdeveloped in experience sampling, but also relevant for family medicine. It is therefore important to check whether the current version of the PsyMate™ can be used in family medicine and how it should be adapted and implemented.

Implementation of mHealth tools in routine clinical care

A meta-analysis shows that there are only a few evidence-based monitoring apps for chronically ill patients[48]. Also, once an app acquires scientific credentials, the dissemination into daily clinical practice remains challenging[49]. It is difficult for healthcare professionals to keep track of what is available and to separate the wheat from the chaff. To facilitate this transfer from academic research to routine clinical care, attention needs not only be paid to the technology but also to the feasibility (i.e., the extent to which the technology is easy to use) and the usability (i.e., the extent to which the technology can be embedded in daily clinical practice) of these innovative tools. Additional challenges relate to the end users, the organization and the implementation process[50]. Therefore, the active involvement of relevant stakeholders is needed for successful, sustainable implementation of innovative tools[50]. In summary, healthcare professionals need evidence-based tools that are feasible and usable in the care for patients with psychosocial problems in family medicine. However, integration of mHealth tools in the work processes of healthcare professionals remains a challenge. More research is needed into the feasibility and usability of these mHealth tools in routine clinical care in general and the doctors' practices in particular.

Thesis aims, research questions and thesis outline

The general aim of the research described in this thesis was to explore the continued development and implementation of experience-sampling technology, in this case the PsyMate™, to support problem explorations for patients suffering from mental health problems in family medicine. This thesis is divided into three parts, including five studies (see Figure 1.1). **Part I** starts

with an exploration of the current practice regarding the use of electronic diaries in healthcare. **Part II** extends the research into the feasibility of experience-sampling technology by adding objective momentary cognition tasks. **Part III** explores the development and implementation of this technology in family medicine, by co-creation sessions with end users and an interprofessional project group. The research questions for each part are:

Part I: Exploring current practice

1) What is the current empirical knowledge regarding factors that influence the use of electronic diaries in healthcare?

Part II: Cognition in daily life

2) How feasible is the use of a momentary cognition task, measuring information processing speed (mDSST), within experience-sampling technology to assess cognitive performance in daily life?
3) How feasible and valid is the use of two momentary cognition tasks, measuring information processing speed (mDSST), and concentration and visuospatial working memory (mVSWMT), within experience-sampling technology to assess cognitive performance in daily life and what are the lessons learned regarding the development and use of these tasks?

Part III: Continued development and implementation of experience-sampling technology in family medicine

4) How can the PsyMate™ be optimized and what are the experiences of the psychological assistants with the redesigned PsyMate™?
5) How can the PsyMate™ be used as an mHealth tool to support detailed functional analyses in daily clinical practice?
6) How can the PsyMate™ be used as an mHealth tool to support problem explorations for patients with anxiety or sleeping problems who are seen by psychological assistants in family medicine and how do they experience its use?

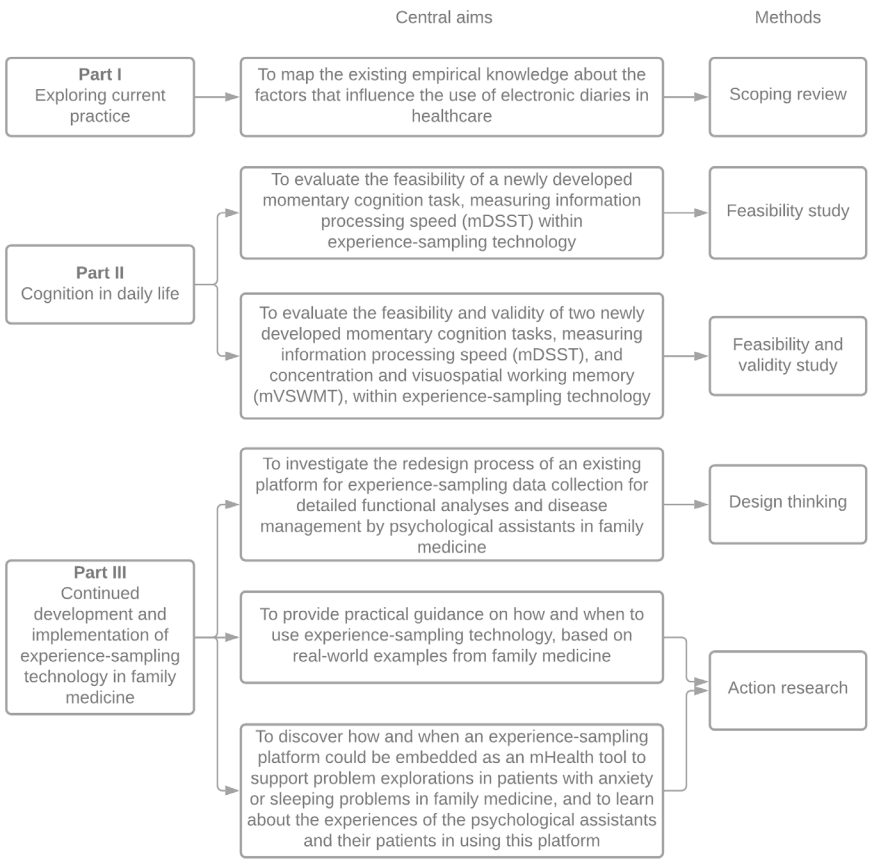


Figure 1.1 Systematic overview of the entire thesis project.

Chapter 2 provides an overview of the current empirical knowledge about the factors that influence the use of electronic diaries in healthcare. Directed content analysis was used to summarize the findings, based on the Consolidated Framework for Implementation Research (CFIR[50]). **Chapter 3** describes a pilot study to assess the feasibility of a newly developed objective cognition task measuring information processing speed within an ESM paradigm in a general population. **Chapter 4** extends the study in Chapter 3, by adding a second objective cognition task measuring concentration and visuospatial working memory. Feasibility and validity are examined by looking at the contextualization of momentary cognition outcomes. Besides, the focus is on end-users' task evaluation and lessons learned concerning the

development and use of momentary cognition tasks within an ESM paradigm. **Chapter 5** presents the redesign process of experience-sampling technology, the PsyMate™, in family medicine to support problem explorations in patients who are seen by a psychological assistant. A qualitative study was conducted consisting of co-creation sessions and a focus group with healthcare professionals and an interprofessional project group. An exploratory unsystematic review was performed to explore the organization of mental healthcare and the use of eHealth in family medicine. Furthermore, the qualitative data was analyzed using conventional content analysis. **Chapter 6** provides practical guidance on how and when to use experience-sampling technology to support detailed functional analyses in routine clinical practice, thereby integrating empirical knowledge and expert experiences. Two clinical use cases are presented following a step-by-step guide to implement this technology within work processes. Special attention is payed to recommendations to facilitate successful use. The results of the aforementioned studies were used as input for the action research in the last chapter. **Chapter 7** describes the iterative process of testing and evaluating the use of experience-sampling technology to support problem explorations in patients with anxiety and/or sleeping problems who are referred to a psychological assistant in family medicine. This study also focused on the experiences of both healthcare professionals and their patients. Qualitative data were collected by means of observations, interviews, patient records, and a logbook. The whole process was analyzed using directed content analysis, organized by the CFIR[50]. **Chapter 8** summarizes the main findings of this thesis and discusses the methodological considerations in the light of clinical, research and educational implications. Lessons learned and recommendations are also defined in the light of these domains.

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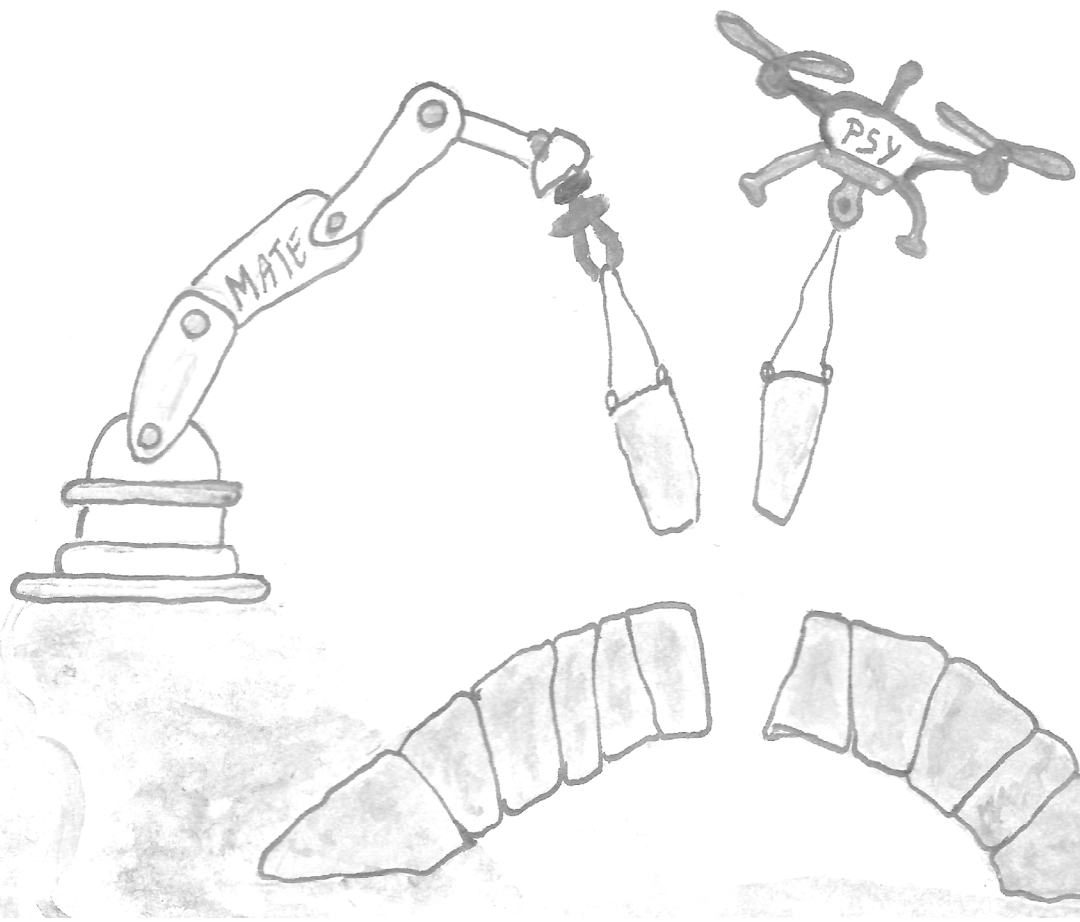
Part I

Exploring current practice



Chapter 2

Factors that influence the use of electronic diaries in health care: Scoping review

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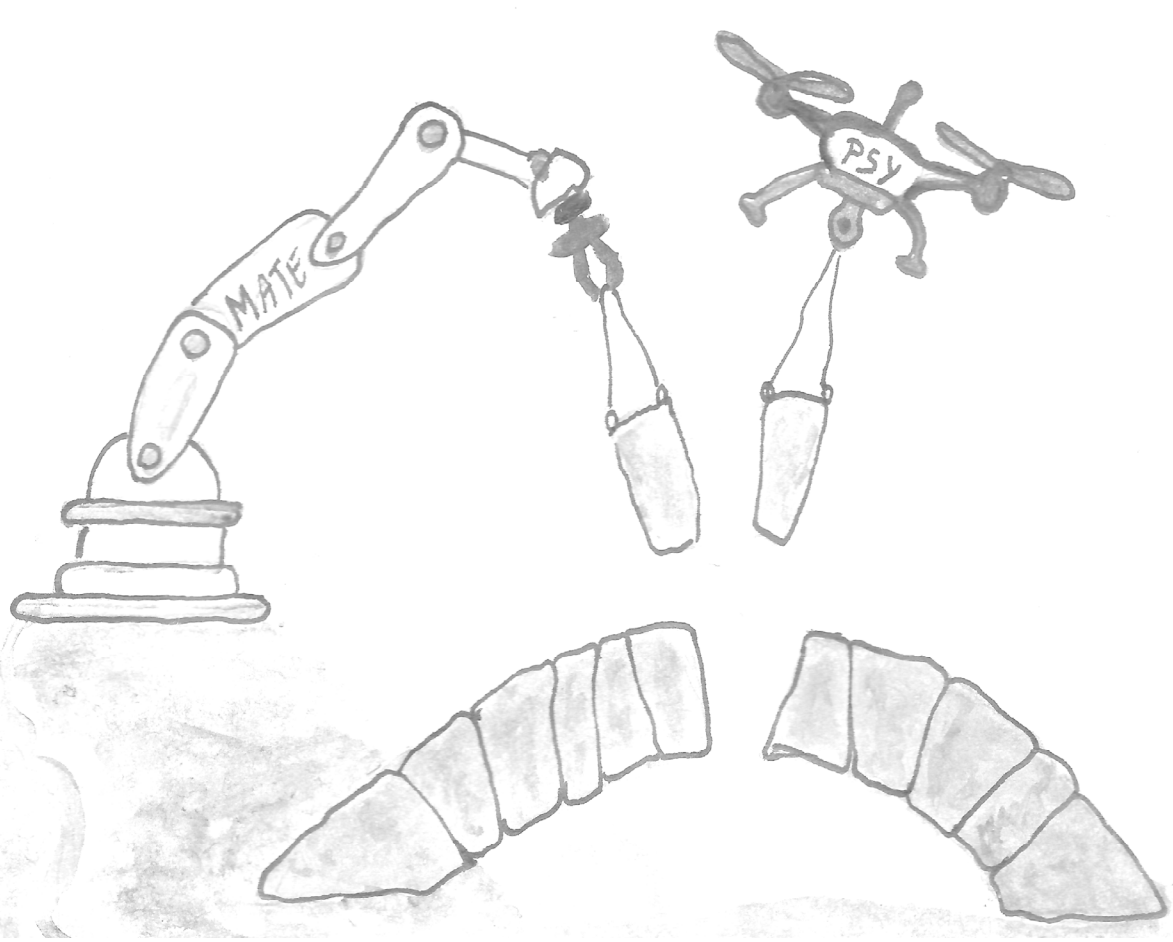
JMIR Mhealth Uhealth 2021;9(6):e19536



Abstract

Background

A large number of people suffer from psychosocial or physical problems. Adequate strategies to alleviate needs are scarce or lacking. Symptom variation can offer insights into personal profiles of coping and resilience (detailed functional analyses). Hence, diaries are used to report mood and behavior occurring in daily life. To reduce inaccuracies, biases, and noncompliance with paper diaries, a shift to electronic diaries has occurred. Although these diaries are increasingly used in health care, information is lacking about what determines their use.

Objective

The aim of this study was to map the existing empirical knowledge and gaps concerning factors that influence the use of electronic diaries, defined as repeated recording of psychosocial or physical data lasting at least one week using a smartphone or a computer, in health care.

Methods

A scoping review of the literature published between January 2000 and December 2018 was conducted using queries in PubMed and PsycInfo databases. English or Dutch publications based on empirical data about factors that influence the use of electronic diaries for psychosocial or physical purposes in health care were included. Both databases were screened, and findings were summarized using a directed content analysis organized by the Consolidated Framework for Implementation Research (CFIR).

Results

Out of 3170 articles, 22 studies were selected for qualitative synthesis. Eleven themes were determined in the CFIR categories of intervention, user characteristics, and process. No information was found for the CFIR categories inner (e.g., organizational resources, innovation climate) and outer (e.g., external policies and incentives, pressure from competitors) settings. Reminders, attractive designs, tailored and clear data visualizations (intervention), smartphone experience, and intrinsic motivation to change behavior (user characteristics) could influence the use of electronic diaries. During the implementation process, attention should be paid to both theoretical and practical training.

Conclusions

Design aspects, user characteristics, and training and instructions determine the use of electronic diaries in health care. It is remarkable that there were no empirical data about factors related to embedding electronic diaries in daily clinical practice. More research is needed to better understand influencing factors for optimal electronic diary use.

Introduction

Health care professionals are insufficiently aware of symptom variability and contextual fluctuations; therefore, their interventions are based on incomplete information[1–5]. Patients are asked to recall their mood, thoughts, behavior, and experiences over the past weeks or even months. Recalling information from memory, though, is known to be incomplete and inaccurate[6,7]. To minimize inaccuracies and biases, prospective diaries are used to collect patients' mood, thoughts, behavior, and experiences in the relevant context close to the time of occurrence[8]. Because these health-related strategies often require management of vulnerabilities, long-term patient engagement is important. However, patients experience that it is difficult to be engaged in the use of diaries for long periods of time. Compliance is often poor, and adequate reports on contextual variation are lacking[8]. Paper diaries are remarkably completed in the parking lot before meeting the clinician[9]. In one-third of the days, paper diaries contain entries while the log booklets were not opened[8,10].

To overcome noncompliance with paper diaries, researchers and clinicians have shifted from paper to electronic diaries. Both paper and electronic diaries can be used in research to observe individuals in their context, gather data about sensitive topics, or to actively engage individuals in monitoring and reflecting on behaviors, their underlying mechanisms, and processes. Furthermore, these diaries can be implemented in intervention studies, clinical trials, and routine care[11,12]. Electronic diaries are, however, more reliable and logistically easier to implement[13,14]. They allow individuals to monitor in daily life with little retrospection and reduced obtrusiveness. Electronic diaries are signal-contingent and often record response-time information, which improves reliability[15–18]. Nonetheless, electronic diaries also have disadvantages. Development and maintenance are costly[12]. Technical problems occur, and not all patients are acquainted with smartphones and require instructions and coaching[15]. Furthermore, research on compliance is ambiguous. For instance, the percentage of completed diary entries with electronic diaries ranges from less than 50% to 99%[18–20]. High participant motivation is related to accurate data collection and less faked compliance[13].

Previous research states that various factors are related to the use of electronic diaries, such as the design (i.e., ease of use, entertainment value), the social context (i.e., satisfaction and connection with others), and the user's characteristics (i.e., education and self-efficacy)[21–23]. However, no complete overview is available concerning empirical data about the factors related to the

use of these tools. Therefore, the main aim of this paper was to map the existing empirical knowledge about the factors that influence the use of electronic diaries in health care. Electronic diaries in health care were defined as repeated individual psychosocial or physical data collection using measurement tools on a smartphone (applications) or on a computer (website), including among others, experience sampling, ambulatory assessment, and ecological momentary assessment. In addition, use was defined as the repeated recording of information in electronic diaries by patients or healthy individuals for at least one week, including adherence, compliance, and engagement. The cut-off point was determined based on the expected recall bias and necessary data for comprehensive functional diagnostics.

Methods

In order to map existing knowledge concerning the topic of interest and to identify any gaps, this scoping review was based on the methodological framework proposed by Arksey and O'Malley[24]. This framework includes 5 specific steps: identify the research question, identify relevant studies, select relevant studies, chart the data, and summarize and report the results. The selection of relevant studies was not based on methodological quality, but on relevance.

Identify the research question

The research question of this scoping review was based on prior research and the expertise of the research team. It is summarized as: "What is the current empirical knowledge regarding factors that influence the use of electronic diaries in health care?"

Identify and select relevant studies

A structured literature search was conducted using the PubMed and PsycInfo databases to search for articles published between 2000 and 2018. The search was limited to human adults and articles published in Dutch or English. Both free-text search terms and MESH headings were used. The search strategy included 2 different concepts: "continued use" and "electronic diaries." The search string used is depicted in Textbox 2.1. In addition to the database search, reference lists of relevant studies were screened manually for further

relevant papers. This is a valuable step (snowball method) to identify articles that have been missed in the database search because electronic databases may be incomplete and they can vary in coverage, indexing, and depth of information[24]. Moreover, 2 experts in the field were contacted to identify key authors or key publications on the topic of interest.

Textbox 2.1 Search string.

1. Use: "compliance (MeSH) OR intention (MeSH) OR motivation (MeSH) OR 'continued usage' OR use OR continuance OR adherence OR engagement";

AND

2. Electronic diaries: "momentary (MeSH: ecological momentary assessment) OR 'real time data' (MeSH) OR e-diaries OR electronic diar* OR structured diar* OR computer diar* OR 'experience sampling'OR ambulatory assessment OR electronic assessment* OR electronic interview* OR self-monitoring"

Limits:
- Publication date: 2000-2018
- Humans: adult
- Language: English, Dutch

Two researchers (NEMD, LMJH) reviewed the retrieved studies using a 3-step screening process: titles, abstracts, and full articles. The screening process of a scoping review is not linear but rather iterative, which required the researchers to engage with each step in a reflexive way and repeat steps to ensure that the literature was covered in an extensive way. If the relevance of a study was unclear from the title, the abstract was ordered, and if the relevance of a study was unclear from the abstract, the full article was ordered. As a check on the 3-step screening process, we read the full texts of a random sample of 50 titles and 50 abstracts. In only 4 articles, we found information in the results or the discussion related to our scope. Relevant studies with the following criteria were included: (1) using electronic diaries for psychosocial or physical data, (2) describing factors that influence the use of electronic diaries, and (3) a focus on health care. No methodological criteria were applied, and articles based on empirical data were included. Studies were excluded when the definitions of electronic diaries or use in the article did not match with the ones used in this manuscript (i.e., the data collection method: single moment data collection or passive self-monitoring using sensors, activity trackers, or biomarkers). Studies that used a combination of active and passive monitoring were not excluded. Moreover, studies were excluded when the article did not include factors that

influence the use of electronic diaries as the outcome (i.e., the study aim: experiences with disease management, epidemiology, health technology assessment, prediction models, outcome and effect studies, and the study design [reviews, secondary analysis, protocols]). Studies in which disease management were based on or complemented with self-reporting and studies about technology acceptance were not excluded. Furthermore, we excluded studies with a target population other than adults. For children and adolescents, we expect that different factors influence the use of electronic diaries specifically and interventions in general as parents, for instance, need to give their permission. At each step, the articles were categorized as relevant, irrelevant, and dubious according to the aforementioned exclusion criteria. Differences were discussed until consensus was reached. When no consensus was reached or questions remained, a third researcher (CvZ) was consulted.

Chart the data

The data were charted using Excel spreadsheets and included study details (author, title, database, journal, year of publication, study location [published and conducted], study population and sample size, study aims, design, and setting), intervention characteristics (aim, content, and duration of the electronic diary), and key findings (factors that influence the use). These factors were organized according to the Consolidated Framework for Implementation Research (CFIR)[25]. This framework consists of 5 categories (i.e., intervention characteristics, outer setting, inner setting, individual characteristics, and process) related to sustainable implementation. The intervention characteristics category includes, among others, the complexity of the electronic diary or the ability to test the electronic diary on a small scale. The outer setting category is comprised of the economic, political, and social context of the organization. The inner setting category includes, among others, the internal architecture of the organization and the innovation climate. The individual characteristics category is comprised of, among others, the individual's knowledge, beliefs, and self-efficacy regarding the intervention or the implementation process. The process category includes activities (planning, engaging, executing, reflecting, and evaluating) related to the implementation process.

Summarize and report the results

Content analysis was done independently by 2 reviewers (NEMD, LMJH) based on the 5 categories of the CFIR[25]: (1) intervention, (2) outer setting, (3) inner

setting, (4) individual characteristics, and (5) process. Directed content analysis, using inductive reasoning, was used to validate or conceptually extend the framework[26]. The themes were based on our previous work[27] and emerged from the data. After coding, the researchers compared their codes until consensus was reached. They identified key themes into which the results could be divided.

Results

The database search resulted in 3650 hits (see Figure 2.1). After removing duplicates and reviewing 3170 titles, 273 abstracts were screened, of which 50 full texts were evaluated. In total, 20 articles were included based on the predefined eligibility criteria. Two articles were included from the additional hand search, which resulted in 22 articles in total for qualitative synthesis. The publication patterns are summarized in Table S2.1 (see Supplementary materials).

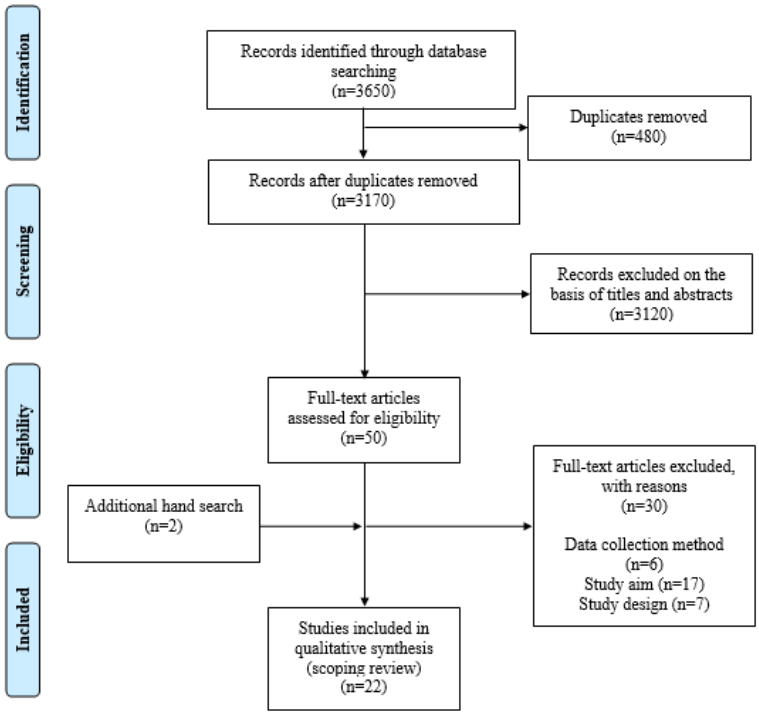


Figure 2.1 Scoping review flow diagram.

Electronic diary and study characteristics

More detailed information about the content of the 22 selected studies with empirical data on factors that influence the use of electronic diaries in health care can be found in Table 2.1. Electronic diaries were used either to monitor one's own behavior in order to get insight into underlying patterns or mechanisms (monitoring: 12/22, 55%) or to actively achieve change (intervention: 10/22, 45%). They mainly focused on measuring lifestyle behaviors (14/22, 64%) and constructs such as pain or mood. Participants completed these electronic diaries via palmtop (3/22, 14%), smartphone (14/22, 64%), or (tablet) computer (5/22, 22%). The assessment frequency ranged from 12 times a day, an example of the experience sampling method or ecological momentary assessment (EMA), to weekly, and the duration of the data collection varied from 2 weeks to 2.5 years.

The factors that influence the use of electronic diaries in health care were not the primary aim in all included studies. These factors were mentioned as part of a larger study, such as a randomized controlled trial or an intervention study. Studies focused on usability in half of the articles (10/22, 45%), followed by feasibility and effectiveness (7/22, 32%) and development (5/22, 23%). The design of these studies was quantitative (11/22, 50%), mixed (6/22, 27%), or qualitative (5/22, 23%). The number of participants ranged from 3 to 348, with a mean age of 49 years. Of these, 37.0% (493/1341) were male. The majority of the studies included patients with physical symptoms (12/22, 55%), whereas healthy individuals (7/22, 32%) and patients with mental health symptoms (3/22, 13%) were less often described.

Factors that influence the use of electronic diaries

The CFIR[25] was used to perform the qualitative thematic analysis of the factors that influence the use of electronic diaries in health care. The results of this qualitative thematic analysis were organized along 3 CFIR categories: intervention[29–31,33–49], user characteristics[28,32,36,37,39,41,42,44,45,49], and process[30–33,38,41,43–45,47,49]. No results were found for the 2 other CFIR categories: inner setting and outer setting. Figure 2.2 gives an overview of these categories, themes, and subthemes.

Table 2.1 Electronic diary (e-diary) and study characteristics.

First author, year, country	e-Diary characteristics			Study characteristics		
	Purpose of use[a] (device)	Constructs measured	Frequency of use and duration	Study aims	Design and data collection	Sample: target population, number of participants, sex, age (years)
Aaron, 2004, US	Intervention: cognitive behavioral therapy-based pain management training (palmtop)	Pain intensity, pain-related activity interference, jaw use limitations, mood, perceived stress	3 times a day for 8 weeks	Self-reported reasons for missing electronic diary interviews (EMA[b])	Quantitative: secondary analysis of existing RCT[c] data (CBT[d]-based pain management training or self-care manual condition)	Patients with TMD[e] (n=62), 16% male (n=10), mean age 38.6 (SD 11.6)
Litcher-Kelly, 2007, US	Monitoring: self-monitoring diaries (palmtop)	Mood, stress, pain, medication use	12 times a day for 3 weeks	Feasibility of an electronic diary	Quantitative: intervention study with continuous log data	Patients with inflammatory bowel disease (n=16), 25% male (n=4), mean age 46.0 (SD 13.6)
Welch, 2007, US	Monitoring: self-monitoring diaries (palmtop)	Food and fluid intake	3 times a day for 12 weeks	Feasibility of electronic self-monitoring diaries	Quantitative: pilot study with surveys	Patients on hemodialysis (n=3), 67% male (n=2), mean age 54
Stevens, 2008, US	Intervention: IT[f] weight loss program (computer)	Weight, food records, exercise minutes	Weekly for a 2.5-year follow-up	First year utilization and development process of an IT weight loss program	Quantitative: RCT with 3 groups (no-further treatment, control condition, or active maintenance weight loss intervention)	Adults with a BMI of 25-45 kg/m^2 who were taking medication for hypertension or hyperlipidemia (n=348), 37% male (n=128), mean age 56

Table 2.1 (continued)

First author, year, country	e-Diary characteristics			Study characteristics		
Webber, 2010, US	Monitoring: internet behavioral weight loss program (computer)	Daily caloric intake, daily exercise, weight	At least weekly for 16 weeks	Motivation and adherence to self-monitoring and weight loss	Quantitative: secondary analysis of existing RCT data (did or did not achieve 5% weight loss)	Adult women with a BMI of 25-40 kg/m^2 (n=66), mean age 50.1 (SD 9.9)
Ahtinen, 2013, Finland	Intervention: Oiva, a mobile mental wellness training application (smartphone)	Reflections and notes on exercises	Daily for a month	Use, acceptance, and usefulness of Oiva	Mixed methods: feasibility study with surveys, app log data and interviews	Individuals interested in stress management (n=15), 40% male (n=6), working age
Ben-Zeev, 2013, US	Intervention: FOCUS, a mobile illness self-management system (smartphone)	Medication adherence, mood regulation, sleep, social functioning, coping with persistent auditory hallucinations	Daily	Development of FOCUS	Mixed methods: usability study with surveys and think-aloud procedure	Patients with schizophrenia or schizoaffective disorder (n=12), 67% male (n=8), mean age 45
Ma, 2013, US	Intervention: eHealth weight loss intervention (computer)	Weight, physical activity	12 weeks, no app use criteria	Acceptance and use of an eHealth weight management intervention	Quantitative: secondary analysis of existing RCT data (coach-led or self-directed group)	Overweight or obese adults with prediabetes and/or metabolic syndrome (n=133), 53% male (n=70), mean age 53.5 (SD 10.5)
Tatara, 2013, Norway	Monitoring: Few Touch, a mobile self-management application (smartphone)	Nutritional habits	1 year, no app use criteria	Factors associated with use of Few Touch, a mobile self-management application	Mixed methods: longitudinal intervention trial with surveys, interviews, and focus groups	Individuals with type 2 diabetes mellitus (n=12), 33% male (n=4), mean age 55.1 (SD 9.6)

Table 2.1 (continued)

First author, year, country	e-Diary characteristics			Study characteristics		
Tang, 2015, UK	Monitoring: publicly available free applications MyFitness Pal, Livestrong, Calorie Count, SparkPeople (smartphone)	Not specified	3 weeks, no app use criteria	Understanding of users' experiences with weight loss or weight control apps	Qualitative: semistructured interviews	Young adults having experience with or interest in using an eHealth weight loss maintenance app (n=19), 54% male (n=10), age range 19–33
Triantafyllidis, 2015, UK	Monitoring: SUPPORT-HF, a remote health monitoring and nonpharmacological, self-monitoring system (tablet computer)	Physiological measurements (blood pressure, weight, oxygen saturation), heart failure symptoms, quality of life	5 days a week for 1 year	Development of SUPPORT-HF	Mixed methods: iterative refinement approach informed by action research	Patients with heart failure (n=26), 65% male (n=17), mean age 72 (SD 15)
Anderson, 2016, Australia	Monitoring: applications about chronic conditions (sleep disorders, migraine, menstrual irregularities, chronic depression, arthritis and Behçet's disease; smartphone)	Ranging from symptom monitoring or management apps to fitness apps	Ranging from several weeks to 2 years	Consumers' experiences with mobile health apps	Qualitative: individual semistructured interviews	Healthy individuals reporting the recent use of any commercially available health/fitness app with capacity for self-monitoring and data input (n=22), 32% male (n=7), age range 18–55

Table 2.1 (continued)

First author, year, country	e-Diary characteristics			Study characteristics		
Batink, 2016, The Netherlands	Intervention: ACT-DL, a mobile acceptance and commitment therapy in daily life training (smartphone)	Sleep quality, appraisal of the day, affect (positive and negative feelings), cognition, context (activity, company and whereabouts)	10 times a day for 3 days each week, for 4 weeks	Feasibility, acceptability, and effectiveness of ACT-DL (EMI[9])	Mixed methods: intervention study with 2 groups (experimental intervention or outpatient treatment)	Patients with a mental health disorder such as anxiety, mood, somatoform, or substance disorders: experimental intervention (n=49), 35% male (n=17), mean age 45.7 (SD 10.0); healthy individuals (n=112), 55% male (n=62), mean age 47.5 (SD 12.4)
Jiang, 2016, US	Monitoring: Pocket Personal Assistant for Training Health (Pocket PATH), a health self-monitoring application (smartphone)	Spirometry, temperature, blood pressure, pulse, symptoms, weight	12 months posttransplantation, no app use criteria	Acceptance and use of Pocket PATH	Quantitative: cross-sectional correlational design with secondary analysis of existing RCT data	Lung transplantation recipients transferred to the acute cardiothoracic unit (n=96), 51% male (n=49), mean age 57 (SD 14)
Naughton, 2016, UK	Intervention: Q-sense, a smoking cessation mobile phone application (smartphone)	Smoking behavior, psychological context, situational context	1 month before until 2 weeks after a preset quit date	Feasibility of Q-sense (EMI)	Mixed methods: an explanatory sequential mixed methods design with app log data and semistructured interviews	Adult smokers willing to set a quit date in the period between 1 week and 1 month after inclusion (n=15), 53% male (n=8), age range 18-45

Table 2.1 (continued)

First author, year, country	e-Diary characteristics			Study characteristics		
Timmerman, 2016, The Netherlands	Monitoring: telehealth care application with a symptom monitoring module and web-based exercise module (smartphone and computer)	Pain, fatigue, dyspnea	3 days a week during 2 weeks presurgery, the first month postsurgery, and 2 weeks prior to the doctor consultation at 3 and 6 months postsurgery	Development and usability of a multimodal ICT[h]-supported rehabilitation program for lung cancer	Qualitative: user-centered design with interviews and focus groups	Patients with NSCLC[i] (n=10), 30% male (n=3), mean age 62 (SD 11)
Burke, 2017, US	Intervention: standard behavioral intervention for weight (smartphone)	Not specified	5 times a day for 12 months	Lessons learned from development and implementation of an EMA study, focusing on the methods and logistics of conducting an EMA study and including strategies to ensure adequate adherence to EMA prompts	Qualitative: single-group, observational design	Former participants of laboratory weight loss studies (n=133), 9% male (n=12), mean age 51.09 (SD 10.10)
Crane, 2017, UK	Monitoring: DrinkLess, an application (smartphone)	Consequences of alcohol consumption, mood, productivity, clarity, sleep quality	Daily, at least 2 weeks, no app use criteria	Usability of DrinkLess	Qualitative: usability studies with think-aloud procedure and semistructured interviews	Healthy individuals (n=12 for both studies), 50% male (n=6), mean age 42 (first study) and 40 (second study)
Freyne, 2017, Australia	Intervention: PMRP[j], a behavioral-based mobile weight management program and application (smartphone)	Meal diary for previous day, current weight, dietary intake, update food diary	3 times a day for an intervention period of 12 weeks, followed by another 12-week period	Role of push notifications in persuading users to engage with self-monitoring tasks	Quantitative: intervention study with app log data	Overweight adults (BMI >25 kg/m^2; n=75), 27% male (n=20), mean age 48.6

Table 2.1 (continued)

First author, year, country	e-Diary characteristics			Study characteristics		
Kreyenbuhl, 2018, US	Intervention: MedActive, an application (smartphone)	Medication adherence, positive psychotic symptoms, medication side effects	Daily for 2 weeks	Acceptability and feasibility of MedActive (EMA)	Quantitative: user-centered design with surveys	Patients with schizophrenia spectrum disorder taking ≥1 oral antipsychotic medications (n=7), 100% male (n=7), mean age 47.6 (SD 10.4)
Liu, 2018, US	Monitoring: LoseIt, a physical activity and diet tracking application (smartphone)	Food intake	At least 3 days a week for 2 weeks	Effectiveness of LoseIt	Quantitative: randomized trial with 2 groups (goal setting reminders or generic reminders) with pre- and posttests	College students (n=50), 38% male (n=19), mean age 21 (SD 1.8)
Tomko, 2018, US	Monitoring: REDCap, ambulatory assessment software (computer)	Smoking, substance use, medication adherence	3 times daily for 8 weeks	Feasibility of ambulatory assessment (here applied in smoking cessation) for research purposes (EMA)	Quantitative: feasibility study within a double-blind RCT with 2 groups (N-acetylcysteine or placebo)	Adult smokers (n=36), 50% male (n=18), mean age 41.1 (SD 12.7)

[a] The purpose of use category is based on the authors' interpretation of the described goal of the electronic diary. [b] EMA: ecological momentary assessment. [c] RCT: randomized controlled trial.[d] CBT: cognitive behavioral therapy. [e] TMD: temporomandibular disorder. [f] IT: information technology. [g] EMI: ecological momentary intervention. [h] ICT: information communication technology. [i]NSCLC: non-small cell lung cancer. [j]PMRP: Partial Meal Replacement Program.

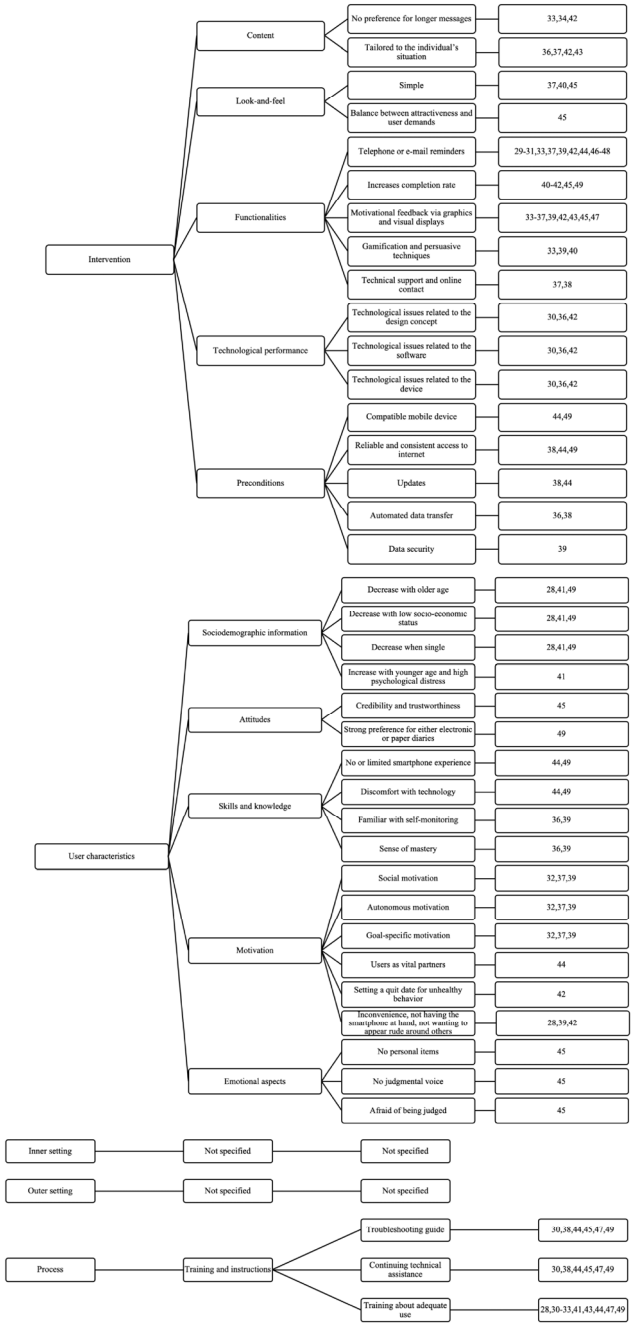


Figure 2.2 Visual representation of the factors that influence the use of electronic diaries in health care.

Intervention

The first category describes the key attributes of an electronic diary device, a smartphone application, or a web-based module. Five themes specify the intervention.

The first theme, "content", refers to the information in an electronic diary. Smartphone applications and web-based modules consisted of several content types like EMA, reminders, and reward messages[33,40,45,47–49]. This content supports communication between the patient and the health care professional. Long messages are considered too time-consuming to read, and users would therefore skip screens[33,34,42]. Furthermore, users may prefer both cartoons or videos and text[40–42,45,49]. Moreover, diary questions should be tailored to the individual's situation[36,37,42,43]. Users are inconclusive about the scope of the constructs measured; some may prefer an exclusive focus on one topic, whereas others may find that too limited[37,47].

The second theme, "look and feel", refers to the configuration or layout of an electronic diary. The user interface should be both simple and attractive[37,40,45]. However, a balance between attractiveness and user demands is required. Users may prefer a visually appealing user interface with minimal demands on them[45].

The third theme, "functionalities", refers to the activities that a user can perform within an application, ranging from procedures for recording and uploading data to customization of the user interface. Telephone or email reminders, either programmable or automated, notify the user to complete a questionnaire, which increases the completion rate[29–31,33,37,39,42,44,46–48]. Furthermore, manually entering several indicators per day increases participant burden[40–42,45,49]. Moreover, users want to receive motivational feedback about their results via clear graphics and visual displays[33–37,39,42,43,45,47]. Gamification and persuasive techniques can be used to provide motivational feedback to increase completion rates[33,39,40]. Additionally, Tang et al.[37] and Triantafyllidis et al.[38] identified that technical support and online contact with, for example, a health care professional increase the use of an electronic diary.

The fourth theme, "technological performance", refers to the technological issues that users encounter while using an electronic diary. Users can experience technological issues related to the design concept (e.g., navigation problems), the software, or the device (e.g., battery attrition). These errors reduce the usability of an electronic diary[30,36,42].

The fifth theme, "preconditions", refers to the conditions that must be fulfilled before a smartphone application or a web-based module can function properly. Burke et al.[44] and Tomko et al.[49] suggested that users are provided with a compatible mobile device (with sufficient memory, processing speed, and a functioning camera) to overcome the barrier of installing additional hardware or software on the user's device. Moreover, Burke et al.[44], Tomko et al.[49], and Triantafyllidis et al.[38] stated that users need reliable and consistent access to the internet while using the tool. Furthermore, they suggested checking for operating system and other smartphone updates that potentially interfere with the smartphone application of interest[38,44]. The electronic diary should be updated continuously; hence, bandwidth limitations should be taken into account, especially for web-based modules[31]. Automated data transfer to the background server or another device must be seamless for the individual to be able to use the device with minimal effort[36,38]. Depending on the type of data, users highly value data security. They are especially concerned that data would not be shared with health insurers[39].

User characteristics

The second category describes the characteristics of the individuals who use the electronic diary, in this case, healthy individuals and patients with physical or psychosocial problems. Five themes specify the user characteristics.

The first theme, "sociodemographic information", refers to the characteristics of a population such as gender, age, and marital status. The use of an electronic diary decreases when individuals are older, have a low socioeconomic status, or are unmarried, separated, divorced, or widowed[28,41,49], whereas an increase in the use of these tools is seen when individuals experience high psychological distress[41].

The second theme, "attitudes", refers to the way a user feels and behaves with regard to an electronic diary. Crane et al.[45] concluded that users' positive attitudes towards smartphone applications or web-based modules are based on credibility and trustworthiness of the information. Moreover, Tomko et al.[49] stated that users may have strong preferences for either electronic or paper diaries.

The third theme, "skills and knowledge", refers to the information that a user has about electronic diaries and the ability to use these tools. Users with no or limited smartphone experience and who experience discomfort with technology will not use electronic diaries adequately. Extra staff is required to

train these users[44,49]. Additionally, users who become familiar with self-monitoring or get a sense of mastery over their problems will lose their motivation and consequently stop or reduce their app use[36,39].

The fourth theme, "motivation", refers to the needs, desires, and drives of the individual to use an electronic diary. Naughton et al.[42], Anderson et al.[39], and Aaron et al.[28] stated that missing data are not caused by low motivation, but by discomfort, not having the smartphone at hand, or not wanting to appear rude around others. Social motivation, autonomous motivation, and goal-specific motivation increase the adherence to using electronic diaries[32,37,39]. Furthermore, making users vital partners in the development of an electronic diary keeps them motivated to use these devices[44]. In case of unhealthy behaviors, setting a quit date boosts users' commitment[42].

The fifth theme, "emotional aspects", refers to the feelings that are induced by using an electronic diary. When diary questions are too personal or judgmental, users are less likely to engage with a smartphone application or a web-based module[45]. Furthermore, they want to keep their data private because they are afraid of being judged[45]. However, in the study by Aaron et al.[28], emotional aspects were the least mentioned reasons for missing a questionnaire, although Crane et al.[45] found that users feel guilty when diaries are missed.

Process

The third category describes the activities related to the implementation process. One theme specifies the process.

The theme, "training and instructions", refers to how users are guided and instructed to adequately use an electronic diary. Training (e.g., face-to-face group kick-off presentation, training session to familiarize with the tool and troubleshoot issues) could result in higher use of these tools[28,30–33,41,43,44,47,49]. Furthermore, users may prefer a troubleshooting guide with step-by-step instructions or continuing technical assistance in case of technological issues from the staff or development team[30,38,44,45,47,49].

Discussion

Principal findings

This scoping review maps the existing knowledge and gaps concerning factors that influence the use of electronic diaries in health care. Due to technological developments in the last decades, electronic diaries have become increasingly available and popular in research and routine clinical practice. This increased interest is also visible in the large number of articles published between 2000 and 2018. However, only a small number of these articles focused on factors that influence the use of electronic diaries. Additionally, an even smaller number of the selected articles focused on implementing these tools in daily clinical practice.

In this scoping review, 22 articles were selected based on the predefined eligibility criteria. For the categories of intervention, user characteristics, and process of the CFIR[25], 11 themes were identified, whereas no empirical data were found for the 2 other CFIR categories: inner setting and outer setting. The use of an electronic diary is facilitated when it is a visually appealing tool with various content types, including reminders, clear in-app data visualizations tailored to the individual, and minimal user demands to increase the user's engagement. A compatible mobile device with reliable internet access and automated data transfer supports adequate use of an electronic diary. Additionally, the user needs to have smartphone experience, intrinsic motivation, and a clear rationale to monitor one's own behavior. Finally, both theoretical training and practical training are recommended to foster the implementation process. However, the required content and procedures of such training were not described in the included studies.

Based on these results and considering relevant implementation and adoption models, 2 findings attract attention. First, it is remarkable that there were only empirical data about the influence of the characteristics of the electronic diary, the individual, and the implementation process, whereas the CFIR and other implementation frameworks also emphasize the importance of factors related to the organization in which the care is provided or the organizational culture (inner setting) and the competition or the pressure from external partners and the regulations or legislation concerning electronic diaries in clinical practice (outer setting)[25]. Recent research on the implementation of patient-reported outcome measures also highlights the

importance of investing sufficient time and resources to support health care professionals[50–54].

Second, the scope of the implementation framework CFIR, used in this review, appears to be wider than adoption models that are traditionally used to evaluate user engagement and continued use of information systems and mobile technologies, like the Technology Acceptance Model[55–59]. The adoption models limit the scope to characteristics of the electronic diary and the individual user, whereas the CFIR also takes into account the process of implementation in daily clinical practice. In this review, the importance of training and instructions was revealed. The importance of hands-on instructions (individual coaching on the job sessions to familiarize with the use of experience-sampling technology in daily clinical practice, using real-world examples) as well as the ability to contact a help desk in case of practical and technological issues was underlined in our previous study as well[27]. Also, regarding the characteristics of the electronic diary, the adoption models have a smaller focus. They only highlight the running software as a contributing factor, while this scoping review identified that the information about and the layout of these diaries, as well as the technological issues and preconditions, also influence their use[55–59]. However, when considering the characteristics of the individual user, this scoping review revealed personal characteristics such as age, along with attitudes, emotions, and behaviors, while adoption models also focus on social influence and self-efficacy as contributing factors[55–59].

Implementation literature emphasizes that attention should be paid to the range of influencing factors to achieve a successful implementation in daily clinical practice[25,50–54]. Consequently, sustainable use of electronic diaries requires that health care organizations or professionals not only direct attention towards software, hardware, and the target population of the tool but also to the economic and political organizational context, the innovation climate in the organization, and the embedding of the tool in routine clinical practice.

Strengths and limitations

Several limitations have to be kept in mind while interpreting the results of this scoping review. The structured literature search was based on a combination of key words defined by preliminary literature exploration and expert consultation. Despite a broad search approach, it is still possible that articles were missed since the research topic was often not the primary aim of the included studies. This possibly resulted in selection bias. However, the additional hand search

minimized this potential shortcoming. It is also worth noting that most of the articles were excluded based on title screening. This can be seen as a limitation, but we think this approach is justifiable in our sensitive search. We performed an iterative screening process that required the researchers to engage in a reflexive way and repeat steps to ensure that the literature was covered in an extensive way. When the relevance of the study was not clear from the title, the abstract was always read. But it is still possible that we missed some articles. Moreover, as an extra check on the 3-step screening process, we read the full texts of a random sample of 50 titles and 50 abstracts. In only 4 articles, we found information in the results or the discussion related to our scope. Furthermore, as the aim of this scoping review was to map the existing empirical knowledge and identify any gaps about factors that influence the use of electronic diaries in health care, no study quality assessment was performed. Moreover, a scoping review does not endeavor to give a summary of the existing literature or compare results (in contrast to a systematic review of, for example, randomized controlled trials on efficacy). Therefore, we did not intend to draw firm conclusions regarding useful and effective features of electronic diaries based on quantified outcomes. We provide, to our knowledge, a first overview of the factors that influence the use of electronic diaries in health care. Future research with longitudinal or mixed methods study designs should focus on the causal relationships between the influencing factors and the use of electronic diaries in health care in order to get a deeper understanding of the causality. Also, a quite diverse sample of studies was included. However, we are convinced that we have achieved the scope of interest of this scoping review. We looked in more detail at similarities and differences in the results of the included studies, based on the purpose of use (monitoring versus intervention), target population (healthy individuals versus patients), setting, study aims, and design (feasibility versus usability versus development). However, we concluded that this synthesis cannot be performed based on the results of the information found in this scoping review. More research is needed in this field. Additionally, the structured literature search was restricted to peer-reviewed databases and so, empirical research. Book chapters and grey literature were not included, which means that additional empirical data can be lacking. This scoping review has several methodological strengths as well. First, a systematic approach was used based on the methodological framework by Arksey and O'Malley[24]. The interprofessional nature of the research team extended the scope of this review, and the consultation of 2 experts in the field validated the search terms. Furthermore, the 3-step screening process was consistently performed by 2

researchers. Second, the thematic analysis organized according to an implementation research perspective led to a synthesis contributing to future understanding of the implementation of electronic diaries in health care.

Conclusion

This scoping review demonstrates that the use of electronic diaries may be influenced by characteristics of the electronic diary, the individual user, and the implementation process. However, the number of empirical studies on the topic was limited. Studies that take into account the setting in which to implement the diaries, such as the organizational context, the implementation climate, and available organizational resources, were lacking. Future research should focus on these factors and on the causal relationships between the different factors to investigate the continued use of these innovative tools.

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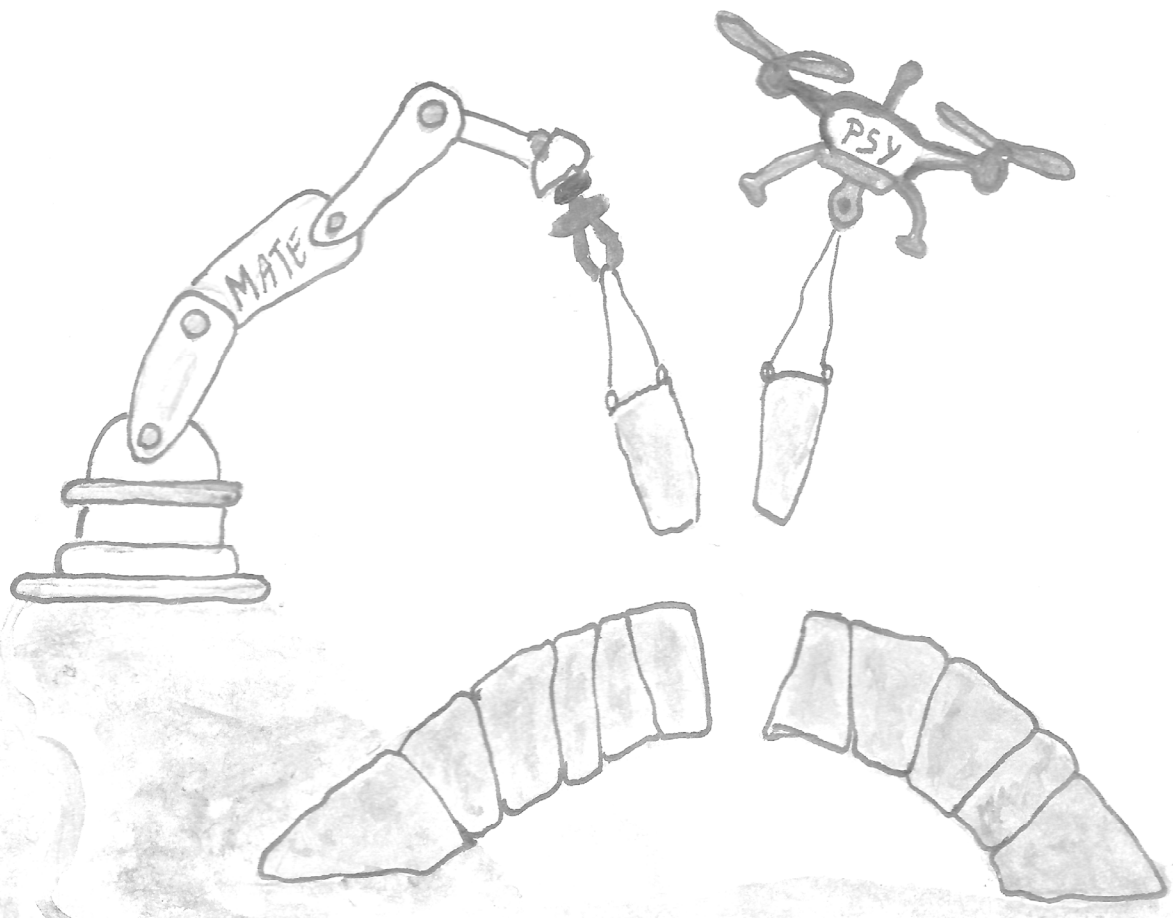
Supplementary materials

Table S2.1 Patterns of publications.

Main aspect	Distribution	N (%)
Database	PubMed	14 (64%)
	PsycInfo	8 (36%)
Publication date	2000–2009	4 (18%)
	2010–2014	5 (23%)
	2015–2018	13 (59%)
Countries	United States of America	12 (54%)
	United Kingdom	4 (18%)
	The Netherlands	2 (9%)
	Norway	1 (5%)
	Australia	2 (9%)
	Finland	1 (5%)

Part II

Cognition in daily life



Chapter 3

Measuring within-day cognitive performance using the experience sampling method: A pilot study in a healthy population

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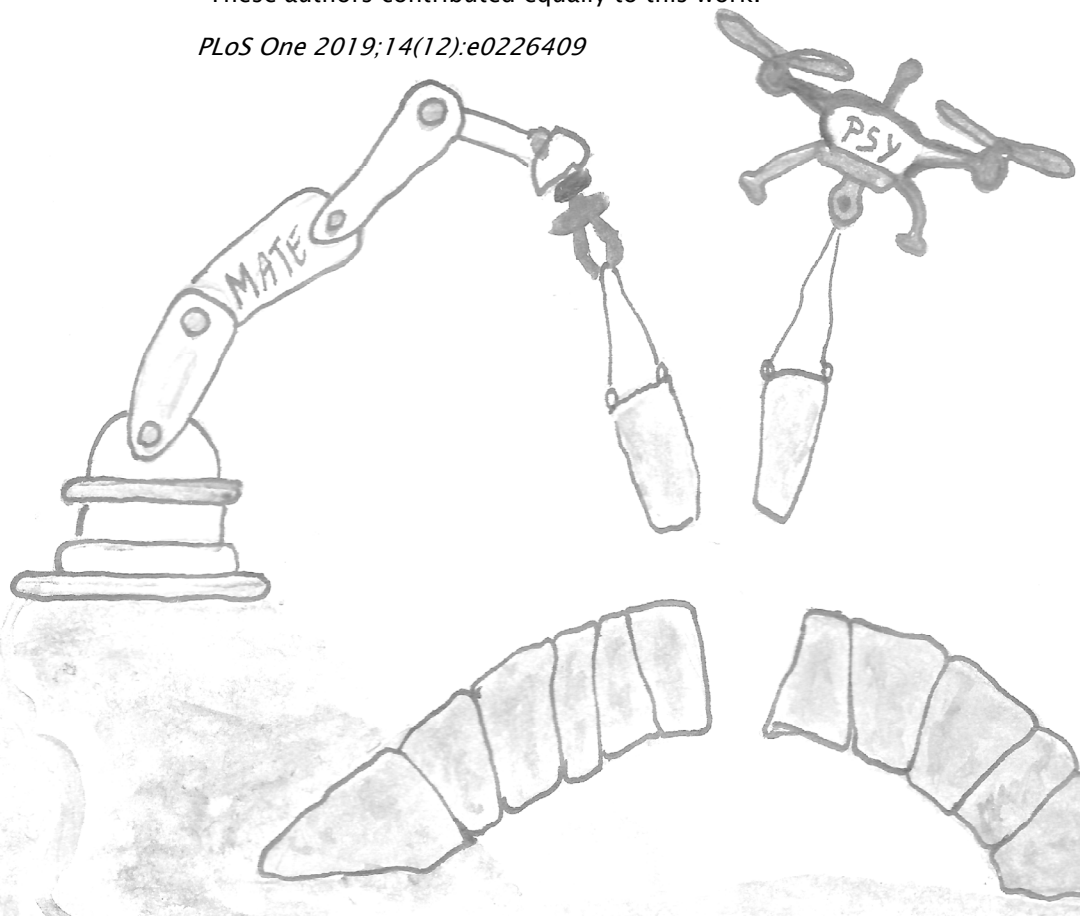

Abstract

Introduction

People with depression, anxiety, or psychosis often complain of confusion, problems concentrating or difficulties cognitively appraising contextual cues. The same applies to people with neurodegenerative diseases or brain damage such as dementia or stroke. Assessments of those cognitive difficulties often occurs in cross-sectional and controlled clinical settings. Information on daily moment-to-moment cognitive fluctuations and its relation to affect and context is lacking. The development and evaluation of a digital cognition task is presented. It enables the fine-grained mapping of cognition and its relation to mood, intrapersonal factors and context.

Methods

The momentary Digit Symbol Substitution Task is a modified digital version of the original paper-and-pencil task, with a duration of 30 seconds and implemented in an experience sampling protocol (8 semi-random assessments a day on 6 consecutive days). It was tested in the healthy population (N=40). Descriptive statistics and multilevel regression analyses were used to determine initial feasibility and assess cognitive patterns in everyday life. Cognition outcome measures were the number of trials within the 30-second sessions and the percentage of correct trials.

Results

Subjects reported the task to be easy, pleasant and do-able. On average, participants completed 11 trials with 97% accuracy per 30-second session. Cognitive variation was related to mood, with an interaction between positive and negative affect for accuracy (% correct) (p=.001) and an association between positive affect and speed (number of trials) (p=.01). Specifically, cheerful, irritated and anxious seem to covary with cognition. Distraction and location are relevant contextual factors. The number of trials showed a learning effect (p<.001) and was sensitive to age (p<.001).

Conclusion

Implementing a digital cognition task within an experience-sampling paradigm shows promise. Fine-tuning in further research and in clinical samples is needed. Gaining insight into cognitive functioning could help patients navigate and adjust the demands of daily life.

Introduction

Various patient populations experience confusion, difficulties to concentrate or problems to cognitively grasp contextual cues[1–5]. To assess an individual's ability to function and cope in everyday life, neuropsychological tests are crucial. The information generated can be included in evaluating whether someone is, for example, capable of independent living or self-care[6]. Given these far-reaching consequences, it is important that the performance measured with a neuropsychological test accurately reflects performance in daily life. A review by Chaytor and Schmitter-Edgecombe [2003] suggests, however, that, when the relationship between tests and measures of daily functioning is considered, neuropsychological tests might only have moderate ecological validity for predicting everyday cognitive functioning[7].

While the general use of neuropsychological tests has gained importance in recent years, the tests themselves as well as the standardized context of administration remained largely the same[8]. Often, a battery of cognition tests (e.g., CANTAB) are used to determine someone's cognitive potential on a range of domains[9]. Individual tests often take several minutes to administer and are performed in the presence of a professional in minimum distraction environments. The goal is to determine a stable cognition factor that provides insight into the individual's general strengths and vulnerabilities[8]. However, the clinical test conditions sharply contrast with everyday environments. Everyday life is comprised of multi-sensory elements such as distracting sounds, smells, lights, or tactile stimuli. Furthermore, daily stressors and mental states can influence an individual's cognitive ability[10,11]. Mood, for example, follows a dynamic pattern in everyday life[12] and its effect on cognition from one moment to the next is seldom considered. Moreover, cognition is known to fluctuate over the day, depending on factors such as the level of alertness or food intake[13,14]. To improve the understanding of cognition in everyday life, the assessments need to take place in natural daily environments.

Ideally, other domains such as mood and behavior are monitored simultaneously so that underlying associations can be learned. Insight into these implicit patterns would enrich treatment for cognitive complaints and provide additional clues for recovery and rehabilitation processes, next to opportunities to tailor interventions to the individual[15]. By providing cognitive assessments within the Experience Sampling Method (ESM) this strategy becomes possible.

ESM, also called Ecological Momentary Assessments (EMA), is a (digital) structured self-assessment diary technique that allows insight into the everyday life of an individual[16]. At several (semi-) random times during the day, eHealth technologies such as Personal Digital Assistants or smartphone apps give signals (beeps) to prompt the collection of momentary experiences. At those moments, participants are asked to reflect on their current mood, environmental context, and activities and report their real-time information to the eHealth technology used. ESM is characterized by a high ecological validity as it collects experiential and contextual data in situ[17]. In-the-moment reflections reduce the recall bias that troubles retrospective self-reports[18]. Furthermore, repeated ESM measures allow a better understanding of between- and within-person variability in psychopathology and beyond[12]. As ESM can be experienced as time-consuming, the questionnaires need to be kept short and the design transparent to avoid overburdening[17].

The initial feasibility and acceptability of cognition tasks in an ESM paradigm are supported by a small number of studies, including domains such as working memory, attention, or processing speed[19]. The feasibility of a digital trail making test assessing processing speed in everyday life, for example, was found to be feasible in Chinese patients with depression[20]. Another study investigated the reliability and validity of three ambulatory cognition tasks measuring different cognitive domains (i.e., Symbol search, Dot memory, and an N-back task)[21]. Results indicated that all three tasks are feasible within an ESM paradigm and show excellent between-person reliability, reliable within-person variability, and construct validity with cross-sectional cognitive assessments[21]. In young adults, a digital processing speed task was not only feasible, but also sensitive to blood alcohol concentration[22].

Notably, most studies on daily life cognition focus only on a limited number of contextual factors in relation to cognitive performance. As everyday life is extremely complex, more research is needed to contextualize daily cognition with extensive intrapersonal (e.g., mood, age, fatigue) and contextual factors (e.g., location, company). Additionally, cognition tasks in everyday environments that take multiple minutes to perform[23] might, on one hand, provide valuable information on daily cognitive functioning. On the other hand, the length of the task can result in a relatively low sampling frequency to not overburden the participant and thus limit the exploration of cognitive fluctuations over the course of the day. In order to learn which factors influence cognitive variation over time, a higher sampling rate is required with shorter beep durations to minimize burden. This strategy would enable to study the

influence of different daily situations on cognition. Ultimately, the test results could be reported back to patients and discussed together with a clinician in relation to other relevant health domains.

The present study aims to build an objective cognition task with a short duration for repeated assessments and to implement this task into a daily life setting. Accordingly, a modified digital version of the Digital Symbol Substitution Task was used within the ESM-based PsyMate™ application on an iPod for six consecutive days by healthy individuals. This digital cognition task is called momentary Digital Symbol Substitution Task (mDSST).

First, the utility and feasibility of the mDSST was determined through the participants' compliance rate and retrospective subjective experience. Second, the focus lay on validation via comprehensive contextualization of daily cognitive performance. The relationship between intrapersonal as well as contextual factors and the mDSST performance was investigated using high frequency ESM sampling (eight times a day).

Prospectively, digital cognition tasks in everyday life may be relevant for improved prevention, treatment, and rehabilitation of psychopathology.

Methods

Participants

Individuals from the general population were recruited via poster advertisement at Maastricht University and through social media as seeds for snowball sampling[24]. Sample size was based on recommendations for pilot studies and other exploratory ESM studies[25–27]. In total, 45 participants provided written informed consent. All individuals were 18 years or older, had sufficient command of the Dutch language, and were able to handle an iPod with the PsyMate™ app. Exclusion criteria were medication use that influences cognitive performance and current treatment for mental illnesses or cognitive complaints. Ethical approval was obtained by the standing ethical committee of the Faculty of Psychology and Neuroscience, Maastricht University (ref.no.183_02_09_2017).

Measurements

PsyMate™

The PsyMate™ is a web-based platform for moment-to-moment assessment of mood and behavior in daily life. It includes an App (iOS and Android), cloud-based data storage, and reporting tool. The PsyMate™ was developed by Maastricht University and Maastricht UMC+ (www.psymate.eu) and programmed to prompt participants using auditory signals eight times a day to complete a self-report questionnaire (approximately two minutes). Signals (beeps) were provided between 7.30 AM and 10.30 PM in semi-random time blocks of 112,5 minutes. The self-report questionnaire assessed mood, physical status (i.e., fatigue, hunger), and context (i.e., location, activity, and persons present). The mood items were combined in two independent constructs[15]: Positive Affect (PA) by averaging 'cheerful', 'energetic', 'relaxed', 'enthusiastic', and 'satisfied', and Negative Affect (NA) using 'insecure', 'down', 'irritated', 'lonely', 'anxious', and 'guilty'. The mood and physical status items were rated on a 7-point Likert scale (1 = not at all, 4 = moderate, 7 = very) and the context items were assessed categorically. The complete item list is included as supporting information (see S3.1 Appendix). In addition to the self-report questionnaire on the beep level, participants were asked to complete a morning and an evening questionnaire. These additional questionnaires consisted of self-report items that assessed respectively sleep duration and sleep quality, and general appraisal of the day. Most items of the morning questionnaire were assessed categorically, whereas all the items of the evening questionnaire were rated on a 7-point Likert scale (1 = not at all, 4 = moderate, 7 = very). Participants were included in the analyses if they completed a minimum of sixteen valid beep moments (1/3 of total), conform with ESM guidelines[28]. All participants were provided with an iPod on which the PsyMate™ app (version 2.0.0.) was installed to standardize the administration of the momentary Digit Symbol Substitution Task (mDSST). To evaluate the PsyMate™ procedure, debriefing questionnaires were provided after the ESM completion.

PsyMate™ mDSST

The mDSST is based on the Digit Symbol Substitution Task from the Wechsler Adult Intelligence Scale (WAIS)[29]. It measures information processing speed and short-term working memory. The modified mDSST primarily assesses information processing speed, but not short-term working memory due to

design choices (e.g., short duration, one-by-one presentation) that are part of the ESM set-up. The task was selected after consultations with psychiatric and neuropsychological healthcare professionals and scholars of daily life assessment. The constraints were that the digital cognition task could be performed multiple times per day and therefore had to be short, sensitive to cognitive fluctuations, and show no or only a small learning effect. The mDSST is thought to fulfil these criteria.

The mDSST started after the standard ESM beep questionnaire. Participants viewed an instruction screen including a button to start the task. The item screen displays the numbers 1 to 9 with a corresponding symbol at the top of the screen (encoding information). For each trial, a number was presented one-by-one in the middle of the screen. Participants had to select the corresponding symbol at the bottom of the screen (see Figure 3.1). Symbols were kept similar to the original Digit Symbol Substitution Task. The task duration was 30 seconds and participants were instructed to complete as many trials as possible while also being as accurate as possible. Five unique combinations of numbers and symbols with corresponding answer keys were programmed beforehand and presented in random order over the course of the 48 beeps. Outcome measures of the PsyMate™ mDSST are the number of trials (how many one-by-one trials are completed within 30-second sessions) and the percentage of correct trials (the number of correctly answered trials divided by the total number of trials).

Debriefing questionnaire

Participants received a debriefing questionnaire with three parts using open-ended and 7-point Likert scale questions: 1) to assess the general experience of participants throughout the week (e.g., was this a normal week, did participation influence your mood, social contact or activities); 2) to evaluate the usability of the PsyMate™ in general (e.g., was the PsyMate™ difficult to use, was the number of questionnaires burdensome, were there any technical issues); and 3) to assess the experiences with the mDSST (e.g., how well do you think you performed on the task, was the task difficult, was the task enjoyable).

Figure 3.1 Momentary digit symbol substitution task in the PsyMate™ application.

Procedure

After participants provided written informed consent, a briefing session of one hour took place. Participants provided sociodemographic information including gender, age, living situation, education level, current occupation, and ethnicity. Additionally, current medication use and treatment for mental illnesses and cognitive complaints were assessed through self-reports. Furthermore, participants received an iPod (5th generation) with the PsyMate™ (v2.0.0.) preinstalled. They were instructed how to use the PsyMate™ and performed a test trial to familiarize themselves with the ESM procedure. Then, the participants used the PsyMate™ for six consecutive days, starting on the day after the briefing session. On the second day of the ESM period, participants were contacted by telephone to assist with potential problems or answer questions. After the ESM period, a debriefing session of one hour took place in which participants completed the debriefing questionnaire and returned the iPod.

Statistical analyses

Descriptive statistics were used to assess participant characteristics, initial feasibility, and acceptability (frequencies) of the ESM protocol. The completion rate was calculated by comparing the mean percentage of valid beep moments to the total number of beep moments. The data collected with the PsyMate™ have a multilevel structure; beeps (level 1) were nested in participants (level 2). Average scores of the variables of interest were person-mean centered to take into account the within-person effect. In order to look at contextualized variation, dummy variables were created for location (at home versus somewhere else), company (alone versus with others), and coffee use since the last beep (yes or no). Furthermore, activity-related stress was conceptualized as an average of the items 'I would rather be doing something else', 'This is difficult for me', and 'I can do this well' (reverse coded). In order to look at learning effects, a log transformation of the replication (sequence number of responded beeps within subjects ranging from 1 (first beep) to 48 (last beep)) was calculated as a proxy measure of time across the six-day period. Additionally, within day time effect was explored using hour of the day and its quadratic function. To assess cognitive variation over time and to check for learning effects, multilevel regression analyses were run with the number of trials within the 30-seconds interval and the percentage of correct trials (for each assessment moment) on the mDSST as dependent variables and respectively time (i.e., log transformation of replication), hour, squared hour, and a log transformation of day number (from day 1 to day 6) as independent variables. Furthermore, multilevel analyses were run to assess the association between positive affect, negative affect, its interaction, and various other contextual factors (e.g., fatigue, distraction) as independent variables and both cognition outcomes as dependent variables. Additionally, multilevel stepwise regression procedures were used to explore the effect of individual mood items on cognition. Both forward and backward strategies were applied. The individual mood items and various other contextual factors were seen as independent variables and cognition as dependent variable. Quadratic function of age, gender, possible learning effects, and within-day effects were considered as covariates in all multilevel models. Analyses were carried out using Stata version 13.0[30]. A two-sided significance level of .05 was used.

Results

Participants

Forty-five participants were included in the ESM protocol, resulting in 1330 valid beep records. Two participants were unable to finish the ESM protocol due to problems with the iPod device (loss of 11 records, 0.83%), one participant was excluded because the iPod was stolen (loss of 9 records, 0.68%), and two participants did not reach the criteria of at least 16 valid beeps due to various reasons (loss of 20 records, 1.50%). The complete dataset consisted of 40 participants with 1293 valid beep records. The participants' age ranged from 21 to 72 years of age with a mean of 30.4 (*SD*=14.79, *Mdn*=23.0). On average, participants completed 33 beeps (*SD*=4.9, range 21–43) of the 48 scheduled beeps. ESM completion rate was 69%. See Table 3.1 for descriptive statistics of the healthy population sample.

Table 3.1 Descriptive statistics for the healthy population sample (N = 40).

	N (%)
Gender (women)	29 (72.5%)
Education level	
Secondary vocational education	5 (13%)
Bachelor degree	20 (50%)
Master degree	15 (37%)
Occupation	
Students	25 (62%)
Fulltime work	10 (25%)
Part-time work	3 (8%)
Voluntary work	1 (2.5%)
No occupation	1 (2,5%)

Feasibility

In order to assess feasibility, the available data from the debriefing questionnaire was used. One participant, whose iPod was stolen, did not complete this evaluation questionnaire, leaving 44 participants in the sample. All other analyses based on ESM/PsyMate™ data were performed with a sample size of forty participants.

Evaluation PsyMate™ procedure

Participants reported that the ESM items were a good representation of their experience (*M*=5.1, *SD*=1.26). They had no difficulty using the PsyMate™ (*M*=1.59, *SD*=1.06) and the verbal and written instructions were clear (verbal: *M*=6.64, *SD*=.53; written: *M*=6.43, *SD*=.70). Furthermore, completing the items had little influence on their mood (*M*=2.07, *SD*=1.26), activities (*M*=1.89, *SD*=1.5), and social contact (*M*=1.55, *SD*=.93). Participating in ESM did not hinder their daily activities (*M*=2.16, *SD*=1.31). With regard to the burden, participants reported that the number of beeps a day (*M*=3.23, *SD*=1.46), the duration of beep completion (*M*=2.32, *SD*=1.29), and the beep sound (*M*=3.18, *SD*=1.97) had low impact.

Evaluation of the mDSST

Participants were motivated to perform well on the mDSST (*M*=5.70, *SD*=.93), the mDSST was moderately pleasant to perform (*M*=4.43, *SD*=1.37), and participants would recommend the task to others (*M*=5.48, *SD*=1.17). Overall, the task was experienced as easy (*M*=1.80, *SD*=1.15). However, when participants had to assess their own performance retrospectively, they indicated to have performed moderately on the mDSST (*M*=4.55, *SD*=1.19). Also in retrospect, they reported to be moderately distracted during the task (*M*=3.51, *SD*=1.39).

Variation in cognition

Participants completed on average 11.39 trials within 30-second sessions (*SD*=1.32, range 3-15), with an average percentage correct of 97.11 (*SD*=2.01, range 28.6-100). The number of trials was positively associated with time (*B*=.36, *SE*=.033, $p<.001$, 95% CI=.30, .43), with a positive within-day effect for hour of the day (*B*=.03, *SE*=.007, $p<.001$, 95% CI=.01, .04), and a positive between-day effect for day number (*B*=.45, *SE*=.05, $p<.001$, 95% CI=.35, .54). The percentage of correct trials was not associated with time (*B*=-.26, *SE*=.19, *p*=.17, 95% CI=-.63, .11), with no within-day (*B*=-.04, *SE*=.04, *p*=.36, 95% CI=-.11, .04) or between-day effect (*B*=-.21, *SE*=.27, *p*=.45, 95% CI=-.74, .32).

Mood, contextual factors, and cognition

Participants experienced high positive affect (*M*=4.82, *SD*=.77, range 2.68–6.48) and low negative affect (*M*=1.65, *SD*=.47, range 1.01–2.98) throughout the study. They were a little worried (*M*=2.52, *SD*=1.00, range 1.00–4.78) and felt moderately fatigued (*M*=3.69, *SD*=1.03, range 1.55–5.77). Furthermore, they experienced low activity-related stress (*M*=2.68, *SD*=.61, range 1.37–3.73) and were moderately focused on their current activities (*M*=4.87, *SD*=.73, range 3.39–6.63). On the mDSST, they reported a low to moderate level of distraction during this task (*M*=2.88, *SD*=.88, range 1.15–4.67).

Only the main significant aggregated findings from the multilevel regression analyses are reported. Single-item analyses are included in the supplementary material (see S3.1 Table). Participants performed more trials (*B*=.08, *p*=.04) and made less mistakes (*B*=.62, *p*=.001) when experiencing high positive affect. They made more mistakes when experiencing high negative affect (*B*=-1.41, *p*<.001). With regard to the contextual factors, participants performed less trials when being at a different location then home (*B*=-.20, *p*=.002) and when reporting to be distracted (*B*=-.17, *p*<.001). They also made more mistakes when distracted (*B*=-.46, *p*<.001). Fatigue, activity-related stress, worrying, current company, coffee use, and being able to focus were unrelated to both cognition outcome measures. With regard to possible covariates, less trials were performed with higher age (*B*=-.001, *p*<.001), and when being male. A positive association was found between the time measures (i.e., the log-transformed replication variable as time measure, hour, squared hour) and the number of trials (e.g., the log-transformed replication variable as time measure; *B*=.36, *p*<.001). The variables with an association with the cognitive outcome measures were included in further multilevel regression models.

In the final model of the number of trials, participants again performed more trials when experiencing high positive affect (*B*=.20, *p*=.01). In addition, a positive learning effect was present with more trials completed over time (*B*=.38, *p*<.001). Moreover, participants completed less trials when distracted (*B*=-.19, *p*<.001) and at an older age (*B*=-.0008, *p*<.001). The results of this analysis indicated that the six predictors explained 36% of the overall variance (16% within-subject variance and 47% between-subject variance).

In the final model of the percentage of correct trials, a positive interaction effect was found between positive affect and negative affect for the percentage of correct trials. In other words, the influence of negative affect on correctness

is limited when positive affect is high, but stronger when positive affect is low (B=.71, p=.001). Additionally, participants made more mistakes when distracted (B=-.46, p<.001). The results of this analysis indicated that the four predictors explained 3% of the overall variance (5% within-subject variance and 0.1% between-subject variance). The results of the final models are presented in Table 3.2 (the number of trials) and Table 3.3 (the percentage of correct trials).

Table 3.2 Multilevel regression analyses of mood, distraction, time, and age during the mDSST on the number of trials.

	Number of trials				
	B	**SE**	**p**	**95% CI**	
Model 1			<.001*		
Positive Affect	.20	.08	.01*	.04,	.36
Negative Affect	.27	.17	.12	-.07,	.60
Interaction between Positive Affect and Negative Affect	-.04	.04	.34	-.12,	.04
Distracted	-.19	.02	<.001*	-.22,	-.15
Time^{s}	.38	.03	<.001*	.31,	.44
Age^{2}	-.0008	.0001	<.001*	-.001,	-.0005

Note. CI = Confidence Interval. Time^{s} = log-transformed replication score. Age^{2} = squared age. *p<.05.

Table 3.3 Multilevel regression analyses of mood and distraction during the mDSST on the percentage of correct trials.

	Percentage of correct trials				
	B	**SE**	**P**	**95% CI**	
Model 1			<.001*		
Positive Affect	-.89	.43	.04*	-1.73,	-.05
Negative Affect	-4.10	.97	<.001*	-5.99,	-2.21
Interaction between Positive Affect and Negative Affect	.71	.22	.001*	.28,	1.15
Distracted	-.46	.11	<.001*	-.67,	-.26

Note. CI = Confidence Interval. *p<.05.

Exploratory analyses on individual mood items

The pairwise correlation of individual mood items ranged from .42 to .74 for positive affect items and from .30 to .54 for negative affect items. These correlations disregard the nested within-subject variance. When subtracting by subject means to assess within-subject variance only, the correlations were considerably lower (from .24 to .63 for positive affect, and from .18 to .40 for

negative affect). Results are presented in the supporting information (see S3.2 Table).

Exploratory multilevel regression analyses of individual mood items on cognition were computed, using mood items as independent variables and cognitive outcome measures as dependent variables (see S3.3 Table for an overview). Only the items cheerful and energetic were positively associated with the number of trials (respectively B=.12, p<.001; B=.06, p=.02). The positive affect items cheerful (B=.54, p<.001), relaxed (B=.51, p<.001), and satisfied (B=.53, p=.001) were positively associated with the percentage of correct trials. All negative affect items were negatively associated with percentage of correct trials.

In order to weigh item covariation, both forward and backward stepwise strategies were applied. These results are also presented in the supporting information (see S3.3 Table). In the backward-approach, cheerful remained the most prominent positive mood variable associated with the number of trials (B=.13 p<.001) and the percentage of correct trials (B=.36 p=.03). For the negative affect items, irritated showed a positive association with the number of trials (B=.07 p=.01), whereas anxious was negatively associated with the percentage of correct trials (B=-.69 p=.01).

Discussion

A novel digital cognition task, the mDSST, was evaluated for use within a daily life ESM protocol. The first aim was to assess the utility and initial feasibility of the mDSST. The second aim was to study the preliminary internal validation of measuring cognition in daily life, both as varying over time and in relation to contextual and intrapersonal factors.

Feasibility and utility of the PsyMate™ mDSST

ESM data from three participants were removed due to circumstances outside our control and two participants did not reach the minimum beep requirements, leaving 40 participants with analyzable data. Participants completed on average 33 beeps within a 48-beep protocol, resulting in a completion rate of 69%. The participants' overall experience was positive; ESM completion did not hinder daily life and the burden was reported as acceptable. This result is satisfactory and similar to other ESM research with and without a cognition task[19,23,31,32].

The cognition task was evaluated as easy and pleasant to perform. Task motivation was high and participants felt competitive towards the task, although several participants indicated that this competitiveness faded towards the end of the six-day assessment period. This is an indication that the task is less suited for longer data collection periods, as is relevant in clinical practice. Solutions in this context should alternate the task with another cognition measure or provide cognitive assessments in a subset of beep-moments each day.

Contextualization of the PsyMate mDSST

Information processing speed was measured with a modified momentary version of the Digit Symbol Substitution Task that yielded two outcome measures: the number of trials within 30 seconds and the percentage of correct trials[29]. On average, participants completed 11 trials within 30-second sessions (speed) and answered 97% correct (accuracy). This high correctness score indicates that the task is easy, something that is also reflected in the participants' retrospective evaluation. The choice for a DSST-based task was deliberate because it proved sensitive to detect cognitive complaints and changes in cognitive functioning in clinical samples[33,34]. As this is a cognitive healthy sample, it is unsurprising that participants made little mistakes. Generally, cognitive performance can be viewed as a trade-off between accuracy and speed. Here, accuracy showed a ceiling effect (with reduced variability) while speed is a more sensitive measure. Only the number of trials showed a learning effect over time, with a slight increase of trials during the first half of the ESM period followed by a stabilization. Additionally, more trials were completed towards the end of the day.

The relationship between mood and the accuracy outcome reflected a positive interaction effect between positive affect, negative affect, and the percentage of correct trials. In situations were negative affect is high, participants also tend to make more mistakes, an effect that is strongest when positive affect is low. Zooming in on individual mood items, only cheerful and anxious seemed to be associated with the accuracy outcome. Therefore, it has merit to unpack the positive and negative mood aggregations to get relevant information and clues for clinical practice. A possible explanation could be that people are less able to focus on a task when they feel anxious. This negative influence of mood on cognitive performance is observed in clinically depressed patients and might be caused by distractions due to ruminations[35,36]. Here,

participants who got distracted during the task also made more mistakes. As distraction was assessed after task completion, it is possible that participants who noticed that they made mistakes, consequently scored higher on distraction. Overall, the explained variance for accuracy in relation to mood and contextual factors is neglible (3%) and combined with a ceiling effect it seems to be an irrelevant chance finding in a population without cognitive complaints.

A small positive association was found between mood (positive affect and more specifically cheerful) and the speed outcome. Participants who were more cheerful also completed more trials irrespective of learning effects. With regard to contextual and intrapersonal factors, a small negative association was found between age and speed, indicating that older participants overall completed less trials. The original Digit Symbol Substitution task is known to be sensitive in identifying age-related performance and processing speed often explains a large part of the variance in these studies[37]. Our modified digital version of the task was also age-sensitive. With regard to gender, males seemed to perform slower compared to females, an effect that disappeared in the final model. In the original Digit Substitution tests, men also seem to perform less well when averaged[38,39]. In this convenience sample however, females were overrepresented (73%) and further research is needed.

Similar to the accuracy outcome, higher distraction was associated with fewer completed trials within a 30-second session. Here, the overall explained variance is clearly higher (36%). There is more variation over time with only a small learning effect. Indicating that the speed outcome is more suited to assess cognition in the current sample.

Several daily life factors were explored. Only distraction was associated with cognition, whereas other factors such as activity-related stress, company, and being able to focus were not. One other study looked at situational cues in relation to cognitive performance within an ESM paradigm. They found that working memory performance did not differ for people at work versus at home, but that short-term memory improved during worktime[40]. Possibly, processing speed is less sensitive to contextual changes.

Notably, fatigue did not vary significantly over time and had no effect on cognition. This was surprising, since other studies with a young population show a negative impact of tiredness on mental processing and increased difficulties with focusing on a task[41–43]. However, the mDSST was only 30 seconds while a standard cognitive assessment is longer (often 2 minutes). It is likely that the association of cognition with fatigue only occurs in longer or more demanding tasks, which are not suited to the ESM paradigm.

Strengths and limitations

The PsyMate™ app with the mDSST can be used on an individual's own smartphone and is not restricted to the provided iPod. The use of cognition tasks on smartphones is feasible[50,51]. By using iPod devices across participants, the device specifications during the initial validity were standardized. In the early stages of task development, uncertainty about test characteristics, design choices, and device specifications exists. The use of the same device, the iPod, reduced the uncertainties about factors that might influence outcome across the study sample. In later stages, the influence of different devices (i.e., own smartphones) will become less problematic as the goal shifts towards an evaluation of within-person variability for clinical purposes.

Additionally, the mDSST was developed in an inter-professional context. Researchers (both in mental health and somatic care), physicians, neuropsychologists, clinicians, and software developers worked together to accomplish a tool that can prospectively be used across disciplines and in daily practice.

Although the study has several advantages, limitations need to be kept in mind. First, our sample was mainly restricted to female students (70% women, 61% students, median age was 23). The study, however, was intended as a pilot study using convenience sampling to assess initial feasibility and validity. The mDSST has shown merit for daily life assessment and age sensitivity of the mDSST could already be indicated. Nonetheless, using a more heterogeneous population, a broader age range (through stratification), as well as populations with cognitive impairments, will increase knowledge about task sensitivity as well as a more diverse examination of between- and within-person variance in task performance.

Second, technical problems have influenced the study outcomes. The beep questionnaire was only available for ten minutes. When participants initiated the questionnaire within the ten-minute boundary, the software should allow them to finish the task. However, the PsyMate™ app stopped after 10 minutes sharp, which resulted in 15 unfinished and interrupted tasks. The number of trials statistic was unreliable in these cases. Furthermore, the first participants indicated not hearing the beep sound (leading to eighteen missed beeps). This problem was resolved by a system update that enabled a louder and more intrusive beep sound. The technological issues concerning the mDSST seem unlikely to have influenced the performance outcome; the proportion of correct

answers was high. Nevertheless, participants experienced those issues as unpleasant and in the future a more reliable technology should be used.

Finally, while reflecting on the task, two participants reported making mistakes by accidentally pressing the wrong symbol since the buttons were too small. In addition, sixteen participants reported that they made mistakes due to the slow processing of the iPod. The mDSST could be improved by using smartphones with a larger screen so that the size of the buttons is increased. Another option would be to rotate the screen into landscape mode.

Future direction

In light of the current study results, several questions still remain. Valuable, but limited information on the psychometric properties of the 30-second mDDST is gathered. It would be interesting to examine if the time interval can be further decreased (e.g., to 15 seconds) and still yields reliable data. A shorter duration could increase the feasibility and decrease the influence of distractions. The outcome measures of the task can be extended to include response time (milliseconds) to get an idea about the influence of distractions on task performance. Future research should investigate construct validity by comparing performance to the paper-and-pencil version of the DSST. This study is in progress. Sleep quality was assessed using the morning questionnaire, but not taken into account here due to power problems. Poor sleep quality can negatively influence cognitive performance during the day[13]. More attention needs to be paid to the influence of sleep quality and fatigue on cognitive performance in daily life. Smartwatches exist that can accurately track sleep patterns. It would be interesting to link objectively gathered sleep data to ESM cognition and fatigue outcomes.

The mDSST predominantly focuses on processing speed, but other tasks measuring additional cognitive constructs could be designed for use in an experience-sampling paradigm. This would allow to compute the discriminant validity, as was done by Sliwinski and colleagues[21]. However, it is unclear whether a battery of mobile cognition tasks is necessary for clinical purposes. Insight into daily cognitive fluctuations may be possible with an aspecific cognition task. Repeated cognitive testing using ESM technology do not allow for a conclusive assessment across cognitive constructs, cross-sectional test batteries are more suited for this purpose. Gaining a general sense of cognitive functioning in relation to other domains can provide concrete ideas on how to deal with cognitive deficits that are individually relevant during everyday life.

Although in this study, the various contextual factors did not show an effect on cognitive performance it still seems valuable to examine possible links more closely. All these factors arguably influence daily cognitive functioning and should further be explored in the context of the rehabilitation process.

Clinical implications

This study is moving away from a classic cross-sectional assessment of cognition to an ecological assessment of cognitive variation. The combination of the mDSST with experience sampling allows for an examination of the link between cognition and contextual and intrapersonal information. ESM is used in clinical assessments and to implement in situ interventions in various populations. Using this method helps to raise awareness for variability patterns in everyday life and it is used to support self-management and improve well-being[15]. Thus, making ESM a valuable tool to supplement assessments of behavior and mood, with the monitoring of cognitive abilities and its daily fluctuations.

Cognitive impairments are known to influence recovery and self-care behavior in various populations. In schizophrenia and depression, there is evidence that cognitive deficits contribute to poor psychosocial functioning[44,45], while in bipolar disorders there is an association between cognitive dysfunction and the course and length of the illness[46]. A study by Cameron et al. [2010] showed that in patients with heart failure, cognitive problems hindered decision-making[47]. Individuals with diabetes, who experienced greater cognitive difficulties, were less likely to remain adherent to exercise or diet[48]. Teaching individuals self-management techniques is generally recommended for rehabilitation purposes, for example after a stroke[49].

Understanding oneself and one's (cognitive) abilities is important for self-management. By monitoring cognition with ESM and by examining the results afterwards, knowledge can be gained about previously non-transparent patterns between behavior, mood, and cognition, facilitating this understanding[15]. Learning when difficulties arise and under which circumstances, could help patients to adjust their tasks accordingly. Individuals might thus plan their days according to their cognitive abilities and, for example, schedule resting moments when cognitive exhaustion occurs. Keeping track of minor changes towards recovery motivates patients and helps clinicians to adapt treatment plans. Cognition tasks like the mDSST can be helpful in supporting future treatment, prevention, and rehabilitation.

Conclusions

Adding a digital cognition task to an experience-sampling paradigm proved to be feasible in healthy individuals. The mDSST is promising and sensitive to detect cognitive variability in relation to mood, intrapersonal, and contextual factors. Although the task seems promising, further exploration is needed in more diverse age samples and in clinical populations with cognitive complaints. The implementation could be improved by providing some minor changes to the task (e.g., larger buttons or screen for visibility). It is clinically relevant to grasp how cognition fluctuates over time and relates to daily life functioning. By providing patients and clinicians with feedback on this data, cognitive rehabilitation and self-management can be improved.

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Supplementary materials

S3.1 Appendix. Experience sampling items

Experience Sampling Protocol: Beep questionnaire

	Item	7-point Likert scale or categorical options
1	I feel cheerful	1 = not at all 4 = moderate 7 = very much
2	I feel energetic	1 = not at all 4 = moderate 7 = very much
3	I feel insecure	1 = not at all 4 = moderate 7 = very much
4	I feel relaxed	1 = not at all 4 = moderate 7 = very much
5	I feel down	1 = not at all 4 = moderate 7 = very much
6	I feel irritated	1 = not at all 4 = moderate 7 = very much
7	I feel satisfied	1 = not at all 4 = moderate 7 = very much
8	I feel lonely	1 = not at all 4 = moderate 7 = very much
9	I feel enthusiastic	1 = not at all 4 = moderate 7 = very much
10	I feel anxious	1 = not at all 4 = moderate 7 = very much
11	I feel guilty	1 = not at all 4 = moderate 7 = very much
12	I'm worrying about things	1 = not at all 4 = moderate 7 = very much
13	I generally feel well at the moment	1 = not at all 4 = moderate 7 = very much
14	What am I doing	work, school/housekeeping/self-care/relaxing/sport/eating, drinking /traveling, on the road/having a conversation/something else/nothing
15	I can do this well	1 = not at all 4 = moderate 7 = very much
16	This is difficult for me	1 = not at all 4 = moderate 7 = very much
17	I would rather be doing something else	1 = not at all 4 = moderate 7 = very much
18	I am focused	1 = not at all 4 = moderate 7 = very much
19	Where am I	at home/at someone else's home/work, school/public space/on the road/somewhere else
20	Who am I with	partner/family/housemates/friends/colleagues/acquaintances/strangers, others / nobody
21a	Company: I like this company	1 = not at all 4 = moderate 7 = very much
22a	Company: I would rather be alone	1 = not at all 4 = moderate 7 = very much
21b	Alone: I like being alone	1 = not at all 4 = moderate 7 = very much
22b	Alone: I would rather be in company	1 = not at all 4 = moderate 7 = very much
23	I don't feel well	1 = not at all 4 = moderate 7 = very much
24	I am tired	1 = not at all 4 = moderate 7 = very much
25	Since the last beep I have used	alcohol/medication/coffee, caffeine/smoking, nicotine/cannabis/other drugs/nothing
26	mDSST instruction screen	
	mDSST	30 seconds task duration
27	I got distracted during the task	1 = not at all 4 = moderate 7 = very much
28	This beep disturbed me	1 = not at all 4 = moderate 7 = very much
29	Thanks!	

S3.1 Table. Individual multilevel regression analyses

Multilevel regression analyses of the explored ESM items separate for number of trials and percentage of correct trials

	Number of trials					Percentage of correct trials				
	B	SE	p	95% CI		B	SE	p	95% CI	
Positive Affect	.08	.04	.04*	.005,	.16	.62	.19	.001*	.24,	.99
Cheerful	.12	.03	<.001*	.06,	.18	.54	.15	<.001*	.24,	.85
Energetic	.06	.03	.02*	.01,	.12	.14	.14	.32	−.14,	.42
Relaxed	.01	.03	.78	−.05,	.06	.51	.14	<.001*	.23,	.80
Satisfied	.02	.03	.51	−.04,	.08	.53	.16	.001*	.22,	.83
Enthusiastic	.02	.03	.53	−.04,	.07	.13	.14	.34	−.14,	.39
Negative Affect	−.03	.06	.58	−.14,	.08	−1.41	.28	.000*	−1.96,	−.86
Down	−.04	.03	.24	−.10,	.03	−.40	.17	.02*	−.74,	−.06
Insecure	−.01	.03	.80	−.08,	.06	−.62	.18	<.001*	−.96,	−.27
Irritated	−.004	.03	.89	−.06,	.05	−.54	.14	<.001*	−.81,	−.27
Lonely	.02	.04	.68	−.06,	.09	−.56	.19	.003*	−.94,	−.19
Anxious	−.005	.05	.92	−.10,	.09	−.90	.25	<.001*	−1.39,	−.41
Guilty	−.03	.04	.41	−.12,	.05	−.65	.21	.002*	−1.07,	−.23
Fatigue	−.01	.02	.52	−.06,	.03	−.06	.11	.59	− .29,	.16
Worrying	.02	.03	.54	−.04,	.07	−.26	.14	.07	−.54,	.02
Focused	.01	.03	.70	−.04,	.06	.10	.13	.44	−.16,	.36
Distracted	−.17	.02	<.001*	−.21,	−.13	−.46	.11	<.001*	−.67,	−.25
Act. stress	.02	.03	.44	−.03,	.07	−.11	.14	.44	−.38,	.17
Location	−.20	.06	.002*	−.32,	.07	.26	.34	.45	−.41,	.93
Company	−.13	.07	.05	−.26,	.001	−.02	.35	.95	−.72,	.67
Coffee use	−.08	.09	.37	−.25,	.09	−.37	.46	.42	−1.28,	.53
Age^2	−.001	.0001	<.001*	−.001,	−.0005	−.0002	.0003	.50	−.0007,	.0004
Gender	−1.09	.44	.01*	−1.95,	−.22	.04	.72	.96	−1.38,	1.46
Time^s	.36	.03	<.001*	.30,	.43	−.26	.19	.17	−.63,	.11
Hour	.03	.01	<.001*	.01,	.04	−.03	.04	.36	−.11,	.04
Hour^2	.001	.0002	.001*	.0003,	.001	−.001	.001	.30	−.004,	.001

Note. CI = Confidence Interval, Act. Stress = Activity-related Stress. Location = dummy variable of being at home versus somewhere else. Company = dummy variable of being alone versus with others. Coffee use = dummy variable of coffee use since the last beep versus no coffee use. Age^2 = quadratic function of age. Time^s = log-transformed replication score. Hour = hours within a day. Hour^2 = quadratic function of hour. *p <.05.

S3.2 Table. Correlations between mood items

Table A Pearson correlates for single positive affect items.

Variables	1	2	3	4	5
Overall variance					
1. Cheerful	–				
2. Energetic	.74*	–			
3. Relaxed	.47*	.42*	–		
4. Satisfied	.59*	.55*	.57*	–	
5. Enthusiastic	.67*	.66*	.48*	.62*	–
Within-subject variance					
1. Cheerful	–				
2. Energetic	.63*	–			
3. Relaxed	.29*	.24*	–		
4. Satisfied	.43*	.39*	.41*	–	
5. Enthusiastic	.50*	.50*	.30*	.43*	–

Note. All $p<.001$.

Table B Pearson correlates for single negative affect items.

Variables	1	2	3	4	5	6
Overall variance						
1. Down	–					
2. Insecure	.45*	–				
3. Irritated	.44*	.27*	–			
4. Lonely	.49*	.40*	.30*	–		
5. Anxious	.45*	.54*	.32*	.46*	–	
6. Guilty	.33*	.34*	.31*	.30*	.48*	–
Within-subject variance						
1. Down	–					
2. Insecure	.33*	–				
3. Irritated	.40*	.18*	–			
4. Lonely	.35*	.25*	.20*	–		
5. Anxious	.31*	.37*	.22*	.28*	–	
6. Guilty	.27*	.20*	.21*	.18*	.29*	–

Note. All *$p<.001$.

S3.3 Table. Multilevel stepwise regression analyses

Table A Multilevel stepwise forward and backward regression analyses of individual ESM items for number of trials.

	Number of trials				
	B	**SE**	**p**	**95% CI**	
Forward (overall)			<. 001*		
· Cheerful	.10	.03	<. 001*	.05,	.16
· Location	−.003	.06	.96	−.13,	.12
· Distraction	−.19	.02	<. 001*	−.23,	−.15
· Time$	.35	.03	<. 001*	.28,	.41
· Hour	.13	.05	.01	.03,	.23
· Hour²	−.004	.002	.02	−.007	−.0006
· Age²	−.0008	.0001	<. 001*	−.001	−.0006
Backward (overall)			<. 001*		
· Cheerful	.13	.03	<.001*	.07,	.19
· Irritated	.07	.03	.01*	.02,	.12
· Age²	−.0008	.0001	<.001*	−.001,	−.0006
· Time$	.35	.03	<.001*	.29,	.42
· Hour	.12	.05	.02*	.02,	.22
· Hour²	−.004	.002	.03*	−.009,	−.0004

Note. CI = Confidence Interval. Age² = quadratic function of age. Time$ = log-transformed replication score. Hour = hours within a day. Hour² = quadratic function of hour. *p<.05.

Table B Multilevel stepwise forward and backward regression analyses of individual ESM items for percentage of correct trials.

	Percentage of correct trials				
	B	**SE**	**p**	**95% CI**	
Forward (overall)			<. 001*		
· Cheerful	.33	.17	.06	−.007,	.66
· Relaxed	.21	.16	.20	−.11,	.52
· Insecure	−.36	.18	.05	−.72,	.002
· Irritated	−.27	.15	.07	−.57,	.02
· Distracted	−.43	.11	<.001*	−.63,	−.22
Backward (overall)			<. 001*		
· Cheerful	.36	.17	.03*	.04,	.69
· Relaxed	.31	.16	.05	.003,	.62
· Anxious	−.69	.26	.01*	−1.19,	−.19
· Location	.75	.35	.04*	.05,	1.44
· Distracted	−.53	.11	<.001*	−.74,	−.32

Note. CI = Confidence Interval. *p<.05.

Chapter 4

Digital assessment of working memory and processing speed in everyday life: Feasibility, validation, and lessons-learned

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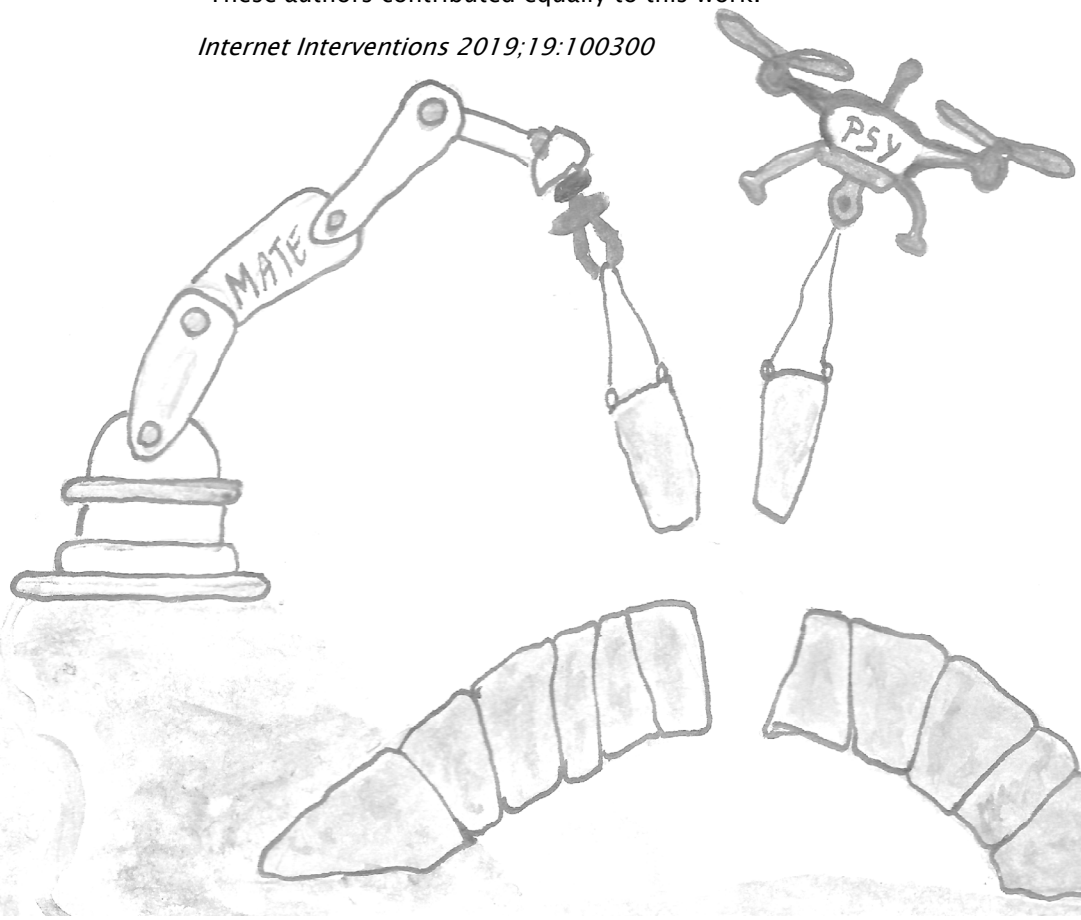


Abstract

Objectives

Cognitive functioning is often impaired in mental and neurological conditions and might fluctuate throughout the day. An existing experience-sampling tool was upgraded to assess individual's cognition in everyday life. The objectives were to test the feasibility and validity of two momentary cognition tasks.

Methods

The momentary Visuospatial Working Memory Task (mVSWMT) and momentary Digit Symbol Substitution Task (mDSST) were add-ons to an experience sampling method (ESM) smartphone app. Healthy adults (n=49) between 19 and 73 years of age performed the tasks within an ESM questionnaire 8 times a day, over 6 consecutive days. Feasibility was determined through completion rate and participant experience. Validity was assessed through contextualization of cognitive performance within intrapersonal and situational factors in everyday life.

Findings

Participants experienced the tasks as pleasant, felt motivated, and the completion rate was high (71%). Social context, age, and distraction influenced cognitive performance in everyday life. The mVSWMT was too difficult as only 37% of recalls were correct and thus requires adjustments (i.e. fixed time between encoding and recall; more trials per moment). The mDSST speed outcome seems the most sensitive outcome measure to capture between- and within-person variance.

Conclusions

Short momentary cognition tasks for repeated assessment are feasible and hold promise, but more research is needed to improve validity and applicability in different samples. Recommendations for teams engaging in the field include matching task design with traditional neuropsychological tests and involving a multidisciplinary team as well as users. Special attention for individual needs can improve motivation and prevent frustration. Finally, tests should be attractive and competitive to stimulate engagement, but still reflect actual cognitive functioning.

Introduction

Cognition is a key determinant when it comes to the question how well an individual manages daily tasks and performs everyday activities. Only if a person can remember, concentrate, communicate, plan, and reason, is he/she able to cope with the requirements of life. The link between cognition and functioning has been demonstrated not only in people with cognitive impairments[1] or mental health issues[2], but also healthy individuals[3]. Therefore, it is necessary to take cognition into account when aiming to understand daily patterns or support functioning.

Memory functions, processing speed, and other cognitive abilities are usually assessed in clinical or laboratory settings rather than natural environments. Brief cognitive screenings are used in routine primary care to identify individuals at risk for cognitive dysfunction, while comprehensive, multidimensional neuropsychological batteries have the purpose to establish a diagnose or functional[4]. Casaletto and Heaton [2017] highlight the 'common complaint' regarding neuropsychological assessments to be 'their apparent lack of relevance to the real-life problems' (p.11) that individuals experience in their everyday life[5]. Furthermore, as doctor visits occur periodically[6], the assessments provide a rather temporary picture of one's cognitive ability. This traditional approach may thus affect the ecological validity of neuropsychological test results[7].

An empirically validated daily diary method, known as the Experience Sampling Method (ESM) or Ecological Momentary Assessment (EMA), allows to collect real-world information[8–10]. Digital ESM technologies using smartphone apps prompt participants repeatedly over the day to reflect on their own behavior, affect, and contextual factors[11,12]. Over the last decade, interest has increased to not only depict affect and activities with experience sampling, but also to include the area of cognitive functioning. It is relevant to bridge the lab-life gap and observe cognition closely in everyday life and in a more dynamic way[13]. Learning that cognitive performance can fluctuate over time and grasping which daily circumstances influence cognitive performance can help patients to optimize activities in daily life. Momentary cognition tasks provide a more dynamic understanding of cognition throughout the day that can be clinically relevant when recovering from somatic or psychological complaints. For ecologically valid cognitive assessments, digital diary methods delivered via smartphone apps offer unique opportunities.

The status of cognitive assessments in everyday life

Cognitive assessments in everyday life through technology are relatively new. A recent review by Moore et al. [2017] has identified 12 studies that use self-administered digital cognitive assessments[14]. A brief literature search on PubMed identified 13 additional studies (see Figure 4.1 for a visualized summary).

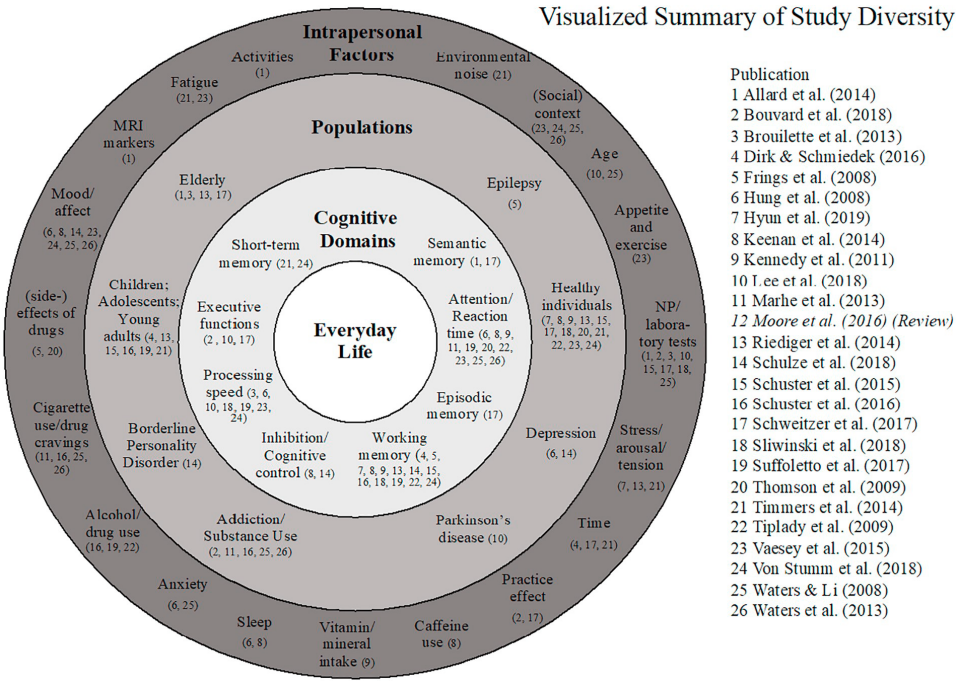


Figure 4.1 Visualized summary of studies focusing on cognitive assessments in everyday life by cognitive domains, populations, and the intrapersonal factors set in relation with outcome(s) (see Publication); this summary does not aim to be exhaustive, but provides a first overview of the field. NP=Neuropsychological.

Various cognitive domains are considered for the assessments in everyday life. Often, more than one task is used and multiple domains are evaluated. Working memory and attention/reaction time are most prevalent, which may be explained by the fact that these domains are generally relevant for various patient populations as they are affected in neurological conditions[15,16] as well as mental illnesses[17,18]. Participants' age ranged from adolescents to older adults. While some studies focused on healthy individuals[19–22], others included

patient populations[23–25]. Normative data remains unavailable and, therefore, the validation of mobile cognitive assessments in healthy individuals is still relevant.

To describe the internal validity of the momentary tasks, the contextualization of the momentary performance is a key element. Therefore, previous studies took intrapersonal factors such as age, mood, and drug use into account. Furthermore, psychometric properties of the mobile cognition tasks, including between-person reliability, within-person reliability, and construct validity should be[14].

The present study

The present study aims to evaluate the feasibility and validity through contextualization of two newly developed, short momentary cognition tasks implemented in an existing platform with a high sampling frequency. A high sampling frequency of eight times a day allows to describe a detailed picture of daily mood and cognition fluctuations. Furthermore, high-frequency sampling is the standard in this particular ESM platform[9], which is broadly used in research as well as in clinical settings[26,27]. This ESM tool has the advantage of being available for both Android and iOS users. It is crucial to build on existing technologies rather than reinventing new devices to support sustainable use. Therefore, this ESM tool is an important target for future cognition task development. A healthy sample was recruited to perform a visuospatial working memory task and a processing speed task within a momentary assessment. Additionally, the ESM items assess a wide range of momentary intrapersonal and situational factors such as mood and social context.

To determine the feasibility, completion rate and participant satisfaction were used. Validity was assessed through an exploration of the contextual variation of cognitive performance. Cognitive performance measured with the momentary cognition tasks was evaluated by relating cognition outcomes to each other as well as to relevant ESM measures such as mood, fatigue, and current company. The results are discussed with regard to lessons-learned during the development process and future implications. Prospectively, researchers and clinicians who are already familiar with the smartphone app can include cognitive measures in everyday life alongside affect and context to understand and support various patient populations.

Methods

Participants

Recruitment from the general population was performed via snowball sampling, using media advertisements and the personal network as seeds. Sample size was based on previous feasibility studies using the same experience sampling app and aimed for a minimum of 30 participants[28,29]. Fifty-one participants provided written informed consent. Participants were at least 18 years old, had a full understanding of the Dutch language, and were able to handle a smartphone device (Android) with a beta version of the PsyMate™ app (version 213-253) (see Section Experience sampling method for details). Participants who could not use their own smartphone device were provided with a 5th generation iPod on which the same version of the PsyMate™ app was installed. Individuals were excluded based on medication use that could influence cognitive performance and current treatment for cognitive or mental health complaints. The standing ethical committee of the Faculty of Psychology and Neuroscience, Maastricht University (ref.no.183_02_09_2017) granted ethical approval and the study was carried out in accordance with the Declaration of Helsinki.

Measurements

No traditional neuropsychological tasks were included in this study as the focus lay on the contextualization of the momentary cognition scores and their within-day fluctuation. To validate ESM items, the correlation between similar and dissimilar ESM items is suggested[9]. As suggested by Chen et al. [2015], patterns of associations between items of quality of experiences (i.e., cognition) and other momentary items such as emotions related to the experiences should be logical, thereby supporting the internal validity of the data[30].

Experience sampling method (ESM)

The ESM was administered using the PsyMate™ Suite; a smartphone app and a cloud-based platform developed by Maastricht University and Maastricht UMC+ (www.psymate.eu). PsyMate™ is a parametrized and flexible tool for repeated assessments in everyday life. The application was programmed to emit an auditory and visual prompt (beep signal) eight times a day for six consecutive days, signaling the availability of a self-report questionnaire. These beep

questionnaires were provided at semi-random time blocks of 112.5 min, between 7.30 AM and 10.30 PM and remained available for response during 15 min. Beep questionnaires included mood (i.e., positive and negative affect), physical status (i.e., hunger, fatigue, and pain), and context (i.e., location, activity, and social company) items as well as the two cognition tasks. Positive affect (PA) included the items 'cheerful', 'energetic', 'relaxed', 'enthusiastic', and 'satisfied', while negative affect (NA) was composed of the items 'insecure', 'down', 'irritated', 'lonely', 'anxious', and 'guilty'. In line with ESM guidelines[9], a minimum of 16 valid beep questionnaires (1/3 of total) per participant had to be completed to be included in the analyses. One ESM assessment including the two momentary cognition tasks would not take longer than 2 min to complete.

In addition to the beep questionnaires, participants completed a morning assessment and an evening assessment every day, each consisting of seven self-report items. The morning questionnaire focused on self-reported sleep quality. The evening questionnaire focused on a global appraisal of the day. The majority of the items were answered on a seven-point Likert scale (1=not at all, 4=moderate, 7=very). Some items contained categories (e.g. 0, 1, 2, 3, 4, 5, or>5 times awake during the night). The full list of ESM items is included in Appendix 4.A.

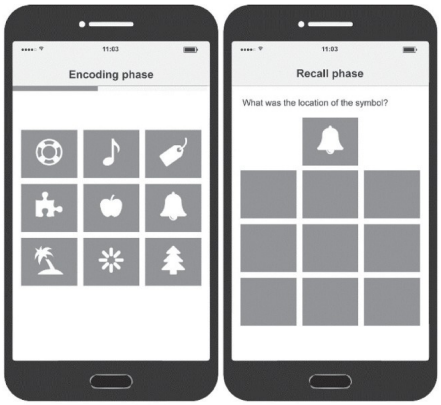
PsyMate™ momentary Visualspatial Working Memory Task (mVSWMT)

The concept of the PsyMate™ mVSWMT is based on the popular card game 'Memory', also known as 'Concentration' or 'Match Match', where players turn cards to find matching pairs. 'Memory' has been used to study concentration and memory functions in various age groups[31,32]. The mVSWMT aims to measure concentration and visuospatial working memory (i.e., encoding, maintaining, and retrieving visual information). The development team included psychiatric and neuropsychological healthcare professionals as well as ESM researchers. This team defined the following requirements for the mDSST: participants should be able to perform the mobile cognition task several times a day, the task needs to be short, sensitive to cognitive variation, and demonstrates no or a small learning effect.

The participants were instructed that they would see nine icons to remember. After the participant pressed the start button, icons were presented in a three-by-three grid for eight seconds (encoding phase; see left part of Figure 4.2a). Next, participants answered two interference questions on a seven-point Likert scale: 'I think I remembered it all', and 'Generally, I feel well

at the moment'. During the recall phase (see right part of Figure 4.2a), participants were presented with a three-by-three grid of blanc squares with one icon from the original nine above. An instruction stated to select the square of the original location of the presented icon. The selected square revealed the icons underneath to provide feedback. In this first conceptualization, only one trial per beep is provided to keep the ESM assessments as short as possible. Every beep moment, a unique set of symbols was presented. The grids were filled at random from a selection of 122 unique icons (see Figure 4.2b) and a random icon cue was selected from the grid. The outcome measure was correct/incorrect (correct=1) during recall. The icons presented in the mVSWMT were chosen as they represent well-known objects of everyday life and are easily recognizable.

a



b

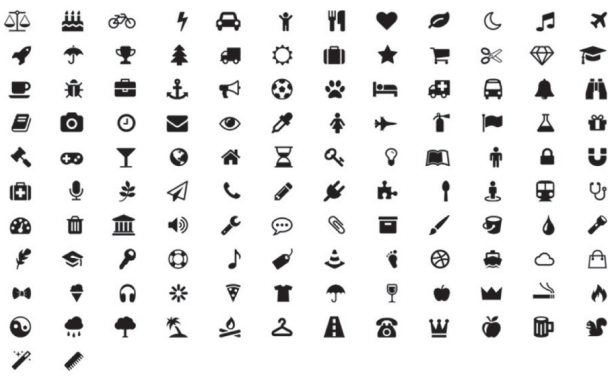


Figure 4.2 **a**) PsyMate™ momentary Visuospatial Working Memory Task (mVSWMT) encoding and recall phase. **b**) Summary of icons presented in the PsyMate™ mVSWMT.

PsyMate™ momentary Digital Symbol Substitution Task (mDSST)

The PsyMate™ mDSST was inspired by the paper-pencil version of the Digit Symbol Substitution Task (DSST) of the Wechsler Adult Intelligence Scale (WAIS). The original WAIS task measures information processing speed and short-term working memory[33]. The PsyMate™ version aims to measure information processing speed. The mDSST fulfils the momentary task requirements (performable several times a day; short; sensitive to cognitive variation; no/small learning effect) and the same team was consulted during task development.

At the end of the regular ESM beep questionnaire, an instruction screen appeared with a start button to be pressed when ready. At the top of the task screen, the numbers 1 to 9 with a corresponding symbol (similar to the WAIS DSST) were displayed for encoding. In the middle of the screen, different numbers were displayed one-by-one for each trial. At the bottom of the screen, participants had to select the symbol that corresponds to the number presented in the middle of the screen (see Figure 4.3). Within a 30-seconds timeframe, participants had to accurately complete as many trials as possible. The 30-second timeframe was chosen to keep the ESM assessments as brief as possible, thereby minimizing interference during daily routines. While the number-symbol combinations stayed the same during a beep questionnaire, different sets of combinations were used across beeps. In total, ten unique encoding combinations with corresponding answer keys were used at random. Two mDSST outcome measures were computed: the number of trials (speed) and the percentage of correct trials (accuracy).

Debriefing questionnaire

Participants received a debriefing questionnaire that focused on their general experiences during the ESM week (e.g., 'Was this a normal week?', 'Did the PsyMate™ use influence your daily activities?'), the usability of the PsyMate™ (e.g., 'Were the PsyMate™ instructions clear?', 'Was using the PsyMate™ stressful?'), and their experiences with the PsyMate™ mDSST and mVSWMT (e.g., 'To what extent was the task pleasant to perform?', 'Did you experience any technical difficulties?'). Both seven-point Likert scale questions and open-ended questions were used.

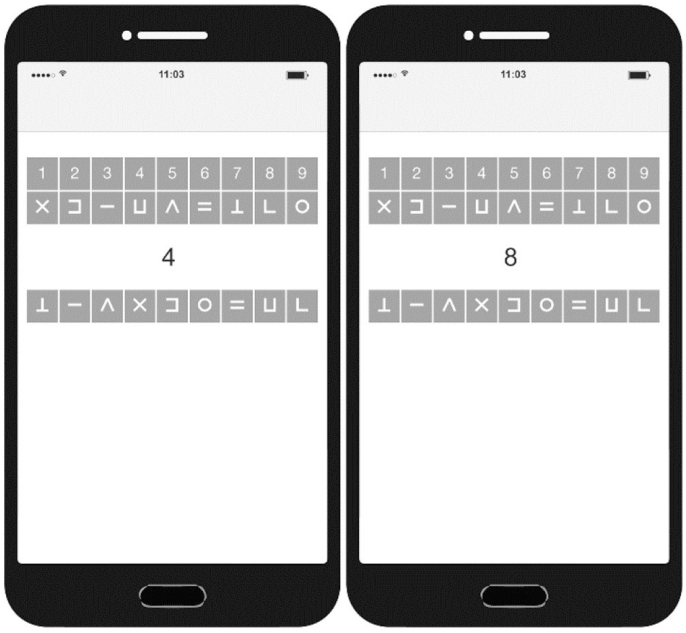


Figure 4.3 PsyMate™ momentary Digit Symbol Sustitution Task (mDSST).

Procedure

Following informed consent, a one-hour briefing session took place at Maastricht University or at the participant's home. Sociodemographic information was gathered (e.g., gender, age, living situation, education level, current occupation, and ethnicity) and additional information was asked on current medication use, earlier treatment for mental illnesses, and cognitive complaints. After these general assessments, either the PsyMate™ was installed on the participant's smartphone device or the participant received an iPod with the latest PsyMate™ version installed. After checking the device settings for battery saving options and allowing push notifications, participants were instructed on how to use the PsyMate™ and the cognition tasks. Test trials were completed to become acquainted with the ESM procedure. Participants started with their six-day ESM period on the following day. During the second day, participants were called to check whether the application was working properly and to clarify potential questions. After the ESM period, a one-hour debriefing session took place during which participants completed the debriefing

questionnaire and provided specific feedback with regard to the two cognition tasks.

Statistical analyses

Participant characteristics, feasibility, and acceptability of both cognition tasks were assessed by means of descriptive statistics (frequencies). The completion rate was calculated by comparing the mean percentage of valid beep moments to the total number of beep moments. The data collected with the PsyMate™ have a multilevel structure; beeps (level 1) were nested within participants (level 2). Multilevel regression analyses were used to assess cognitive variation over time and to check for learning effects. The session counter score was used as a proxy measure of time and consists of a sequence of beeps within subjects, ranging from 1 (first beep) up to 48 (last beep). Learning effects were examined by using the session counter to assess the effect over time, hours to assess a within-day time effect and study day (day 1 to 6) to assess a between-day time effect. It is expected that learning will not be linear; therefore, all time variables will be transformed to a logarithmic or quadratic function. Correct/Incorrect (mVSWMT), the number of trials within the 30-seconds time interval (speed), and the percentage of correct trials (accuracy) (mDSST) were used as dependent variables and a log transformation of the session counter (time), hour and its quadratic function, and a log transformation of study day as independent variables. To assess contextualization, dummy variables were created for location (at home vs. somewhere else) and company (alone vs. with others). Activity-related stress was conceptualized as an average of the items 'I would rather be doing something else', 'This is difficult for me', and 'I can do this well' (reverse coded). To assess the association between PA, NA, fatigue, activity-related stress, distraction, worrying, focusing, location, company, and sleep quality as independent variables and the cognition outcomes of the mVSWMT and mDSST as dependent variables, multilevel regression analyses were computed. Covariates in these multilevel models were quadratic age, gender, and possible learning effects as measured with the time variables. In order to investigate age effects, subgroup multilevel regression analyses were performed, splitting participants into a young group (<45 years) and an old group (45 years or older). Furthermore, Fischer-z transformations of by-subject Pearson's pairwise correlations were calculated between the cognitive outcome measures. Analyses were carried out using Stata version 13.0[34]. A two-sided significance level of .05 was used throughout.

Results

Participants

Seventy-one individuals expressed their interest in the study, of which 66 met the eligibility criteria. From these individuals, seven were not allowed to use mobile phones during work, four individuals did not have enough time, one could not participate because no device was available, and three individuals did not reply after receiving the information. In total, 51 individuals consented to be included, resulting in a 66% recruitment rate.

From the 51 participants who provided informed consent, two participants were excluded because of current treatment for mental health problems. This left data from 49 participants and 1499 beep records. Data of five participants could not be used due to technical problems (beta release of the software: loss of 70 records (4.67%), n=3 transmission problems, n=2 broken devices), leaving a final dataset with 44 participants and 1429 valid beep records. On average, participants completed 34 out of 48 beeps (*SD*=7.03, range 17-47), resulting in a completion rate of 71%. The age of the *n*=44 participants ranged from 19 to 73 years with a median of 36 years (*M*=40, *SD*=14.82). Sixty-six percent were women. Highest education level was skewed, with 6% having finished low education, 18% middle education, and 76% high education. Most participants had a fulltime job (61%), others worked part time (23%), studied (7%), took care of their own household (5%), or were retired (4%).

Feasibility

Evaluation of the PsyMate™ procedure

The items represented the participants' experiences well (*M*=5.70, *SD*=1.53), the PsyMate™ was easy to use (reverse coded, *M*=1.25, *SD*=.78), and the verbal and written instructions were clear (respectively *M*=6.86, *SD*=.41; *M*=6.84, *SD*=.48). The PsyMate™ did not influence the participants' mood (*M*=2.11, *SD*=1.53), activities (*M*=1.91, *SD*=1.01), or social contact (*M*=1.91, *SD*=1.18). The number of beeps, duration of a beep, and sound had a low impact on the burden (respectively *M*=3.2, *SD*=1.79; *M*=2.61, *SD*=1.86; *M*=2.32, *SD*=1.62). Three people found the length of the questionnaire too long.

Evaluation of the mVSWMT

Participants reported that the mVSWMT was pleasant to use (*M*=5.05, *SD*=1.57), but rather difficult (*M*=4.61, *SD*=1.79). Six participants indicated that the interference questions between encoding and recall made the task difficult. Participants did not get distracted during the task (*M*=2.93, *SD*=1.53) and were highly motivated to perform well (*M*=5.84, *SD*=1.16). They indicated that they made few inaccuracies (*M*=1.75, *SD*=1.28) and would recommend the task to others (*M*=5.25, *SD*=1.62). They provided some suggestions for further improvement, namely a longer encoding phase and a timer. Participants reported strategies to recall the icons: reading aloud (7 times), creating a story or a mnemonic (6 times), remembering the icons and the location of the icons (5 times), and remembering the first, the middle, or the last row (6 times).

Evaluation of the mDSST

Participants reported that the mDSST was pleasant (*M*=5.66, *SD*=1.22) and easy to use (reverse coded, *M*=1.86, *SD*=.90). They were not distracted during the task (*M*=3.00, *SD*=1.43) and highly motivated to perform well (*M*=5.93, *SD*=1.13). Participants reported that they made few inaccuracies (e.g., tapping symbol X instead of symbol Y) (*M*=3.00, *SD*=1.54). Fourteen people commented that the size of the response buttons was too small, potentially leading to inaccuracies. Participants would recommend the task to others (*M*=5.82, *SD*=1.11). They provided some suggestions for further improvement: to increase the symbol and number size or rotate the screen horizontally. This was especially an issue for iPod users since the screen was smaller.

Contextual factors

Participants experienced high PA (*M*=5.08, *SD*=.69, range 3.35–6.66) and low NA (*M*=1.49, *SD*=.55, range 1.01–3.20). Furthermore, they felt moderately fatigued (*M*=3.01, *SD*=1.19, range 1–5.64), were a little worried (*M*=2.23, *SD*=1.15, range 1–5.43), and experienced low activity-related stress (*M*=2.44, *SD*=.56, range 1.61–3.69). Overall, participants reported a high level of focus during an activity (*M*=4.78, *SD*=.77, range 3.11–6.45) and experienced low to moderate distraction during the mDSST (*M*=2.79, *SD*=.88, range 1.05–4.53). Participants were alone in 29% of the time and in company 71% of the time. Furthermore, they spend 56% of the time at home and 44% somewhere else. According to the morning questionnaire, participants fell asleep after 5 to 15

min (40%) and woke up once during the night (34%). Participants slept well (*M*=5.25, *SD*=.80, range 3.46–7) and felt well rested at the start of the day (*M*=4.62, *SD*=1.03, range 2.67–6.65).

Cognition in relation to contextual factors

mVSWMT

Overall, participants were correct in 37% of the mVSWMT assessments (*SD*=.16, range .07–.74). There was no association between time (session counter score) and the mVSWMT outcome, (*B*=.01, *SE*=.01, *p*=.32, 95% CI=−.01, .04), showing no within-day time effect (*B*=−.004, *SE*=.003, *p*=.17, 95% CI=−.01, .002), nor between-day time effect (*B*=.04, *SE*=.03, *p*=.17, 95% CI=−.02, .09), indicating no learning-effect.

Participants made more mistakes when experiencing high PA (*B*=−.03, *p*=.04), when in company (vs. being alone; *B*=−.10, *p*<.001), and when being distracted (*B*=−.03, *p*=.001). Being able to focus during an activity resulted in more correct answers (*B*=.04, *p*<.001). NA, fatigue, activity-related stress, location, worrying, and sleep quality (morning questionnaire) were not associated with the mVSWMT outcome. More mistakes were made with higher age (*B*=−.00005, *p*=.002), whereas gender was not associated. For all results, see Appendix 4.B.

To build the final multilevel regression model, a basis of PA, NA, and its interaction effect was extended with variables that were associated with the cognition outcome measure. No interaction effect was found between PA, NA, and the mVSWMT outcome. The effect of PA disappeared and participants again made more mistakes when in company (*B*=−.09, *p*=.002), when distracted (*B*=−.02, *p*=.03), and with older age (*B*=-.00006, *p*<.001). Being able to focus during an activity was associated with more correct answers (*B*=.05, *p*<.001). The results of this analysis indicated that the seven predictors explained 6% of the overall variance (3% within-subject variance and 28% between-subject variance). Results of the final model for correct/incorrect are presented in Table 4.1.

Table 4.1 Final model of the mVSWMT outcome correct/incorrect.

	Correct/incorrect				
	B	SE	p	95% CI	
Model			<.000***		
PA	−.06	.03	.08	−.13,	.01
NA	−.06	.09	.48	−.25,	.12
PA x NA	.01	.02	.33	−.03,	.05
Focus	.05	.01	<.001***	.03,	.07
Company$	−.09	.03	.002**	−.14,	−.03
Distraction	−.02	.01	.03*	−.03,	−.001
Age^2	−.00006	.00002	<.001***	−.00009,	−.00002

Note. PA = positive affect. NA = negative affect. PA x NA = interaction between positive and negative affect. Company$ = dummy variable of being alone versus with others. Age^2 = quadratic function of age. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

mDSST

Due to technical problems, 82 times (5.7%) the mDSST did not follow the ESM questionnaire. These records were removed, leaving a sample of 42 participants with 1347 beep records. Participants completed on average 12 trials (SD=2.57, min=7.21, max=16.83) within the 30-second timeframe, with on average 97% accuracy (SD=1.81, min=92.29, max=100). Participants completed more trials over time (beep 1 vs. beep 48; B=.32, SE=.04, p<.001, 95% CI=.24, .40), showed no within-day time effect (B=.01, SE=.01, p=.12, 95% CI=−.003, .03), but more completed trials at later study days (B=.61, SE=.08, p<.001, 95% CI=.45, .76). Accuracy was not associated with time (B=.08, SE=.20, p=.71, 95% CI=−.32, .47), showing no within-day time effect (B=.05, SE=.04, p=.25, 95% CI=−.03, .13) nor between-day time effect (B=−.02, SE=.36, p=.96, 95% CI=−.72, .68).

NA, activity-related stress, location, sleep quality, and gender were not associated with either cognitive outcome measure. Looking at speed, participants completed less trials when in company (B=−.29, p=.001), when being distracted (B=−.15, p<.001), and with older age (B=−.001, p<.001). Furthermore, participants completed more trials when worrying (B=.09, p=.02). PA and being able to focus were not associated with speed. Looking at accuracy, participants made more mistakes when being tired (B=−.34, p=.007) and with more distraction (B=−.54, p<.001). Participants made less mistakes when they experienced more PA (B=.45, p=.03) and when they could focus better (B=.36, p=.01). Company was not associated with accuracy. For all results, see Appendix 4.4C.

Again, the basic model was extended with variables that were associated with the mDSST outcome measures. In the final model of speed (see Table 4.2), mood showed no effect, and time and worry effects disappeared. Participants completed fewer trials when in company (B=−.18, p=.04), when being distracted (B=−.15, p<.001), and with older age (B=−.002 p<.001). The results of this analysis indicated that the nine predictors explained 48% of the overall variance (8% within-subject variance and 56% between-subject variance).

Table 4.2 Final model of the mDSST speed outcome.

	Speed				
	B	**SE**	**p**	**95% CI**	
Model			<.001***		
PA	.04	.11	.74	−.18,	.26
NA	.01	.30	.97	−.57,	.59
PA x NA	−.02	.06	.81	−.14,	.11
Worry	.06	.04	.14	−.02,	.14
Company$^{\$}$	−.18	.09	.04*	−.34,	−.01
Distraction	−.15	.02	<.001***	−.20,	−.10
Age^{2}	−.002	.0002	<.001***	−.002,	−.001
Time$^{\$}$	.17	.10	.08	−.02,	.37
Study day$^{\$}$	.34	.18	.06	−.02,	.70

Note. PA = positive affect. NA = negative affect. PA x NA = interaction between positive and negative affect. Company$^{\$}$ = dummy variable of being alone versus with others. Age^{2} = quadratic function of age. Time$^{\$}$ = log-transformed replication score. Study day$^{\$}$ = log-transformed day of study score. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

In the final model of accuracy (see Table 4.3), the effect of fatigue and PA disappeared and no other mood effects were found. Participants made more mistakes when being distracted (B=−.51, p<.001). The results of this analysis indicated that the six predictors explained 3% of the overall variance (2% within-subject variance and 20% between-subject variance).

Table 4.3 Final model of the mDSST accuracy outcome.

	Accuracy				
	B	**SE**	**p**	**95% CI**	
Model			<.001***		
PA	−.22	.50	.67	−1.19,	.76
NA	−1.15	1.28	.37	−3.66,	1.36
PA x NA	.25	.28	.37	−.30,	.81
Fatigue	−.22	.14	.13	−.50,	.06
Focus	.14	.15	.34	−.15,	.44
Distraction	−.51	.11	<.001***	−.72,	−.30

Note. PA = positive affect. NA = negative affect. PA x NA = interaction between positive and negative affect. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

Young vs. older age and cognition

In order to gain more insight into age effects, exploratory subgroup analyses were performed for both cognition tasks. Splitting age groups for the mVSWMT data resulted in n=26 (59%) in the young group (<45 years) and n=18 (41%) in the older age group (45 years or older). In both groups, being able to focus resulted in more correct answers (young age: B=.05, p<.001; older age: B=.04, p=.01). However, in the older group, participants made more mistakes when being in company (B=−.13, p=.001) and with increasing age (B=−.00007, p=.047).

With the mDSST data, data from two participants were excluded due to technical problems (see Section *mDSST*), leaving n=26 in the young group (62%) and n=16 in the older age group (38%). Results for speed remained largely the same in both groups, showing a main effect of distraction with higher distraction resulting in more mistakes. A similar result was found in both groups for accuracy, where higher distraction resulted in fewer trials. The difference was that the younger group completed more trials over time (B=.30, p=.047). The older group did not show a time effect on number of beeps (log-transformed session counter score), but completed more trials over study days (B=.47, p=.02) and when PA was higher (B=.33, p=.04). In addition, fewer trials were completed when being in company (B=−.22, p=.02), and with increasing age (B=−.001, p<.001) within the older group but not the younger group. Results of the subgroup analyses are presented in Appendix 4.4D.

Correlations between mVSWMT and mDSST

Fisher-z transformations of by subject pairwise correlations were used between the mVSWMT outcome correct/incorrect, and the mDSST outcomes speed and accuracy. Over subject averages, there were no significant correlations between correct/ incorrect and speed (z=1.36, p=.09), nor accuracy (z=−.35, p=.64).

Discussion

Feasibility of the momentary cognition tasks

This study confirms the feasibility of two newly developed momentary cognition tasks within the PsyMate™ app in healthy individuals. The completion rate was high (71%) and is in line with other ESM studies with and without cognition

tasks[35,36]. Furthermore, participants overall experienced the cognition tasks as pleasant and were motivated to perform well.

Although entertaining, the mVSWMT was experienced as difficult. In only 37% of the mVSWMT assessments the icon location was remembered correctly, with a range from 7% to 74% between participants. Differences may reflect the use of strategies, such as thinking of an 'icon-story' or trying to group the icons per row. In other momentary visuospatial working memory studies, participants identified the correct location(s) in 90% of their responses[37–39]. In these studies, neutral circles in a grid were presented while meaningful icons were used in the mVSWMT (see Figure 4.2b). Remembering the location combined with the meaning of the icon requires a higher cognitive demand. The choice for the here-used icons was made to test a greater working memory capacity[40,41]. Furthermore, the meaningful icons were expected to motivate the participant, which was confirmed by the positive feedback (see Section Evaluation of the mVSWMT). Participants responded randomly on the interference items to perform better on the mVSWMT. Prospectively a different interference[39] should be considered. For example, a fixed timer could be applied to standardize the interference between encoding and recall.

In contrast, participants experienced the mDSST as easy, which resulted in a ceiling effect for accuracy (97% correct). This high accuracy is in line with another digital processing speed task named the Color-Shape Test, where participants answered correctly in 97% of the attempts[42]. In the paper-pencil DSST version, participants also make little mistakes reflected by a high accuracy, while the speed outcome proves more sensitive to cognitive variations[33]. The mDSST speed performance varied between and within subjects, which indicates this outcome to be suitable in detecting momentary cognitive fluctuations.

These feasibility results confirm that both tasks are appropriate, but need fine-tuning. For instance, the font size could be increased or the screen rotated to further improve the mDSST. Nevertheless, some limitations need to be acknowledged. In the mVSWMT analyses, the position of the icons could not be taken into account due to technical limitations. Descriptive background analysis revealed that a slight primacy and recency effect appeared, as participants remembered the first or last icons slightly more often. The discrepancy between identified location and actual location may be an interesting aspect of a momentary working memory task in the future. Additionally, the sample was healthy and highly educated resulting in limited generalizability of the

feasibility results. Next steps may include testing the adjusted mDSST and mVSWMT in more diverse healthy and clinical populations.

Validity of momentary cognition tasks through contextualization

Initial evidence for the validity of the momentary cognition tasks was provided by relating cognitive performance with intrapersonal factors (e.g., mood, fatigue, stress, sleep-related outcomes) and contextual factors (e.g., being in company of others) to evaluate and understand momentary cognitive performance. Surprisingly, mood and fatigue had no effect on cognitive performance. One explanation could be that the participants were healthy, well rested, and overall in a positive mood (see Section Contextual factors). Timmers et al. [2014] also found no indication for an effect of fatigue on cognition (i.e., short-term memory) in healthy young adults[43]. Previous findings on the relation between mood and cognition in daily life are inconclusive. While one study found no association between changes in mood and cognitive functioning[44], another study reported that higher positive mood resulted in less interference during an emotional Stroop task[45]. Stronger associations may appear in clinical populations[46,47].

Individual performance on the mVSWMT and mDSST was diminished when distracted and in social company. Logically and confirmed by experiments, distraction has a negative influence on cognitive performance[48]. The negative influence of being in company was also previously reported: Von Stumm [2018] argues that being alone may help to focus one's attention and thus improve cognitive performance[44]. In contrast, it cannot be assumed that social context truly lowers a person's cognitive ability. This result may rather be related to variations in situational demands[44]. In the present study, participants were in company in 71% of the time. Hence, future studies may take the potentially mediating factors of company and distraction into account when analyzing momentary cognitive fluctuations.

Age sensitivity was found for both tasks with associations between age and visuospatial working memory and processing speed in everyday life. As expected, Zimprich and Kurtz [2013], younger adults performed better[49]. It is important to disentangle the cognitive decline in performance from an assessment bias. Compared to younger adults, older adults tend to experience technologies as less easy to use[50]. Additionally, older adults may have impaired hearing or vision, potentially affecting the usability and thus outcomes of technology-based assessments. Previous studies, however, confirmed the

feasibility, reliability, and validity of digital assessments in the elderly[42,51,52]. All participants became better over time, but the learning curve was steeper for younger adults than for older adults. Learning effects were reported in previous mobile cognition tasks and may not affect sensitivity negatively[52]. Descriptive background analysis revealed that learning stabilized after 10 to 15 beeps and a steady state is reached within the first days of the study.

The non-significant correlation between the two momentary tasks suggests that different cognitive domains are measured, namely processing speed (mDSST) and visuospatial working memory (mVSWMT). This finding is in line with previous research that also found no correlation between momentary working memory and processing speed, possibly due to the unreliability of one task[44]. Strategy use was different between the two momentary tasks in this study. The lack of correlation could be due to a different approach in both tasks, hindering a comparison of cognitive performance per se. It is expected that the current tasks will correlate after adjustment are made and when tested in a clinical sample with cognitive complaints. If no correlation shows, it might be that strategy use is moderating cognitive performance.

The present validation study did not focus on correlations with traditional neuropsychological tests. However, an in-house (unpublished) trial with 50 healthy participants showed that outcomes of a two-minute mDSST and paper-pencil DSST correlated (partial r=.50, p<.001). Participants reported that the digital version was slightly more difficult, as learning the digit-symbol combinations was challenging and the next number could not be anticipated. This preliminary finding provides initial evidence that the 30-second mDSST measures processing speed, but needs extension to confirm construct validity.

Overall, these validity findings can be seen as a proof of concept for the contextualization of momentary cognitive performance. Future research is needed to disentangle the complex interaction between mood, context, and cognition further. In addition, limitations include not taking the education level and the relation with traditional neuropsychological tests into account as part of the validation. Furthermore, the developed tasks are still artificial[13], in the sense that individuals normally do not perform these tasks, but actually search for their keys or process information to plan their days.

Next steps are the final adjustments of the app and testing both tasks in populations with different cognitive profiles. Clinical populations may include people with schizophrenia, major depression, or brain damage. Furthermore, situations that influence the cognitive performance such as tiredness, alcohol use, or medication intake may provide relevant insight into the validity of the

tasks. Cognitive assessments in everyday life, in combination with momentary sampling of mood and context, may prospectively give individuals more insight into their functioning and thus support self-management and planning. This study is an important step in the anticipated personalization of holistic mobile health[12].

Suggestions for future development and use of momentary cognition tasks

Reflecting on the overall development and use of the mDSST and mVSWMT, a number of lessons were learned and can be implemented in future studies (see Table 4.4). Most momentary cognition tasks are inspired by traditional neuropsychological tests. For example, in addition to the DSST used as reference in the present study or by Suffoletto et al. [2017][53], other studies used momentary processing speed tasks based on the Trail B test or the Stroop task[46,54]. Furthermore, the laboratory n-back task assessing working memory capacity has been adapted to fit into a momentary approach[55–58]. A direct translation can be problematic due to the variability of everyday life that needs repeated assessments in complex environments. Smartphone assessments can offer new possibilities for task development and use. Furthermore, input from a multi-disciplinary team involving neuropsychological healthcare professionals and ESM experts should guide the development. Other stakeholders, including clinicians and patients, should be consulted during development and evaluation. The participant's self-report and observations of the technology use[59] can provide insights into their perspective and experience when measuring momentary cognition within an ESM paradigm.

Table 4.4 Suggestions for future task development and use.

Suggestions for Momentary Cognition Tasks	
Task Development	**Task Use**
• Involve a multi-disciplinary team • Orientate concepts on traditional neuropsychological tests • Balance enjoyment/gamification with context information (experiences and physical context) • Ideal outcomes need to show clinically relevant within- and between-subject variance, be age-sensitive, and show no ceiling-effect • Use comparison data to determine between-subject variance; within-subject data serves as its own control	• Tailor beep frequency and sampling duration to the research/clinical question • Balance length and number of tasks, and additional momentary items • Limit assessment time (e.g., 2 minutes) • Adjust difficulty levels to individual abilities to prevent frustration and maintain motivation • Consider momentary context during interpretation (e.g. distraction) • Consider learning-effects (particularly in early trials)

Gamification is a strategy to increase motivation. An example of gamification to measure cognition is the Sea Hero Quest smartphone app (www.seaheroquest.com). Participants orient themselves in a virtual sea world and get rewards when performing well. This quest may be a valid method to assess navigation skills in a fun way[60], however, it may be less suited for clinical practice were repeated assessments of cognitive performance are interwoven with assessments of mood and context. It is important to strike a balance between a thoughtful completion of the ESM items and the competitiveness and enjoyment of a cognitive performance task.

Testing the cognition task in a healthy sample is a useful way to test feasibility and validity[37,43]. Adjustments can be made before introducing the task to a more vulnerable clinical population. A benefit of ESM is that individuals can be their own controls and performance can be compared within one dataset[14,61].

Another aspect to consider is the beep frequency. While a high intensity may reveal more fluctuations, beep length and time investment need to be considered. The strength of a good ESM questionnaire lies in the intuitiveness of assessments and it is very important that users are able to complete the questionnaires without over thinking the answers and with minimal interference to their usual routine[61]. Adding a cognition task should not change the adherence to good ESM practice. When assessments are made repeatedly and in the flow of daily life, the beep length should not exceed a couple of minutes to prevent interference. Potentially, tasks can alternate at random across assessments to minimize fatigue effects. In general, participant's experience should be explored and if necessary, guide task adjustments when feelings of over- or under stimulation appear. Task difficulty may be tailored to the individual's ability. Working memory tasks with varying levels of difficulty have been tested in other ESM tools[53,62]. Ideally, momentary assessment promotes a flow in everyday life. Tasks should remain challenging when users reach a level of experienced achievement that relates to the individual's overall cognitive ability (e.g., being correct in 70% of the cases). The right difficulty level can prevent a loss of motivation and simultaneously preclude frustration or even resentment[63,64]. Prospectively, studies may consider automatically adjusting the level based on an individual's performance.

When implementing momentary cognition tasks, the sampling duration needs to be tailored to the research or clinical question[61]. Examples include single case assessments running over months or years, where continued experience sampling can illustrate useful insight into the course of a

disease[65,66]. In the assessment process at memory clinics, weeklong momentary cognition tasks can supplement traditional neuropsychological test batteries and provide information on cognitive fluctuations in everyday life[50]. Side momentary cognition tasks parallel to the dose adjustments of drugs[55]. Finally, in rehabilitation centers, e.g., after brain damage, momentary cognition tasks may determine the effectiveness of the treatment when applied before and after a program. Insight into momentary cognitive fluctuations in context can be used to provide individuals with feedback and guidance to deal with cognitive complaints in daily life.

Conclusions

Momentary cognition tasks aim to depict fluctuation of cognitive performance in everyday life and hold promise for future research and clinical use. Prospectively, the task application needs to be extended, for example into different cognitive domains or patient populations. Furthermore, the interaction with other intrapersonal factors requires further disentanglement. Next steps can be guided by the suggestions resulting from this study such as involving a multi-disciplinary team, tailoring the set-up to the individual, and balancing the level of enjoyment and seriousness.

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Appendix 4.A

Table 4.A.1 Experience Sampling Protocol: Beep questionnaire.

	Item	7-point Likert scale or categorical options
1	I feel cheerful	1 = not at all 4 = moderate 7 = very much
2	I feel energetic	1 = not at all 4 = moderate 7 = very much
3	I feel insecure	1 = not at all 4 = moderate 7 = very much
4	I feel relaxed	1 = not at all 4 = moderate 7 = very much
5	I feel down	1 = not at all 4 = moderate 7 = very much
6	I feel irritated	1 = not at all 4 = moderate 7 = very much
7	I feel satisfied	1 = not at all 4 = moderate 7 = very much
8	I feel lonely	1 = not at all 4 = moderate 7 = very much
9	I feel enthusiastic	1 = not at all 4 = moderate 7 = very much
10	I feel anxious	1 = not at all 4 = moderate 7 = very much
11	I feel guilty	1 = not at all 4 = moderate 7 = very much
12	I'm worrying about things	1 = not at all 4 = moderate 7 = very much
13	mVSWMT instruction screen mVSWMT part 1: encoding	
14	I think I remembered it all	1 = not at all 4 = moderate 7 = very much
15	I generally feel well at the moment	1 = not at all 4 = moderate 7 = very much
16	mVSWMT instruction screen mVSWMT part 2: recall	
17	What am I doing (right before the beep)	work, school/housekeeping/self-care/relaxing/sport, movement/eating, drinking /traveling, on the road/having a conversation/something else/nothing
18	I can do this well	1 = not at all 4 = moderate 7 = very much
19	This is difficult for me	1 = not at all 4 = moderate 7 = very much
20	I would rather be doing something else	1 = not at all 4 = moderate 7 = very much
21	I am focused	1 = not at all 4 = moderate 7 = very much
22	Where am I (just before the beep)	at home/at someone else's home/work, school/public space/on the road/somewhere else
23	Who am I with (just before the beep)	partner/family/housemates/friends/colleagues/acquaintances/strangers, others / nobody
24a	Company: I like this company	1 = not at all 4 = moderate 7 = very much
25a	Company: I would rather be alone	1 = not at all 4 = moderate 7 = very much
24b	Alone: I like being alone	1 = not at all 4 = moderate 7 = very much
25b	Alone: I would rather be in company	1 = not at all 4 = moderate 7 = very much
26	I don't feel well	1 = not at all 4 = moderate 7 = very much
27	I am tired	1 = not at all 4 = moderate 7 = very much
28	Since the last beep I have used	alcohol/medication/coffee, caffeine/smoking, nicotine/cannabis/other drugs/nothing
29	mDSST instruction screen mDSST	30-seconds timeframe
30	I got distracted during the task	1 = not at all 4 = moderate 7 = very much
31	This beep disturbed me	1 = not at all 4 = moderate 7 = very much
31	Thanks!	

Table 4.A.2 Experience Sampling Protocol: Morning questionnaire.

	Item	7-point Likert scale or categorical options
1	I generally felt well today	1 = not at all 4 = moderate 7 = very much
2	I generally felt tired today	1 = not at all 4 = moderate 7 = very much
3	I generally felt tense today	1 = not at all 4 = moderate 7 = very much
4	I generally worried a lot today	1 = not at all 4 = moderate 7 = very much
5	I generally could concentrate well today	1 = not at all 4 = moderate 7 = very much
6	I generally felt forgetful today	1 = not at all 4 = moderate 7 = very much
7	Goodnight!	1 = not at all 4 = moderate 7 = very much

Table 4.A.3 Experience Sampling Protocol: Evening questionnaire.

	Item	7-point Likert scale or categorical options
1	How long did it take before I fell asleep last night?	0 - 5 minutes/5 - 15 minutes/15 - 30 minutes/ 30 - 45 minutes/ 45 minutes - 1 hour/ 1 - 2 hours/ 2 - 4 hours/ > 4 hours
2	How often did I wake up last night?	0/1/2/3/4/5/> 5
3	How long did I lie awake this morning before getting up?	0 - 5 minutes/5 - 15 minutes/15 - 30 minutes/ 30 - 45 minutes/ 45 minutes - 1 hour/ 1 - 2 hours/ 2 - 4 hours/ > 4 hours
4	I slept well	1 = not at all 4 = moderate 7 = very much
5	I feel well rested	1 = not at all 4 = moderate 7 = very much
6	I am looking forward to this day	1 = not at all 4 = moderate 7 = very much
7	Thanks!	1 = not at all 4 = moderate 7 = very much

Appendix 4.B

Table 4.B Individual multilevel regression analyses of mood, context, and sleep quality on the mVSWMT outcome correct/incorrect.

	Correct/incorrect				
	B	SE	P	95% CI	
Positive affect	-.03	.02	.04*	-.06,	-.001
Negative affect	-.0003	.03	.99	-.05,	.05
Worry	.002	.01	.89	-.02,	.02
Fatigue	-.01	.01	.54	-.02,	.01
Focus	.04	.01	<.001***	.02,	.06
Activity-related stress	-.01	.01	.49	-.03,	.02
Company$	-.10	.03	<.001***	-.16,	-.05
Location$	-.02	.03	.38	-.07,	.03
Distraction	-.03	.01	.001**	-.04,	-.01
Time until sleep	.01	.01	.23	-.01,	.04
Number of wake-ups	-.005	.01	.67	-.03,	.02
Slept well	.01	.01	.47	-.01,	.03
Well rested	.005	.01	.65	-.02,	.03
Age^2	-.00005	.00002	.002*	-.00009,	-.00002
Gender	-.04	.05	.47	-.14,	.06

Note. Company$ = dummy variable of being alone versus with others. Location$ = dummy variable of being at home versus somewhere else. Age^2 = quadratic function of age. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

Appendix 4.C

Table 4.C Individual multilevel regression analyses of mood, context and sleep quality on the mDSST outcomes speed and accuracy.

	Speed					Accuracy				
	B	SE	p	95% CI		B	SE	p	95% CI	
PA	−.01	.05	.90	−.11,	.10	.45	.21	.03*	.03,	.87
NA	−.05	.10	.61	−.24,	.14	−.39	.34	.25	−1.04,	.27
Worry	.09	.04	.02*	.01,	.17	−.20	.15	.17	−.50,	.09
Fatigue	−.02	.03	.46	−.09,	.04	−.34	.12	.007**	−.58,	−.09
Focus	.02	.03	.50	−.04,	.08	.36	.14	.008**	.09,	.63
Act-stress$	.05	.04	.18	−.03,	.13	−.14	.18	.44	−.48,	.21
Company$	−.29	.09	.001**	−.46,	−.12	−.003	.39	.99	−.77,	.76
Location$	−.09	.08	.26	−.25,	.07	.34	.36	.34	−.36,	1.05
Distraction	−.15	.02	<.001***	−.20,	−.10	−.54	.41	<.001***	−.74,	−.33
Time-sleep$	−.04	.04	.32	−.11,	.04	−.07	.17	.67	−.40,	.25
Wake-ups$	−.01	.04	.82	−.08,	.07	−.08	.16	.63	−.40,	.24
Slept well	−.01	.04	.84	−.08,	.07	−.16	.17	.35	−.49,	.17
Well rested	.01	.04	.86	−.07,	.08	.08	.16	.62	−.24,	.40
Age^2	−.001	.0002	<.001***	−.002,	−.001	.0002	.0002	.47	−.0003,	.0006
Gender	.47	.85	.58	−1.19,	2.14	.71	.58	.23	−.44,	1.85

Note. PA = positive affect. NA = negative affect. Act-stress$ = activity-related stress. Company$ = dummy variable of being alone versus with others. Location$ = dummy variable of being at home versus somewhere else. Time-sleep$ = time until sleep. Wake-ups$ = number of wake-ups at night. Age^2 = quadratic function of age. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

Appendix 4.D

Table 4.D.1 Subgroup analyses on age for the mVSWMT outcome correct/incorrect.

	<45 years of age					45 years or older				
	B	SE	p	95% CI		B	SE	p	95% CI	
Model			<.001***					<.001***		
PA	−.08	.05	.08	−.18,	.009	−.01	.06	.88	−.14,	.12
NA	−.10	.11	.36	−.32,	.12	.11	.22	.62	−.32,	.54
PA x NA	.02	.03	.56	−.04,	.07	−.03	.04	.55	−.11,	.06
Focus	.05	.01	<.001***	.02,	.08	.04	.02	.01**	.008,	.07
Company$	−.05	.04	.21	−.13,	.03	−.13	.04	.001**	−.21,	−.05
Distraction	−.02	.01	.11	−.04,	.004	−.01	.01	.22	−.04,	.009
Age^2	−.00005	.00009	.55	−.0002,	.0001	−.00007	.00004	.047*	−.0001,	−1.13e-06

Note. PA = positive affect. NA = negative affect. PA x NA = interaction between positive and negative affect. Company$ = dummy variable of being alone versus with others. Age^2 = quadratic function of age. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

Table 4.D.2 Subgroup analyses on age for the mDSST speed outcome.

	<45 years of age					45 years or older				
	B	SE	p	95% CI		B	SE	p	95% CI	
Model			<.001***					<.001***		
PA	−.05	.17	.77	−.37,	.28	.33	.16	.04*	.02,	.63
NA	−.27	.39	.49	−1.04,	.49	1.01	.53	.06	−.02,	2.05
PA x NA	.03	.09	.74	−.14,	.20	−.17	.11	.10	−.38,	.04
Worry	.10	.06	.10	−.02,	.21	−.01	.05	.78	−.12,	.09
Company$	−.17	.13	.20	−.43,	.09	−.22	.09	.02*	−.40,	−.03
Distraction	−.19	.04	<.001***	−.26,	−.13	−.08	.03	.004**	−.13,	−.02
Age^2	−.0007	.001	.57	−.003,	.002	−.001	.0003	<.001***	−.002,	−.0008
Time$	.30	.15	.047*	.004,	.59	.009	.11	.94	−.21,	.23
Study day$	.24	.28	.40	−.31,	.78	.47	.21	.02	.07,	.88

Note. PA = positive affect, NA = negative affect. PA x NA = interaction between positive and negative affect. Company$ = dummy variable of being alone versus with others. Age^2 = quadratic function of age, Time$ = log-transformed replication score. Study day$ = log-transformed day of study score. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

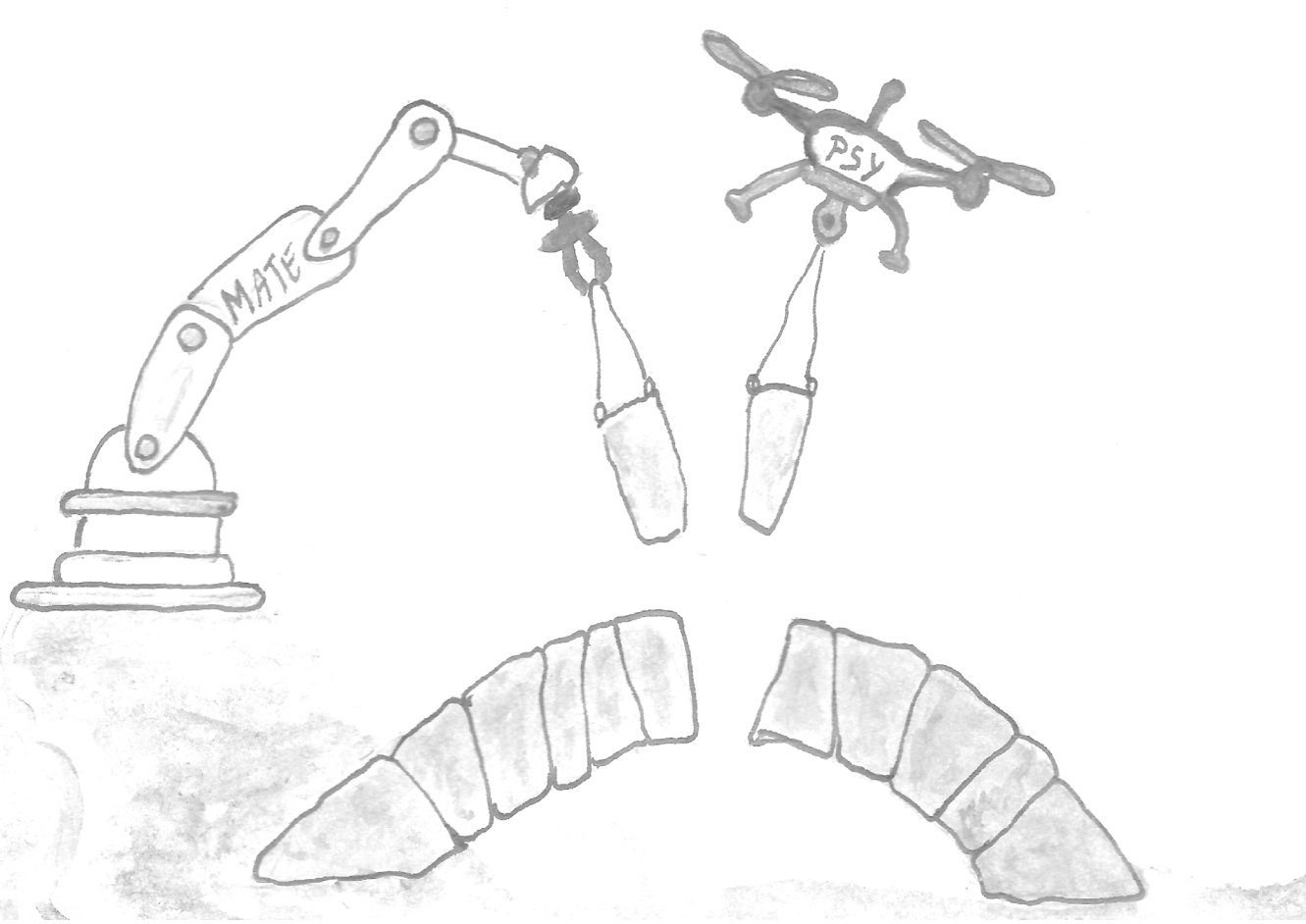
Table 4.D.3 Subgroup analyses on age for the mDSST accuracy outcome.

	<45 years of age					45 years or older				
	B	SE	p	95% CI		B	SE	p	95% CI	
Model			.004**					.003**		
PA	−.86	.68	.21	−.2.18,	.47	.88	.91	.34	−.91,	2.67
NA	−1.92	1.57	.22	−5.004,	1.15	1.11	3.11	.72	−4.98,	7.20
PA x NA	.37	.36	.30	−.34,	1.08	−.15	.61	.80	−1.36,	1.05
Fatigue	−.34	.20	.10	−.74,	.06	−.08	.20	.70	−.47,	.31
Focus	.25	.21	.23	−.15,	.65	−.02	.22	.93	−.45,	.41
Distraction	−.44	.15	.003**	−.73,	−.15	−.57	.16	<.001***	−.88,	−.27

Note. PA = positive affect. NA = negative affect. PA x NA = interaction between positive and negative affect. CI = Confidence Interval. *p<.05, **p<.01, ***p<.001.

Part III

Continued development and implementation of experience-sampling technology in family medicine



Chapter 5

Implementing experience sampling technology for functional analysis in family medicine – A design thinking approach

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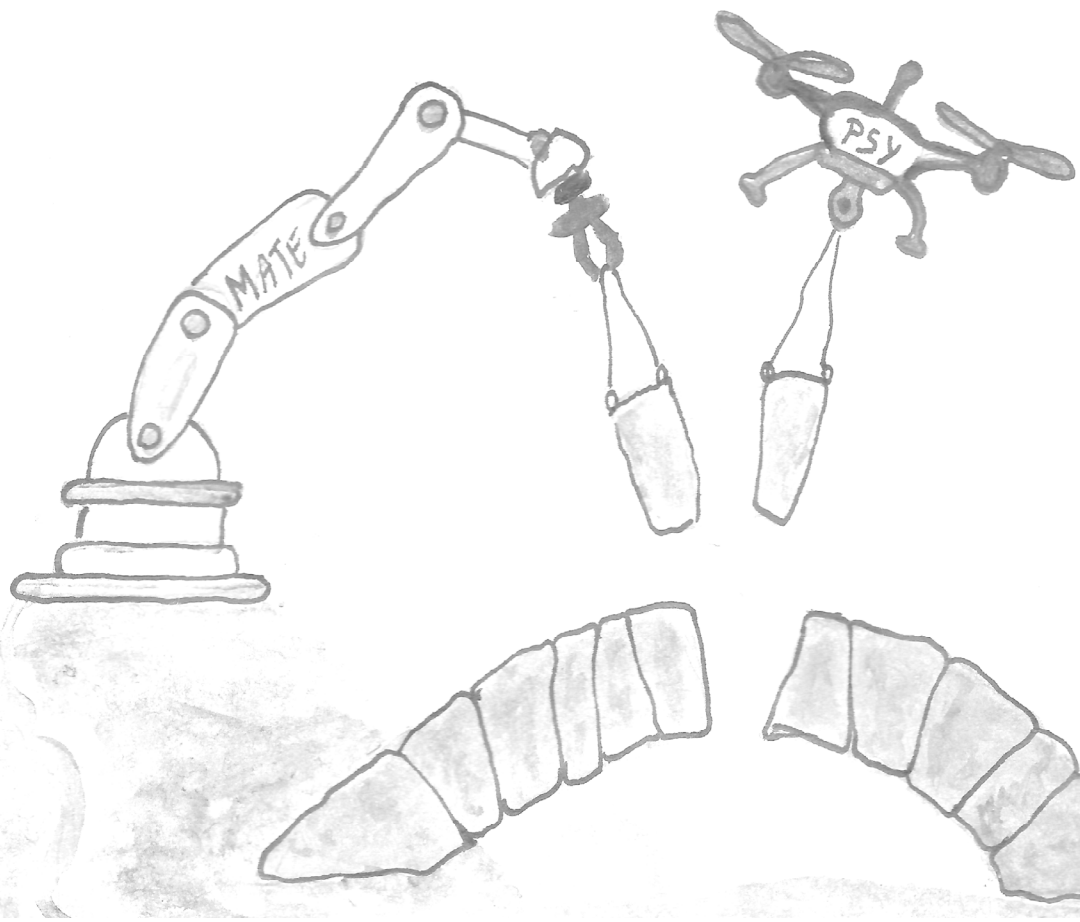

Abstract

Background

A paradigm shift in health care from illness to wellbeing requires new assessment technologies and intervention strategies. Self-monitoring tools based on the Experience Sampling Method (ESM) might provide a solution. They enable patients to monitor both vulnerability and resilience in daily life. Although ESM solutions are extensively used in research, a translation from science into daily clinical practice is needed.

Objective

To investigate the redesign process of an existing platform for ESM data collection for detailed functional analysis and disease management used by psychological assistants to the general practitioner (PAGPs) in family medicine.

Methods

The experience-sampling platform was reconceptualized according to the design thinking framework in three phases. PAGPs were closely involved in co-creation sessions. In the 'understand' phase, knowledge about end-users' characteristics and current eHealth use was collected (nominal group technique – 2 sessions with N=15). In the 'explore' phase, the key needs concerning the platform content and functionalities were evaluated and prioritized (empathy mapping – 1 session with N=5, moderated user testing – 1 session with N=4). In the 'materialize' phase, the adjusted version of the platform was tested in daily clinical practice (4 months with N=4). The whole process was extensively logged, analyzed using content analysis, and discussed with an interprofessional project group.

Results

In the 'understand' phase, PAGPs emphasized the variability in symptoms reported by patients. Therefore, moment-to-moment assessment of mood and behavior in a daily life context could be valuable. In the 'explore' phase, (motivational) functionalities, technological performance and instructions turned out to be important user requirements and could be improved. In the 'materialize' phase, PAGPs encountered barriers to implement the experience-sampling platform. They were insufficiently facilitated by the regional primary care group and general practitioners.

Conclusion

The redesign process in co-creation yielded meaningful insights into the needs, desires and daily routines in family medicine. Severe barriers were encountered related to the use and uptake of the experience-sampling platform in settings where health care professionals lack the time, knowledge and skills. Future research should focus on the applicability of this platform in family medicine and incorporate patient experiences.

Introduction

Modern health care is faced with two challenges: refocus from an overemphasis on illness to wellbeing to better realize the multidimensional experience of positive health; and the design and implementation of new technologies that support this process. The diagnosis evidence-based group-level symptom reduction model is under strain because it ignores the patient's needs and goals, the transdiagnostic psychological mechanisms at stake in mental disorders, and the importance of the therapist-patient relationship in care[1]. Mental illness is better framed as vulnerabilities. Consequently, patients learn how to cope with these vulnerabilities and develop resilience to increase their wellbeing. The shift from illness to wellbeing is central in the Dutch New Mental Health Movement. It links the concept of recovery to positive health and proposes personalized psychiatry to reach its goals. The vision, developed by the Dutch New Mental Health Movement, states that mental health is contextualized and consequently care should occur embedded within the community. This newly developed vision leads to three engagements: patient engagement according to 'nothing about us without us,' shifting resources from clinical facilities to the neighborhood (context involvement), and enriching contacts with network-based care, both face-to-face and through an online community (virtual expansion)[2]. Care should be a collaborative process between health care professionals, patients and meaningful persons in their environment. In this process, patients should stay in control of their own care process and get empowered to actively participate in their treatment. Equally so, their supportive environment should also be empowered to realize sustainable solutions. These developments are in line with the new definition of health, "as the ability to adapt and control your own life, in the light of social, mental and physical challenges in life", proposed in alternative to the WHO definition of health that was criticized because it tended to medicalize all deviations of optimal functioning[3]. Health is defined in relation to personal goals. It requires a personalized psychiatry which takes into account patients' characteristics, needs and desires in their care process[4]. These developments create a paradigm shift from illness to wellbeing.

New technologies can support this process, but implementation and adoption are challenging. Previous literature shows that only a few studies about the implementation of eHealth in practice are available. They show that eHealth tools are often poorly implemented[5,6]. An essential step in the successful implementation of eHealth is the active involvement of end users

during the development process[6–9]. They focus on the realities of daily practice where eHealth solutions often are less usable and feasible[6,7]. It is essential to take these requirements into consideration to bridge the gap between tools used in research and tools used in daily clinical practice.

Relying on eHealth to realize the paradigm shift from illness to wellbeing is not straightforward and requires a fundamentally new approach. The reason is that eHealth tools are often modified classic interventions that focus on symptom reduction using the strategy of learning skills that should generalize in daily situations. Although anxious patients can learn to relax during (classic) therapy or even in front of a computer at home (eHealth), it is possible that they panic in daily life situations. Transfer from the therapist's office to the individual's daily life cannot be taken for granted. Consequently, self-monitoring tools based on the Experience Sampling Method (ESM) are proposed. Data is collected in daily life using (random) time-based sampling triggers that generate assessments of vulnerable as well as resilient moments. This well-designed data collection procedure with customizable questionnaires is well-accepted in diverse populations[10,11]. In ESM, individuals are asked to complete, for example, a short 2-min questionnaire about thoughts, mood and context at several moments a day and for several days in response to sound triggers (beeps)[12]. This gives insight into daily life functioning[12]. This method has previously been applied in specialized mental health[13–15], but it has never been studied as a data collection method in family medicine where patients present with different problems. This requires reappraisal of methods and procedures. A new setting, a new target population and a new goal of the data collection method ask for a translation from science into daily clinical practice.

Therefore, the main aim of the paper is to investigate the redesign process of the PsyMate™, an ESM tool for detailed functional analysis and disease management, for use by psychological assistants to the general practitioner in family medicine. A more thorough insight into the redesign process of the PsyMate™ in family medicine is needed to provide practical support for implementation of an ESM tool in family medicine.

The following research questions were formulated:

(1) What are the end users' characteristics, needs and goals for use of the PsyMate™ in daily clinical practice?
(2) What are the user requirements and how can the PsyMate™ be optimized?
(3) What are the experiences of the psychological assistants to the general practitioner with the redesigned PsyMate™?

Materials and methods

Design

The model used for the redesign of the PsyMate™ consists of three phases of design thinking (see Figure 5.1)[16]. The 'understand' phase belongs to the concept of understanding the user and the user's problems and consists of the empathize and define stages. The 'explore' phase belongs to the concept of exploring new ideas and representations and consists of the ideate and prototype stages. The 'materialize' phase belongs to the concept of materializing these new ideas and representations, and consists of the test and implement stages. In this study, only the test stage was performed. Table 5.1 provides an overview of the research methodology that was applied in each phase of the design thinking model.

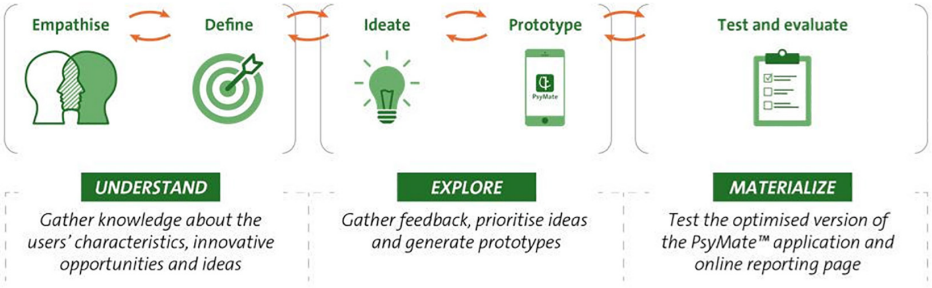

Figure 5.1 The design thinking model used for the redesign of the PsyMate™.

Table 5.1 Overview of the goal, participants, procedure and data collection methods, data analysis and results in each phase of the design thinking model.

Phase	**Understand**	**Explore**		**Materialize**
Stage	**Empathize & Define**	**Ideate**	**Prototype**	**Test**
Goal	Explore the characteristics and mental health problems within the patient group (patients consulting a psychological assistant to the general practitioner in family medicine) and the current use of eHealth in daily clinical practice	Collect key needs and suggestions about the content and functionalities of the PsyMate™ application and web-based reporting tool	Build a new prototype based on the ideas	Evaluate the newly developed prototype, i.e., the adjusted version of the PsyMate™ application and web-based reporting tool: barriers and facilitators of use
Research concept	Usability	Usability		Feasibility
Participants	Psychological assistants to the general practitioner (N = 30; 2 groups of 15 participants each) Mental health care manager and team leader	Psychological assistants to the general practitioner (N = 5) Mental health care manager and team leader Interprofessional project group	Technicians with expertise in software development and design	Psychological assistants to the general practitioner (N = 4)
Procedure and data collection methods	Literature scan concerning users' characteristics and eHealth in clinical care (e.g., purposes, approaches, (dis)advantages, challenges, and use, attitudes and acceptance in family medicine). Two co-creation sessions with the psychological assistants to the general practitioner, the mental health care manager and the team leader using the nominal group technique concerning the patient group and the current use of eHealth in family medicine (30 minutes).	One co-creation session with the psychological assistants to the general practitioner and the team leader using empathy mapping with a patient with a lifestyle problem as a use case, collecting key needs and suggestions concerning the content and functionalities of the PsyMate™ application (1 hour). One co-creation session with the psychological assistants to the general practitioner and the team leader using moderated user testing, collecting key needs and suggestions concerning the content and functionalities of the PsyMate™ web-based reporting tool (1 hour). One co-creation session with the interprofessional project group using the MoSCoW method, prioritizing the collected key needs and suggestions concerning the functionalities of the PsyMate™ application and web-based reporting tool (2 hours).		Individual coaching on the job with the psychological assistants to the general practitioner concerning the use of the PsyMate™ in family medicine (30 minutes). Using the PsyMate™ in daily family medicine practice for four months. Focus group with the psychological assistants to the general practitioner concerning the use of the PsyMate™ in family medicine (2 hours). Individual semi-structured interviews with the psychological assistants to the general practitioner concerning the use of the PsyMate™ in family medicine (30 minutes). Three weekly telephone contact with the psychological assistants to the general practitionerconcerning the use of the PsyMate™ in family medicine.

Table 5.1 (continued)

Phase	Understand	Explore		Materialize
Stage	**Empathize & Define**	**Ideate**	**Prototype**	**Test**
Data analysis	Descriptive content analysis	Conventional content analysis		Consolidated Framework for Implementation Research (CFIR; Damschroder et al, 2009)
Results	Patient characteristics: psychosocial problems ranging from symptoms such as sleep and self-esteem problems to disorders such as anxiety and depressive disorders. Current use of eHealth: diagnostic, psycho-educative and intervention purposes.	Key needs: clear and concise items, possibility to add personal items, and an intuitive and easy-to-use tool with a feedback mechanism (visualize the data). Must Haves for the PsyMate™ application: add reward gamification elements, create insight into the progress of the beeps (in-app feedback), develop an explanimation or a manual, and create a personal profile. Must Haves for the PsyMate™ web-based reporting tool: develop a manual, add a reset button and create a simple and advanced web-based reporting tool. Schould Haves for the PsyMate™ application: add a memo button. Should Haves for the PsyMate™ web-based reporting tool: make the completed memos visible.	Medium-fidelity prototype of the PsyMate™ application and web-based reporting tool. Adopted changes: option to (de)activate five personal items and option to silence the beep sound for a required time span.	Barriers on the level of the inner setting: limited time per consultation and no commitment of the general practitioners. Barriers on the level of the intervention: no in-app feedback, insufficient instructions and no gamification. Barriers on the level of the individual characteristics: mind shift in the way of working and embedding the PsyMate™ in their working process. Strategies on the level of the process: concrete work instructions by means of a manual and an instruction card, use cases (examples), frequent telephone and mailing contact with a researcher and a WhatsApp group consisting of the psychological assistants to the general practitioner, their team leader and a researcher.

Setting and participants

This study was conducted in general practices connected to a regional primary care group in the south of the Netherlands. Psychological assistants to the general practitioner (PAGPs), psychological wellbeing practitioners, have a background as a nurse or doctor's assistant with an additional 2-years training at a University of Applied Sciences[17]. They work independently, though under supervision of a general practitioner. PAGPs assess the nature and severity of complaints, and determine whether an intervention or referral is needed. Furthermore, their tasks include providing support, guidance and short-term treatment (i.e., consultation, psycho-education, case management, screening diagnostics, self-management and aftercare) for patients with psychological or psychosocial problems.

All PAGPs (N=30) of the regional primary care group were invited and took part in the 'understand' phase. They were interested in innovation in family medicine, had at least 2 years of experience and had a full understanding of the Dutch language. Using convenience sampling, PAGPs with an interest in eHealth were recruited via their team leader to take part in the 'explore' phase. Five PAGPs (4 women, 1 man) were included. They had a background in social psychiatry, nursing and psychology, worked in two to five general practices and had working experience between 2 and 4 years (M=3.60, SD=0.80). All PAGPs worked with patients suffering from psychosocial problems ranging from depressive and anxiety disorders to eating disorders and trauma. Four of them were engaged in the 'materialize' phase as well. In order to process all the input and output during the design thinking process, an interprofessional project group with nine researchers and three technicians from different backgrounds (innovations in mental health, autonomy and participation, efficient monitoring, mental health, eHealth and self-management, public health and primary care, communication and multimedia design, and software design and development) was involved. In addition, the PAGPs were asked to include patients with psychological or psychosocial problems for the patient interviews. Ethical approval was obtained for the patient interviews from the Medical Ethics Review Committee of Zuyderland and Zuyd University of Applied Sciences. Furthermore, we adhered to the approved ethical (consent) procedures of the Medical Ethics Review Committee of Zuyderland and Zuyd University of Applied Sciences. Since the PAGPs were the research participants and patients received regular care, these procedures do not require written informed consent. However, oral informed consent was obtained from both the PAGPs and the regional primary

care group. Moreover, they also provided consent for this research via mail. In addition, ethical principles that are outlined in the Dutch "Medical Research Involving Human Subjects Act" were followed throughout the redesign process.

Intervention

PsyMate™ is an ESM platform for moment-to-moment assessment of mood and behavior in the context of daily life and developed by the department of Psychiatry and Neuropsychology of Maastricht University Medical Centre (MUMC+) and Maastricht University (UM). It consists of a smartphone application (Android and iOS), a cloud-based data system and a web-based reporting tool. The smartphone application generates a beep signal 8-10 times a day at semi-random moments between 7.30 AM and 10.30 PM. Users are requested by beep signals to complete a short questionnaire. Typically, nine mood (i.e., positive and negative affect), three physical status (i.e., hunger, fatigue, pain) and three context (i.e., location, activity and persons present) items are assessed repeatedly. The mood and physical status items are scored on a 7-point Likert Scale (1 = not at all, 4 = moderate, 7 = very) and the context items are assessed categorically. In addition, users are asked to complete a morning questionnaire including four items about sleep quality and an evening questionnaire including five items about the overall appraisal of the day and the subjective experience concerning the use of the PsyMate™. Three items of the morning questionnaire are assessed categorically and one item – overall sleep quality – is rated on a 7-point Likert Scale (1 = not at all, 4 = moderate, 7 = very). All items of the evening questionnaire are rated on a 7-point Likert Scale (1 = not at all, 4 = moderate, 7 = very). Table 5.2 presents an overview of the beep, morning and evening questionnaires. The responses are immediately available online and displayed graphically in an interactive web-based reporting tool. The Likert scales (mood and physical status beep items, overall sleep quality and end-of-day assessments) yield ordinal scores and are displayed in line charts. The beep-level context items are nominal scales and are depicted in pie charts. This allows patients and health care professionals to make an accurate analysis of specific behavior in the specific context and get insight into behavioral patterns (both related to vulnerability and resilience). Figure 5.2 illustrates the web-based reporting tool. A detailed description about the tool can be found in Appendix 5.A. All appropriate permissions have been obtained from the trademark holder of PsyMate™ for its use in this research and manuscript.

Table 5.2 Beep, morning and evening questionnaire respectively from the PsyMate™ standard assessment protocol.

Beep questionnaire	
Item	**7-point Likert scale or categorical options**
I feel cheerful	1 = not at all, 4 = moderate, 7 = very
I feel insecure	1 = not at all, 4 = moderate, 7 = very
I feel relaxed	1 = not at all, 4 = moderate, 7 = very
I feel annoyed	1 = not at all, 4 = moderate, 7 = very
I feel satisfied	1 = not at all, 4 = moderate, 7 = very
I feel lonely	1 = not at all, 4 = moderate, 7 = very
I feel anxious	1 = not at all, 4 = moderate, 7 = very
I feel down	1 = not at all, 4 = moderate, 7 = very
I feel guilty	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question	1 = not at all, 4 = moderate, 7 = very
What am I doing?	Select: resting, work or study, household, hygiene, eating/drinking, leisure, other, nothing
I would rather be doing something else	1 = not at all, 4 = moderate, 7 = very
Where am I?	Select: at home, at family or friend's place, at work or school, public place, transport, somewhere else
Who am I with?	Select: partner, family resident, family non-resident, friends, colleagues, acquaintances, strangers or others, nobody
I am hungry	1 = not at all, 4 = moderate, 7 = very
I am tired	1 = not at all, 4 = moderate, 7 = very
I am in pain	1 = not at all, 4 = moderate, 7 = very
Thank you!	
Morning questionnaire	
Item	**7-point Likert scale or categorical options**
How long did it take before I fell asleep last night?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
How often did I wake up last night?	Select: 0, 1, 2, 3, 4, 5, > 5
How long did I lie awake this morning before getting up?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
I slept well	1 = not at all 4 = moderate 7 = very much
Thank you!	
Evening questionnaire	
Item	**7-point Likert scale or categorical options**
I generally felt well today	1 = not at all 4 = moderate 7 = very much
I generally felt tired today	1 = not at all 4 = moderate 7 = very much
I generally felt tense today	1 = not at all 4 = moderate 7 = very much
Filling in the PsyMate™ has influenced my mood	1 = not at all 4 = moderate 7 = very much
Without the PsyMate™ I would have done other things today	1 = not at all 4 = moderate 7 = very much
Thank you!	

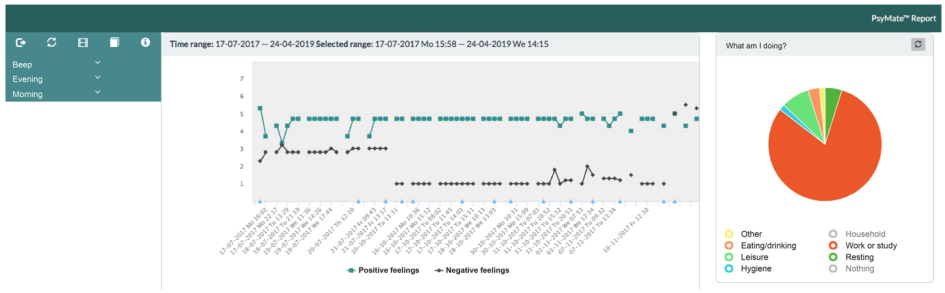

Figure 5.2 An example of the web-based reporting tool.

Data collection and analysis

Phase I: Understand the user and the user's problems

In the 'understand' phase, the patient characteristics and the mental health problems of patients visiting a PAGP in family medicine, and the current use of eHealth in family medicine were explored.

An exploratory unsystematic review was performed to gather more insight into the organization of mental health care in family medicine, more specifically the purposes, approaches, (dis)advantages, challenges, attitudes and acceptance of the use of eHealth. Outcomes were discussed within the interprofessional project group and assimilated in the next phase. Furthermore, two co-creation sessions with fifteen PAGPs each, their team leader and the mental health care manager were performed using the nominal group technique[18] to explore the patient group (patient characteristics and symptoms) and the current use of eHealth. The PAGPs were asked to write down for themselves how they would characterize the patients with mental health problems in their practice. Afterward, each participant provided one patient characteristic in turn without any discussion. Finally, these characteristics were ranked by importance. The same procedure was performed for the eHealth applications they use in the diagnosis and treatment of these patients. Field notes were recorded and analyzed by means of descriptive content analysis. A first list of user requirements was compiled.

Phase II: Explore New Ideas and Representations

In the 'explore' phase, the PAGPs reported on the key needs regarding the content and functionalities of the PsyMate™ application and web-based reporting tool. Furthermore, they provided suggestions for further optimization

of the PsyMate™ application and web-based reporting tool. Moreover, the interprofessional project group gathered the user requirements and optimized the PsyMate™ application and web-based reporting tool based on importance, technological feasibility and the project phase. The PAGPs and the interprofessional project group interacted continuously during the redesign process of the PsyMate™.

One co-creation session was conducted with five PAGPs, their team leader and the mental health care manager of the regional primary care group using empathy mapping[19] to collect key needs and suggestions concerning the content and functionalities of the PsyMate™ application. Empathy mapping is used to get a deeper insight into the end-users' characteristics and their needs. In advance of the session, participants were required to use the PsyMate™ application. Having an intake patient with a lifestyle problem in mind, PAGPs were encouraged to articulate what this patient would 'say,' 'think,' 'do' and 'feel.' During the discussion of the empathy map, participants focused on the match between the current version of the PsyMate™ application and the required content and functionalities for the specific intake case. Next, a second co-creation session was performed with five PAGPs, their team leader and the mental health care manager using moderated user testing[20] to collect key needs and suggestions concerning the content and functionalities of the PsyMate™ web-based reporting tool. Moderated user testing requires active monitoring by a trainer to guide participants through tasks and reply to their questions, in real time. During a live demo, different views of the web-based reporting tool were demonstrated and PAGPs were invited to share their feedback. Qualitative data were recorded and transcribed verbatim. This qualitative data was analyzed by means of conventional content analysis[21], using the qualitative analysis software Nvivo 12 for Windows. Conventional content analysis is used when literature about the topic is lacking. Predetermined categories are avoided and categories flow from the data. Therefore, the content analysis started with open coding and was followed by axial coding to group codes into categories[21]. Two researchers (ND, LH) repeatedly iterated the process of reading transcripts and organized data into groups and categories via open and axial coding. Outcomes were discussed and consensus was reached for the final thematic structure. As a result of both co-creation sessions with the PAGPs, the list of requirements was complemented. Finally, one co-creation session was executed with the interprofessional project group using the MoSCoW method[22] to prioritize the user requirements and suggestions. The MoSCoW method is a requirement prioritization technique to get common understanding with different

stakeholders about the importance of each requirement. Based on the importance and technological feasibility, all requirements were divided into must haves, should haves, could haves and would haves. This prioritization gave input for the software and design experts to make the first adjustments and develop a medium-fidelity prototype of both the PsyMate™ application and web-based reporting tool.

Phase III: Materialize the new ideas and representations

In the 'materialize' phase, the PAGPs field-tested and evaluated the use of the adjusted version of the PsyMate™ application and web-based reporting tool in family medicine. They reported upon the barriers and facilitators of use.

Individual coaching on the job sessions with four PAGPs were conducted to support them in using the PsyMate™ in daily clinical practice. This coaching included the selection of patients who could benefit from the PsyMate™, the introduction of the PsyMate™ to patients in the first consultation, the download and the actual use of the application by patients in between consultations, and the use of the web-based reporting tool in the second and/or subsequent consultations. Next, the PAGPs used the PsyMate™ in their daily clinical practice for 4 months. To keep the PsyMate™ in the spotlight and provide support in case of questions, the researcher (ND) contacted the PAGPs every 3 weeks. Moreover, to have short communication lines, a WhatsApp group was launched. Relevant information was logged. Afterward, one focus group with two PAGPs and two individual semi-structured interviews with the remaining PAGPs were performed to evaluate the barriers and facilitators of using the PsyMate™ in family medicine. The content was based on the Consolidated Framework for Implementation Research (CFIR[23]): intervention characteristics, outer setting, inner setting, individual characteristics and process, and supplemented with questions that arouse during the focus group. Table 5.3 provides an overview of the interview topics. Qualitative data were recorded, transcribed verbatim and analyzed using the qualitative analysis software Nvivo 12 for Windows. CFIR informed the thematic structure during the analysis.

Results

Table 5.1 provides an overview of the research methodology that was applied in each phase of the design thinking model.

Table 5.3 Interview topics regarding the redesign and evaluation of the PsyMate™ in daily practice, used for the individual interviews performed in the materialize phase.

Main topics	Subtopics
Applicability	How many times did you use the PsyMate™ in daily practice?
	For which problems did you use the PsyMate™ in daily practice?
Experiences patients	Content
	Design
	Burden
Experience health care professionals	Individual characteristics (health care professional and patient): attitude, behavior, knowledge, personality traits, motivation, capabilities, skills, learning style
	Relation between patient and health care professional
	Process: planning, execution, reflection, evaluation
	Inner setting: financial, societal, cultural, structural, readiness to implement, peer pressure
	Intervention: content, design, quality, applicability, adaptability, usability, complexity, costs, advantages of the implementation against business as usual, burden
Improvement areas	App
	Web-based reporting tool
	Instruction

Phase I: Understand the user and the user's problems

The first phase reviewed the characteristics of patients consulting PAGPs with mental health or lifestyle problems in family medicine; on usual care as provided by PAGPs; and on the current use of eHealth in the diagnosis and treatment of these patients. According to the literature scan, eHealth is used in family medicine (1) to reach remote patients, (2) to enhance user-friendliness, (3) to improve the accessibility of care, and (4) to stimulate patient' empowerment and independence of health care professionals[24]. Patients from remote regions and patients who are less mobile or have a hearing disability can be reached relatively effortlessly via the internet. eHealth allows health care professionals to tune into the world of the patient. Furthermore, it can be tailored to the individual's needs and communication can be focused. In addition, the patients' anonymity can be maintained. However, the challenge is to engage patients and keep them engaged for a longer time period. Therefore, content needs to be interesting, interactive and updated regularly. Using social media, gaming elements and technology to enhance privacy and external

clinical services are still opportunities that need further investigation. Patients expressed their concerns about the storage and processing of their data, and both patients and health care professionals worry about the reliability and trustworthiness of the content and the devices used[25]. Consequently, health care professionals were hesitant about using eHealth during patient contact due to the technological advancements of the devices. In addition, several individual characteristics also play a role in the acceptance of the use of eHealth in family medicine. For health care professionals, only gender played a role in the use of eHealth meaning that eHealth was more often used by male health care professionals compared to female health care professionals[25]. However, age and educational level contributed to the use of eHealth for patients meaning that young and high educated patients made more use of eHealth than elderly and educationally disadvantaged patients[25].

In the present study, the patients had psychosocial problems ranging from symptoms such as sleep and self-esteem problems to disorders such as anxiety and depressive disorders. According to the PAGPs, the most common problems were anxiety and panic disorders, burnout, depressive disorders, sleep problems and self-esteem. They reported that moment-to-moment assessment might be useful to clarify complaints in patients with vague symptoms. eHealth modules[2] were already used on a small scale by the PAGPs. Applications were implemented for diagnostic, psycho-educative and intervention purposes. The PAGPs noted that the intervention modules are useful, however, the diary modules, designed to collect assessment data, are insufficiently structured and transparent to interpret during patient consultations. The link between diary assessment and interventions is poor. Monitoring tools are often used as home assignments. However, the collected data often remains underused. They seem a separate element. Linking diary data to an intervention is a challenge.

Phase II: Explore new ideas and representations

The second phase targeted the content and functionalities of the current PsyMate™ application and web-based reporting tool and took into account suggestions for improvement from the PAGPs. Based on the prioritization of the suggested improvement areas, reviewed by the interprofessional project group, a medium-fidelity prototype was developed.

Empathy mapping provided insight into what a patient with a lifestyle problem (i.e., emotion regulation problems, disordered eating behavior, reduce alcohol use and stress related problems) would say, think, do and feel during a first

consultation with a PAGP. The empathy map is depicted in Figure 5.3. One example was a woman with overweight who feels down and unattractive. She thinks: "I will never lose weight. I better don't say that I also experience regular eating binges. The PAGP is rather slim." She only drinks water, runs four times a week, does not eat pie anymore and cancels birthday parties. She says that she wants to lose 25 kilos in 6 months. She is really motivated and asks the PAGP to help her achieve her goal. When comparing these ideas with the current content of the application, information that a patient is willing to share – either explicit or implicit – was mainly covered by the beep, morning and evening questionnaires. Suggestions for improvement included the incorporation of clear and concise items; the space to add personal items; the opportunity to silence the beep questionnaire for a certain time span; and this all within an intuitive and easy-to-use tool with a visual feedback mechanism, preferably within the application.

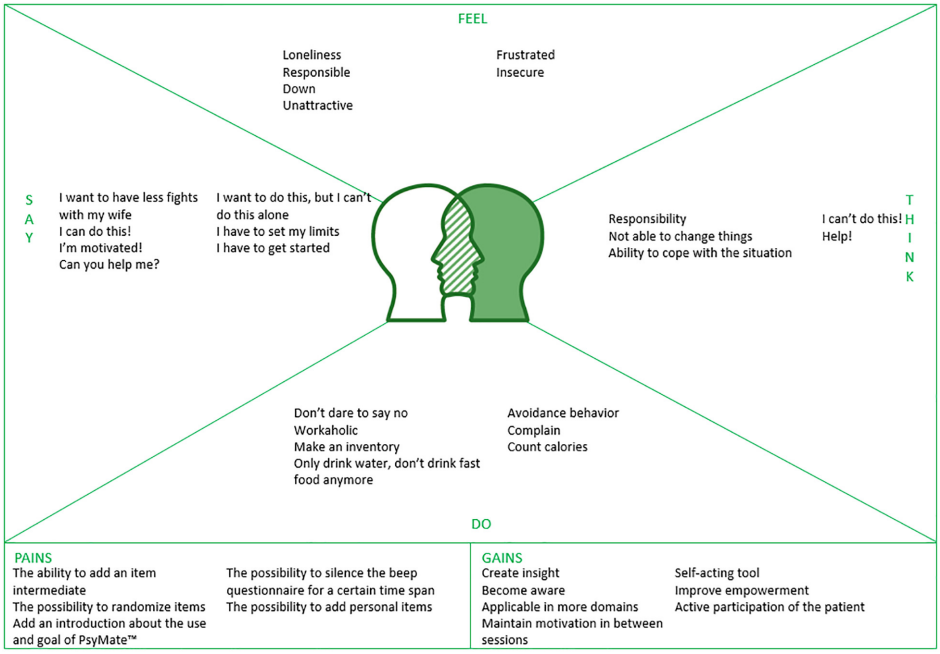

Figure 5.3 An empathy map for a patient with a lifestyle problem during a consult with a psychological assistant to the general practitioner.

Moderated user testing yielded feedback on the web-based reporting tool. In an interactive setting, the PAGPs asked to clarify how to read (e.g., the meaning of different line graphs, symbols, colors and values), interpret [e.g., single (e.g., alone) and combined (e.g., alone at home) values, over various time spans] and explain (e.g., all the information to patients, within a short consultation) the web-based reporting tool. For patients to be encouraged and stay motivated, adequate instructions with a focus on both vulnerabilities and strengths in their daily life – in line with the concept of positive health – were proposed as important references during the implementation. Concerns were raised that less educated or skilled patients would have trouble understanding the web-based reporting tool. For that reason, suggestions for the redesign included one average line for all items, the use of smiley faces, the use of pie charts instead of line charts, and more descriptive information about the meaning of values on the axes of the charts. After all, the PAGPs also agreed that the PsyMate™ was insufficiently used to really be able to assess before redesigning.

"The web-based reporting tool can be super clear in the end, at least if this content and these functionalities stay and eventually it should be fine-tuned once. But fine-tuning is not even necessary now. You have a lot of information that can be very useful, especially in our job because we cannot dig much further." (Psychological assistant to the general practitioner C, moderated user testing, concluding feedback on the web-based reporting tool).

The interprofessional project group prioritized all requirements from the first two phases and weighted the importance of the user requirements to improve usability and technical difficulties to make the changes. The MoSCoW template is shown in Table 5.4. Based on this prioritization, the application was optimized with an option to (de)activate five personal items in the beep questionnaire and the possibility to silence the beep signal for a certain time span.

Table 5.4 User requirements for the PsyMate™ application and web-based reporting tool subdivided within the MoSCoW template.

	Must haves	Should haves	Could haves	Would haves
PsyMate™ application	add reward gamification elements create insight into the progress of the beeps (in-app feedback) develop an explanation or a manual create a personal profile	add a memo button	the ability to randomize items add a menu button add personal items intermediate	adjust the frequency of the beeps adjust the time period add goal setting elements add an e-community function
PsyMate™ web-based reporting tool	develop a manual add a reset button create a simple and advanced web-based reporting tool	make the completed memos visible	add a menu button create a personal profile	make notes add a chat function to keep in contact with the health care professional

Phase III: Materialize the new ideas and representations

The third phase assessed the usability and feasibility of the optimized version of the PsyMate™ application and web-based reporting tool for daily clinical practice by PAGPs. The results were structured according to the five constructs of the Consolidated Framework for Implementation Research (CFIR[23]): intervention characteristics, outer setting, inner setting, individual characteristics and process.

Intervention characteristics

The first domain of CFIR is related to key attributes of the innovation – in this case the PsyMate™ application and web-based reporting tool – and includes for instance the advantage of the intervention compared to an alternative, the complexity of the intervention or the ability to test the intervention on a small scale. The PAGPs had difficulties applying the newly developed prototype PsyMate™ in daily clinical practice. Consequently, they barely used it during their consultations with patients. According to database logs, only 15 patients signed up for the PsyMate™ during the 4-month pilot period. This was confirmed during the three weekly telephone conversations. The PsyMate™ proved to be too complex and disruptive for the highly structured and time-limited work processes in family medicine. As a consequence, effects as well as

(dis)advantages of the tool were not evident. Due to the minimalistic implementation, the focus group and the interviews could not confirm that the PsyMate™ contributed to more in-depth consultations or more insight into the contextual variation of mental states (functional analysis) by PAGPs and patients. The PAGPs lack the knowledge and skills to use the PsyMate™ as a tool to support their functional analysis. Furthermore, the web-based reporting tool was insufficiently intuitive. However, compared to another eHealth application, the moment-to-moment assessment approach of the PsyMate™ was experienced as more valuable for assessment, but the PAGPs required more help to make the link to interventions. The use of the PsyMate™ could be considered both a technological as well as a behavioral innovation.

"PsyMate™ is now seen as a diagnostic tool. It is fairly clear for whom we should not use the PsyMate™. However, we often do not realize when we can use it. When it is possible, we do not think enough about it, we will not make the connection with the PsyMate™ as a tool for detailed functional analysis." (Psychological assistant to the general practitioner C, focus group, evaluation of the use of the PsyMate™ after a 4-month pilot).

Inner and outer setting

The next two domains of CFIR apply to the inner and outer setting of the innovation – in this case the regional primary care group and the general practices – and includes among others the internal architecture of the organization and the innovation climate as well as external policies and incentives. The PAGPs have only 30 min for every patient. This made it difficult to properly introduce the PsyMate™, explain the rationale, provide instructions and discuss collected individual data – aside from all regular consultation topics. In addition, the regional primary care group is a national leader in the implementation of different primary care innovations (e.g., positive health, eHealth). Under the 'Blue Care' (Blauwe Zorg) label, they build innovation networks with regional somatic and mental health specialist resources, health insurers and municipalities. They stimulate eHealth and other innovations. Furthermore, the general practitioners were not involved in the training and briefings. They only gave consent to the PAGP to use the PsyMate™ with their patients as the implementation of an innovation in daily clinical practice. The PsyMate™ was not a registered intervention with a specific financial backing and the PAGPs had to implement it in their regular consultations. From a research

point of view, the PAGPs were the participants of the research and patients did not give consent. Consequently, patient experiences could not be included. The PAGPs reported that patients find it important to have a goal to monitor progress and visualize outcomes. Furthermore, the PAGPs quickly continued with their issues of the day, therefore, forgot to embed the PsyMate™ during the consultations with their patients.

"Apparently, we must be competitive with everything that is already there, but is that true, should we go that far? We must find a balance between going to the PAGP for health and rewarding people for it. We must be careful that it will not become a mass culture. It must remain professional of course." (Psychological assistant to the general practitioner A, focus group, experienced peer pressure).

Individual characteristics

The fourth domain of CFIR concerns the characteristics of the individuals – in this case the PAGPs – and includes for example one's knowledge, beliefs and self-efficacy regarding the intervention. The PAGPs who were interested in using eHealth in their daily clinical practice participated voluntarily in this study. Consequently, probably only the early adopters were included. The PAGPs saw face-to-face contact as the means to collect information. eHealth tools were seen as an addition to the regular treatment instead of as a replacement for the regular treatment. So, implementing tools such as the PsyMate™ requires a mind shift in the way of working. Furthermore, when the PsyMate™ was introduced, it was during the first or the second consultation. During subsequent consultations, the collected individual data was discussed via the web-based reporting tool. Afterward, the use of the PsyMate™ faded. The PAGPs had trouble keeping their patients motivated for a prolonged time period. Ideally, 100 observations are needed for a rich functional analysis. Overall, the PAGPs considered themselves incapable of using the PsyMate™ during their consultations with patients, however, they remained enthusiast.

"It should come naturally. I am struggling to embed the PsyMate™ in my current working routine, but that is because I think it is important to pay attention to the patients when we have a consultation. The assumption is that I do not pay attention to them when I use the PsyMate™ and MindDistrict, although I know it has added value." (Psychological assistant to the general practitioner C, focus group, embedding innovative tools in daily clinical practice).

Process

The fifth and final domain of CFIR is the implementation process and includes planning, engaging, executing, reflecting and evaluating. Although the PAGPs agreed upon the added value of the three-weekly telephone contact with the researcher and the WhatsApp group, coaching did not emphasize the use of the PsyMate™ as a tool for detailed functional analysis enough. In addition, the research team assumed the relevance of understanding symptom variation (functional analysis) was self-evident and no use cases were provided. In practice, the PAGPs were not accustomed to do this and missed hand-on instructions for the use of the PsyMate™ (e.g., introduction and feedback) in daily clinical practice. The PAGPs were rather provided with concrete work instructions by means of a manual and an instruction card. Moreover, the focus group and individual semi-structured interviews, in which the PAGPs shared their experiences and reflected on their own and each other's way of working, led to new insights and a different way of introducing and using the PsyMate™.

"We should keep using the PsyMate™ and then we will see the value again. We should stay alert. Emails will disappear, however, we cannot get out of it when we have to answer a call." (Psychological assistant to the general practitioner A, focus group, the importance of keeping them engaged during the whole study).

Discussion

Principal results

The aim of the current study was to investigate the redesign process of the ESM application PsyMate™ as a tool for detailed functional analysis and disease management used by PAGPs in family medicine. The redesign process was based on a design thinking framework and consisted of three phases: 'understand,' 'explore' and 'materialize.' It disclosed essential insights into the implementation barriers and facilitators in the specific context and procedures of family medicine.

First, end users' characteristics were explored. Patients with psychosocial problems in family medicine are a heterogeneous group, including sleep and self-esteem problems, panic and depressive disorders or vague and unclear symptoms. Because of this diversity and in line with the emerging concept of

positive health, it is important to focus on both vulnerabilities and resilience (strengths) and take transdiagnostic assessment into account[1,3].

Second, users required an intuitive, easy-to-use monitoring tool with clear and concise items and data visualization, preferably within the application. The PAGPs were satisfied with the item content, but suggested improvements for (motivational) functionalities and instructions. A medium-fidelity PsyMate™ prototype was developed based on importance and technological feasibility. This matches criteria from previous research on engagement and satisfaction with mHealth applications: easily accessible and easy-to-use self-monitoring tools with an attractive user interface and tailored to the individual[26,27].

Finally, the PAGPs had difficulties using the PsyMate™ in their daily clinical practice. The most important problems were: (1) there was insufficient time per consultation to properly introduce the PsyMate™ and discuss the results (inner setting); (2) they felt incapable and lacked skills and knowledge to use the PsyMate™ as a functional analysis tool during consultations (individual); and (3) the web-based reporting tool proved difficult to understand (intervention). The underlying problem for the PAGPs was, however, the required mind set to shift from assessing stable diagnoses toward interest in momentary variations in mental state and context that reflect vulnerabilities as well as resilience (strengths). This shift proved difficult to realize, even though the PAGPs were trained in positive health. In addition, it is important to keep in mind that eHealth and ESM are not suitable for every patient. Some patients are not able to fill in repeated assessments due to regulations in the work place. Other patients do not want to gain insight into their complaints and underlying patterns or psychological mechanisms. Consequently, the big question remains how to define the adequate patient population who can benefit from using eHealth and ESM. It is important for future implementations not to assume users are prepared and to better instruct professionals in the clinical use of momentary variations in mental states for functional analysis. These bottlenecks were also identified in research on implementation of patient reported outcome measures (PROMs)[28–35]. The studies highlighted that health care organizations should better prepare the implementation of new technologies by checking knowledge and experience of the staff and believes about the relevance of the tool, and implementing short communication lines. Also important was being able to use the data in their work, taking into account the patients' needs, investing sufficient time and resources, and providing both theoretical and practical training.

Strengths and limitations

The PsyMate™ was redesigned based on a needs assessment using various co-creation methods in close collaboration with the PAGPs, a regional primary care group and an interprofessional project group. Users were well-involved. Second, the PAGPs were coached by the researchers to be able to embed the PsyMate™ in their working routine. Third, field notes were collected and observations and interviews were transcribed to ensure data triangulation. Several strategies were used to enhance the trustworthiness, credibility and transferability of the study. Credibility was increased using peer debriefing sessions with the researchers[36]. Co-creation sessions were conducted by experienced interviewers who frequently checked the meaning of the answers[37]. To improve transferability, information about the design, setting and participants, procedure and data collection methods was documented[38].

As limitation, only the most intrinsically motivated PAGPs participated as they had previously shown interest in using eHealth in daily clinical practice before inclusion in this study. In addition, only the PAGPs and not the patients were involved in the redesign process. However, the PAGPs expressed the patient experiences. Moreover, patient experiences are central in a future study, a series of case studies. Finally, the interprofessional project group was unable to implement all suggestions due to technological and financial constraints. Therefore, prioritization was required. It is, however, unclear whether all suggestions are equally relevant and the realization is necessary for successful implementation.

Implications

A sustainable implementation of mHealth tools remains a challenge in clinical care. The approach and methodology of this study identified barriers and opportunities for implementing a mHealth tool in family medicine which may be relevant to organizations intending to implement mHealth tools. There are several organizational and practical requirements to optimally implement these tools. Health care organizations should pay attention to involve both health care professionals and patients early in the process. If possible, they should be part of the redesign process to assess their needs and desires, and create ownership. Sufficient time and resources are required to ensure that they are ready for the implementation. Organizations should realize that it takes time for a new tool to become part of the daily clinical routine. In this process, nothing can be taken for granted. After all, it is not only a technological change

but it also includes behavioral changes that require theoretical as well as practical training.

Conclusions

By using the design thinking framework, the redesign process revealed meaningful insights into the needs, desires and daily routines for the implementation of the PsyMate™ in family medicine. The PsyMate™ is a valuable tool in mental health and psychiatric research, but implementation in family medicine, with a more diffuse patient group and less consultation time per patient, requires adjustments at all levels: the inner setting, the individual and the intervention. There were severe barriers related to the use and implementation of the PsyMate™ in production-driven care where health care professionals have insufficient time and protocols reduce autonomy in the working process. Then, the lack of knowledge and skills concerning the innovative tool and its utility is difficult to compensate. Future research should focus on the trialability of the use of the PsyMate™ in family medicine and incorporate patient experiences.

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Appendix 5.A

The PsyMate™ users gather data for at least hundred beep moments to be able to optimally use the web-based reporting tool. The application runs on every mobile phone with Android or iOS software (see Appendix Figure 5A.1); the web-based reporting tool is accessible from every computer with Internet connection. People need personalized log in credentials to gain access to both the application and the web-based reporting tool. Monitored data is anonymously and confidentially saved on secured servers that comply with present rules and regulations. The PsyMate™ can be used for different purposes: (1) as a diagnostic tool, (2) for monitoring therapy and medication, (3) for patient empowerment, and (4) prevention purposes[15,39–43]. However, the PsyMate™ is previously only investigated for research purposes in mental health, psychiatry, developmental psychology, and high specialist somatic care. Applications in family medicine were never explored. The moment-to-moment assessment of mood and behavior in the context of daily life give people insight into their daily life patterns. Mechanisms underlying their symptomatology can be charted. People are experts of their daily life. Consequently, treatment can become tailored coproductions. This fosters commitment and motivation by the patient[44]. Tailored coproduction can also lead to patient' empowerment with a focus on mental resilience and an increase in positive experiences. To reduce the chance of relapse, recovered patients can use a self-management tool[44].

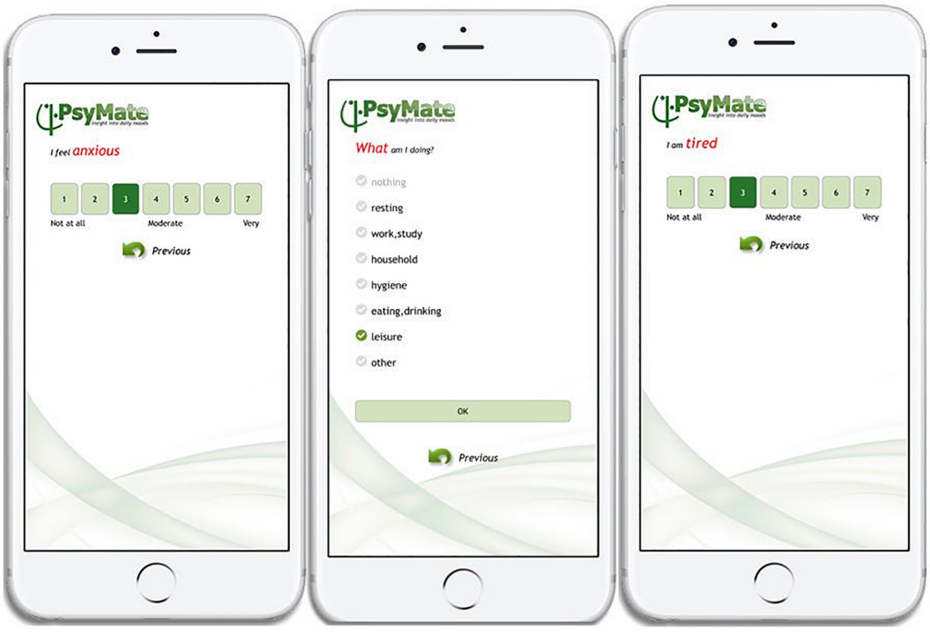

Figure 5A.1 Examples of a mood, context and physical status item within the beep questionnaire.

Chapter 6

How to use experience-sampling technology to understand daily functioning: a practical guide for mental health professionals

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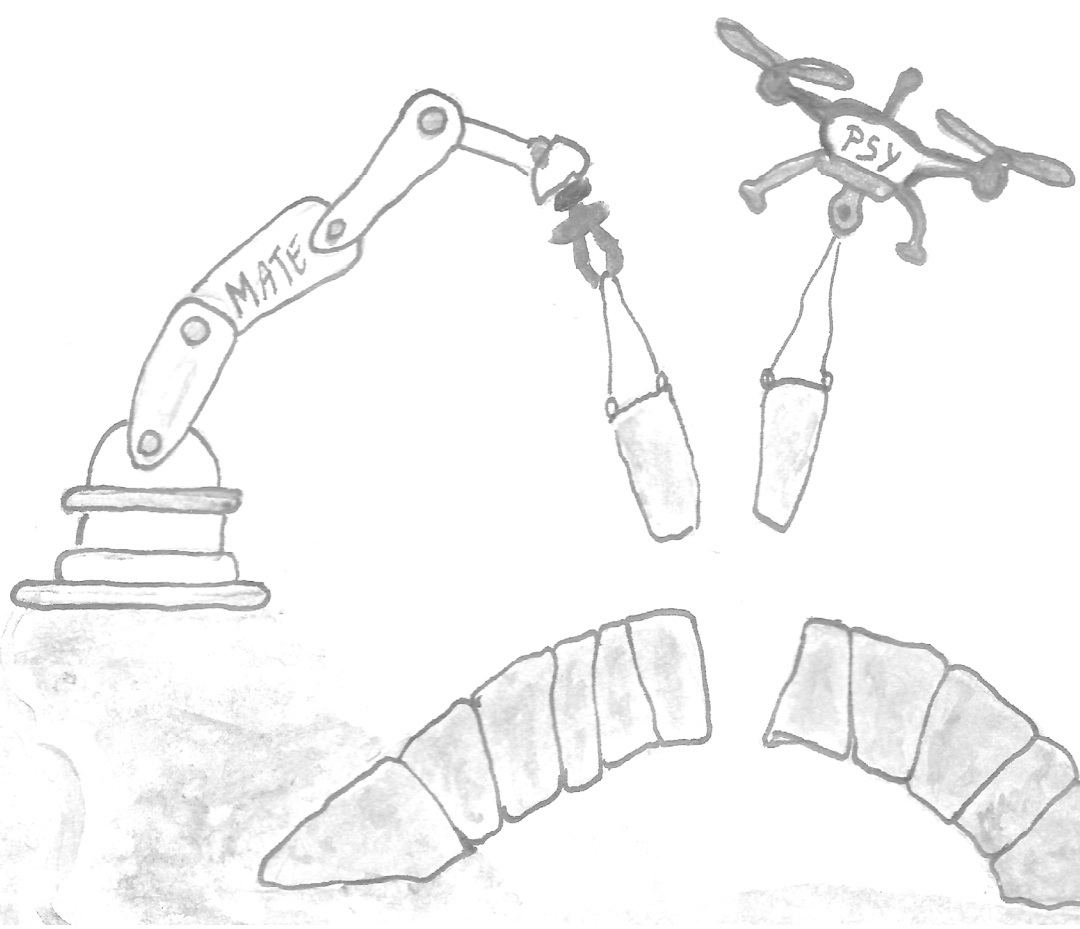
Submitted



Abstract

Satisfying daily life functioning is essential in mental healthcare. Standard assessments focus on symptoms and are designed to detect underlying vulnerabilities. However, they offer insufficient insight into patterns of contextual variability and resilience. Consequently, interventions are planned using incomplete information. The Experience Sampling Method (ESM) is a structured moment-to-moment diary assessing the individual's affect, thoughts, perception and behavior in the daily life context. ESM helps to understand variation in mental states (e.g., anxiety or sleeping problems) as adaptational processes in relation to contextual challenges (functional analysis). Although ESM has been extensively studied across psychological disorders, the adoption by mental health professionals and their patients remains limited because the 'how to' is unclear. This paper presents a practical guide for ESM application in routine clinical care. It integrates empirical knowledge with expert experiences and provides real-world examples and recommendations for successful implementation. The guide comprises how to engage and motivate patients, and how to customize assessments to the patient's needs. It also includes instructions to interpret results and create an atmosphere of shared decision making. The exact use and implementation of experience-sampling technology may vary depending on individual care processes and should be practiced in various populations and healthcare settings.

Introduction

Clinical practice has evolved over time, incorporating new scientific insights to improve treatment. Recognition of the importance of active patient involvement and a holistic, patient-centered approach challenges mental health professionals to adjust their care practices. Additionally, aspects of vulnerability as well as resilience and strengths take equal part in situational explorations[1–3]. This means that assessment is broadened to other health domains such as physical well-being, social participation, daily life functioning, personal recovery and quality of life[4,5]. Furthermore, this inclusion invites mental health professionals to defocus exclusive attention on symptom reduction and comprehensively grasp the realities of the individual's daily life functioning, including strengths and resilience (i.e., the ability to bounce back after stress)[6,7]. To improve patients' resilience, strategies are needed that increase their autonomy and empower them[8–10].

These strategies are not always self-evident and require new and creative techniques to engage patients and integrate relevant knowledge into the treatment process. Understanding mental health variation in the flow of daily life is needed to complement traditional clinical decision-making. Research has shown that information on contextualized symptom variability enriches the understanding of psychopathology at the individual level[11–13]. Mental health professionals often rely on clinical interviews or observations to learn how patients function in daily life. Insight into micro-experiences that occur on the momentary level (in-situ) are useful because they help to provide concrete examples of difficult situations and fuel the conversation on coping and intervention opportunities. However, standard diagnostic instruments offer insufficient detail to describe these in-situ contextualized experiences[11–13]. Generalization of the skills learned during therapy to the often unpredictable reality of everyday life remains challenging[2,11–14]. One possible strategy to increase transfer is to improve in situ assessments to better understand daily life challenges.

For in situ assessments, the technique of diaries is regularly incorporated as a strategy. Valuable information on subjective experiences can be gained when adherence is high. For example, highly detailed descriptions of panic occurrences and corresponding mood states would not be available without diaries[15]. However, this approach also has drawbacks. Often, patients forget to fill in paper diaries in the hectic of daily life. Sometimes, patients binge-complete the diaries right before a treatment session starts[16–18]. Retrospective

completion miss specificity due to memory biases and this increases with larger time gaps. Relevant situational information (e.g., circumstances of a conflict) is lost later on or is coloured by negative memories (as is often the case in depression)[18,19].

Recent technological advances in eHealth and mHealth help solve this problem. Smart devices can trigger questionnaires or send reminders at regular time intervals during the day. Most people use smartphones in normal daily routines. This makes them interesting tools for regular use in healthcare. Several mHealth technologies aim to monitor everyday life functioning holistically and fill the need for assessment instruments that are grounded in the biopsychosocial model[20]. Compared to other holistic electronic diaries that require retrospective completion at fixed moments in the day or week, the Experience Sampling Method (ESM) enables individuals to complete brief momentary assessments several times each day, for several weeks[21,22]. In ESM, beeps signal users at (random) moments to collect snapshots of mood, behavior, perception and cognition in context[21–23]. ESM provides an attractive rationale to collect information about the individual daily life experiences with high ecological validity. The brief momentary assessments do not rely on recollection. Memory biases and cognitive load (i.e., risk of overthinking) are minimal[15]. The collected samples reflect contextual variability in the flow of daily life and can be used to compile a detailed functional analysis (FA; see 'Theoretical background – functional analysis'). This information is important in treatment because it informs on the individual's needs emerging from everyday struggles, thereby ensuring better treatment generalization to this domain. Accounting for everyday variability will help align treatment strategies with real-life situations and possibly improve the long-term impact of care[24,25].

ESM is well studied and has support for its usefulness, feasibility and validity in mental healthcare[26–31]. However, implementation of these applications in routine clinical practice remains challenging. A recent redesign study on ESM use within family medicine revealed severe barriers related to the implementation of ESM as a functional analysis tool[32]. First, ESM is not self-evident and a proper introduction of the experience-sampling platform is necessary. Also, the discussion of the monitoring results requires more time than is available during standard patient consultations. Second, mental health professionals are typically trained to detect vulnerabilities reflected in cross-sectional diagnoses and lack the tools to use ESM including meaningful contextual variability in patient consultations to better understand the value of daily life variation as indicators of personal vulnerability as well as resilience.

Third, the current format of the web-based reporting tool relies on diagrams and graphs, and was difficult to understand intuitively. Although mental health professionals have a positive attitude towards eHealth and ESM use, they still struggle with the implementation because, in addition to some practical barriers, the 'how to' remains unclear[32]. This article provides practical guidance on the decision to use experience-sampling technology, how to introduce it and how to discuss the monitoring results during patient consultations. We first describe experience-sampling technology to support detailed functional analyses and then present clinical use cases to support mental health professionals implementing this approach in routine clinical practice. The article ends with recommendations to facilitate successful use.

Theoretical background – functional analysis

Gaining insight into what is going on in someone's life with respect to biological, psychological and social influences forms the starting point for care[20]. In a collaborative process, mental health professionals and patients work together to construct a 'film of daily life' that ideally reflects improvements in adaptive functioning as the therapy progresses. This process is iterative and therapeutic strategies are updated as new information accumulates or situations change. Functional analysis (FA), also known as (functional) behavioral analysis, behavioral assessment, behavioral case formulation, clinical case formulation or case conceptualization, can help to formulate hypotheses on potential causes and consequences of actual situations occurring from moment-to-moment[33–38]. A FA summarizes relevant elements and explores situational factors (pre and post) that maintain problem behavior, negative emotions or detrimental cognitions[39]. Assumptions are then formulated on the function of problem behavior (e.g., avoiding stressful situations reduces tension), the meaning of situations and events that precede or follow the problem behavior, and the functionality of this (problem) behavior in that meaningful context[39]. The same FA strategy can be used to describe resilience: under which circumstances do problems resolve. Positive and protective moments can be detected and analyzed. Optimally, this approach requires information across health domains, in context and in light of personal (life) goals[4–6,20].

By collating and analyzing repeated assessments (time series or 'micro-epochs'), patterns can emerge reflecting functional similarities or time related

courses (e.g., a fight in the morning with your partner evolves in feeling bad the whole morning, which results in more worrying thoughts). Classic diaries collected in home assignments in cognitive behavioral therapy (CBT) yield only a small set of narrative epochs and are often insufficient to formulate robust FAs. The resulting analyses are often deterministic: non-matching epochs falsify the hypotheses[39]. For instance, the mother seems to panic whenever her children are fighting. However, panic also occurs once when driving alone to the grocery shop, herewith falsifying the conclusion that panic is a result from the children fighting. In ESM data collection, typically dozens of epochs are available. The resulting FAs generate conclusions that are probabilistic (e.g., it occurs more often in this situation compared to that situation) and can be considered as dynamic, changing periodically over the course of treatment[39]. FAs through ESM seem robust and comprehensive, with longer monitoring periods reducing the risks of misinterpretations[29,40,41]. More detailed information can be found in Appendix 6.A.

Intervention – Experience Sampling Method (ESM)

The Experience Sampling Method (ESM) is a structured diary technique to assess individual's moment-to-moment subjective states – mood, cognition, behavior and perception – and relate these to the context (e.g., activities, location, presence of other people)[21]. Alternative terms for ESM are Ecological Momentary Assessment (EMA), ambulatory assessment, beeper studies and structured diary method[22,42–44]. A signaling device (e.g., watch, personal digital assistant, mobile phone) prompts the individual to respond to a short questionnaire at (semi-) random time moments each day. This prospective self-report method determines interpersonal (between-person) and intrapersonal (within-person) mental state variability[21,22]. The collected information can be analyzed statistically to unravel underlying patterns, for example, how social interaction is related to mood. An interactive feedback tool allows users to explore their data through graphs and diagrams. This can be done with raw (e.g., momentary anxiety or pain) or aggregated data (e.g., positive affect subscale or percentage of alone time by day).

The use of experience-sampling technology in real-world examples (use cases).

Three assumptions underlying successful ESM use in routine care are explained. Next, we share our experience with ESM in a step-by-step guide, describing relevant stages and recommendations to facilitate ESM use in routine care. Finally, the step-by-step guide is applied to two use cases to illustrate how a mental health professional can use an experience-sampling tool to formulate a detailed FA.

Assumptions underlying successful ESM use

The use of experience-sampling technology in routine clinical practice relies on three underlying assumptions. First, we believe that a thorough FA across different health domains (symptoms, (social) functioning and goal realization) improves the individual therapeutic process. ESM allows a comprehensive multi-domain assessment. Patients may struggle to understand how, for example, their mood, cognitive functioning, fatigue level and day-to-day activities relate to each other. Repeated momentary assessments provide the information needed to understand these patterns. The expertise of mental health professionals helps to direct attention to relevant underlying relations. Second, by using experience-sampling technology, a collaborative care process is facilitated. Mental health professionals and their patients can decide together on the use of ESM during their care process, the monitoring period, access to the data and interpretation of the monitoring results. Third, it is important that mental health professionals and their patients engage in this process on equal terms and speak the same language. Mental health professionals can use the teach-back method (i.e., paraphrasing summaries or asking patients to summarize) to detect ambiguities, and check whether both understand each other[45].

Step-by-step guide

Table 6.1 provides an overview of the relevant stages and recommendations to use experience-sampling technology to support detailed functional analyses in routine clinical practice.

Determine suitability

Most people, irrespective of their sociodemographic profile (e.g., age, education) can use ESM. The method has successfully been applied across patient populations, in different age ranges and with patients suffering from severe mental health complaints[46–50]. Given that mHealth applications might not suite everyone, it is challenging to predict who will gain from the methodology or who will reject its use. Mental health professionals should, therefore, discuss the use of a smartphone and smartphone applications with the patient and make the implementation in treatment a shared decision. The patient should be able to understand the language of the questionnaires, hear the signal and be willing to respond.

Decision to use the ESM tool

Before mental health professionals introduce innovative tools to their patients, it is recommended that they use and test these tools themselves. Familiarization with the ESM tool and procedure is important to know how and when the tool can be used to support detailed FAs, how to interpret the monitoring results and how to avoid technological problems. Moreover, it allows the mental health professional to function as a role model, thereby acquiring hands-on expertise to help patients with their data collection. In addition to using experience-sampling technology to support detailed FAs, as described here, it can also be used: (1) as a prevention tool, (2) as an intervention, (3) to evaluate therapy and medication, and (4) to strengthen recovery by focusing on strengths and resilience[40,41,51]. However, an experience-sampling tool works best when patients are motivated and have a rationale to use it (e.g., getting insight into the underlying mechanisms and patterns of anxiety symptoms).

Introduction of the ESM tool

Apps to collect ESM data seem self-evident and have a high transparency (face value). However, experience teaches us that mental health professionals should extensively brief patients; explain the rationale and added value of using ESM, and align with the patient's symptoms and care process to enhance engagement. It is important to stress that data management procedures are privacy-proofed and that ESM is used to gain personal insight into the underlying mechanisms of vulnerability and resilience. Collecting sampled mood states under different conditions (e.g., at home, while outdoors, engaged

in work or alone) helps to better understand functional variation. Furthermore, mental health professionals should explain how the data will be presented after a monitoring period.

After explaining the general purpose of ESM, hands-on instruction of the technology itself can start. The experience-sampling application (here we used the PsyMate™ available in the Apple App Store and Google Play Store, see Appendix 6.B) is installed on the patients' smartphone; the user registers on the platform and becomes familiarized with the tool and the procedures. The functions of the home screen buttons are demonstrated and a practice questionnaire completed. It is useful that patients receive instructions about the ESM assessment period (e.g., monitoring between two consecutive consultations) to ensure they know what to expect and to maximize motivation. Typically, ESM monitoring lasts for at least one week (to ensure sufficient data for meaningful explorations), but it is important that patients are aware that collecting more reports or micro-epochs improves the quality of the analyses. When only two or three assessments are available under specific circumstances, conclusions will be less nuanced and potentially biased. More assessments, collected in a broad range of environments, will improve comprehensive conclusions. A good rule to follow is to customize monitoring periods based on purpose and experienced relevance for the patient. Patients may perceive ESM as burdensome and disruptive due to repeated interruption of the daily routine by the signal[21,44]. Burden is less problematic when digital technology facilitates the process and provides unexpected insights with personal meaning. It may help to plan repeated monitoring episodes on key periods during treatment. ESM data is comprehensive, covering relevant clinical outcome domains (e.g., general wellbeing, stress, sleep) and sensitive to change. It can be used as routine outcome measurement in regular care at admission and, for instance, three months later[52]. Experience teaches us that an iterative process starting for two weeks at the start of treatment (the initial assessment of possible mechanisms) and repeated each month (to evaluate effectiveness and update intervention strategies), resuming at the end of the treatment (as a formal outcome evaluation or to strengthen long-term health benefits) ideally supports an empirically-informed customized individual treatment.

Use of the ESM tool

Patients need to remain motivated to complete sufficient moments for meaningful explorations. It is important that mental health professionals

encourage patients also to report in busy environments, at work or school, during sports or while talking to others. When patients are self-conscious or uncomfortable to complete questionnaires about their current mental state in company of others, herewith potentially disclosing they have a mental problem, they could for example learn to reply they are participating in a research project. They can practice this response in a role-play exercise.

Discussion of the ESM results to support functional analyses

The aims of the discussion of the ESM results are: 1) to understand the context of vulnerabilities and resilience, and 2) to decide upon strategies for change. Mental health professionals invite the patient in a mutual session to understand the data (collaborative empiricism). Pre-existing hypotheses can be leading. The exploration of the results often starts with investigating time budgets (e.g., with whom do they spend most of the time?) or by looking at the most salient individual mood items (e.g., cheerful or down). Next, they explore contextual variability by combining mental state with context (e.g., are they worrying more when alone?).

The patient owns the data and can decide with whom to share. This can be their clinician, but other persons such as family or peer workers can also be invited. In addition, patients bring in the personal expertise about their daily life. This is valuable to interpret the results and select person-centered strategies for change.

Mental health professionals and their patients need to be aware of the correlational / probabilistic nature of the data. At best, ESM data leads to hypotheses on what is going on (functional analyses). A hypothesis (e.g., meditation reduces rumination and improves sleep) can be used to formulate a behavior exercise. Its effect can be tested in real-life during a new monitoring period. The process of repeated hypotheses and interventions can disclose underlying mechanisms and patterns that provide clues for improving personal health.

Table 6.1 Step-by-step guide for applying ESM in routine clinical practice.

Determine suitability	• Check if the patient is in possession of a smartphone and sufficiently able to handle the ESM technology (if in doubt, discuss it with the patient) • The patient should understand the language of the questionnaires, hear the signal and be willing to respond (irrespective of sociodemographic profile)
Decision to use the ESM tool	• Familiarize yourself with the tool and procedure • ESM technology can also be used (in addition to supporting detailed functional analyses), for: (1) prevention, (2) intervention, (3) evaluation, and (4) recovery • Take into account the patient's goal (e.g., getting insight into the underlying mechanisms of anxiety symptoms)
Introduction of the ESM tool	• Explain the rationale, added value and functioning of the tool • Download the tool in your consulting room and help the patient to register for the platform • Reassure that the patient gets familiarized with the tool and the procedure • Discuss with the patient the assessment period (at least one week with sufficient assessment frequency, e.g., eight assessments a day) • Adjust the assessment period according to its purpose and experienced relevance of the patient
Use of the ESM tool	Encourage patients also to monitor in busy environments and during challenging moments
Discussion of the ESM results to support functional analyses	• Ask for the patient's experiences with the tool • Discuss the results together with the patient in the following order: 1) patient's expectations, 2) exploration of the context; mood per day and per moment; and mood in relation to context, 3) zoom in on specific hypotheses • Engage the patient in making sense of the ESM results, while being conscious about the correlational, probabilistic nature of the data • If applicable, formulate new hypotheses to test with a follow-up monitoring period in daily life

Patient A: anxiety problems

Background

Patient A, a 62-year-old woman, suffers from intense anxiety symptoms and worries about her competences and skills as a mother, partner, friend, employee and colleague. She is afraid of failing as a mother and in her job. She experiences palpitations, tightness of the chest, dizziness and nausea. Furthermore, her symptoms include restlessness, irritability, loss of concentration and muscle problems. The feeling that she is losing control of

herself dominates her daily life. She experiences intense stress and feels that she will collapse if only one more stressor would occur.

Determine suitability

Before deciding whether ESM might be feasible for this patient, the mental health professional asked whether she owns a smartphone and uses (or is open to use) smartphone applications in her daily routine. This was no problem and the patient downloaded the smartphone application.

Decision to use the ESM tool

The mental health professional decided to introduce the PsyMate™, one of the available ESM tools, to help the patient gain insight into the circumstances of high anxiety and stress (for an example of the beep, morning and evening questionnaires, see Appendix 6.C). Resilience could be assessed by looking for circumstances in which the patient was feeling well and free of anxiety or stress. Further considerations were that the frequency and strength of her symptoms could be explored. In addition, ESM could be used as an intervention; the patient could learn to stay in control and manage her symptoms. Prospective assessment periods could refine the treatment.

Introduction of the ESM tool

The mental health professional demonstrated the rationale and added value of the tool by explaining that the patient would gain insight into what she feels, thinks, perceives and does throughout the day. She was instructed to stick to her own routine. The mental health professional explained the functioning of the tool (e.g., number of beeps, beep frequency, reminders). The patient was coached to download the tool while in the consultation room and the mental health professional helped the patient to register (i.e., request anonymous credentials by e-mail address and register in a protocol). The mental health professional reassured the patient the procedure is privacy-proofed and data confidentiality is guaranteed. After the download and registration, the patient completed practice questionnaires. She asked questions about the procedure and to clarify the content of specific items. Finally, they decided on the assessment period. They agreed to monitor between consecutive consultations, resulting in a two-week monitoring period. The mental health professional encouraged her to complete as much questionnaires as possible without adjusting her daily routines and to monitor also when feeling well.

Use of the ESM tool

The patient used the ESM tool in-between consultations and completed at least eight questionnaires per day.

Discussion of the ESM results to support functional analyses

During the next consultation, the mental health professional and patient discussed the results to better understand when and why anxiety occurs (detailed functional analyses and hypotheses formulation phase). The smartphone application was easy to use, however, she got frustrated by some items that always resulted in the same score. She reported seeing improvement in some items while looking at the web-based reporting tool (exploring experiences with the ESM tool). When they looked at the time budgets (see Figure 6.1), they discovered that she spent most time with her partner and one third of her time was leisure time. This provided a starting point for possible intervention opportunities.

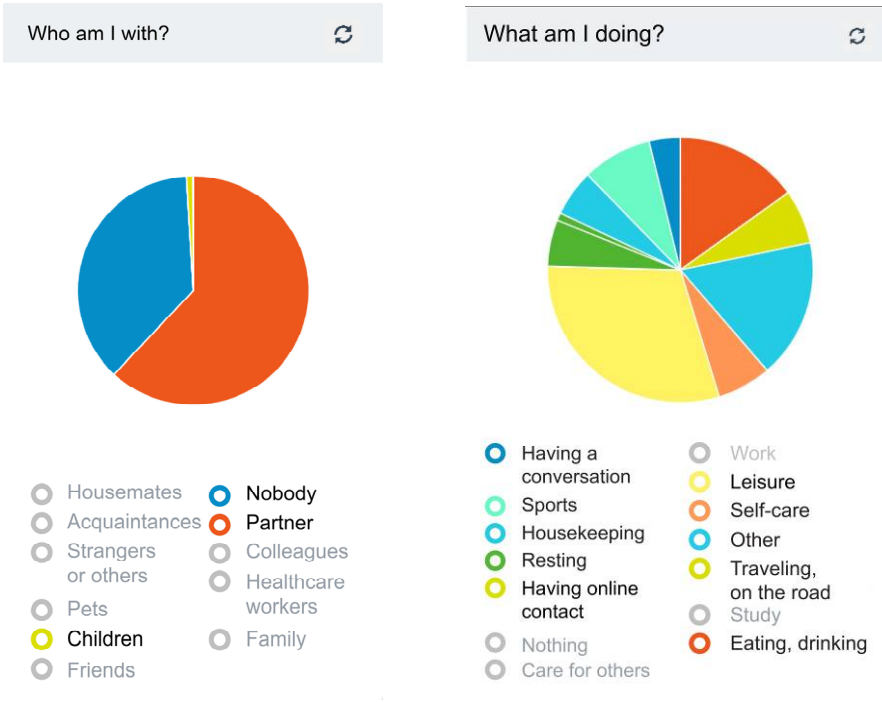


Figure 6.1 An example of the web-based reporting tool displaying the time budgets (e.g., persons present and activities).

Furthermore, the patient wanted to look at two specific items: anxiety and worrying. The graph showed that she worried more in the morning and the afternoon (see Figure 6.2). Anxiety was not related to worrying. She also found that she was less able to concentrate when worrying. According to the patient, this seems intuitive, but it was revealing to see it confirmed in the data. Although she had worrying thoughts and experienced anxiety symptoms, she felt quite satisfied overall.

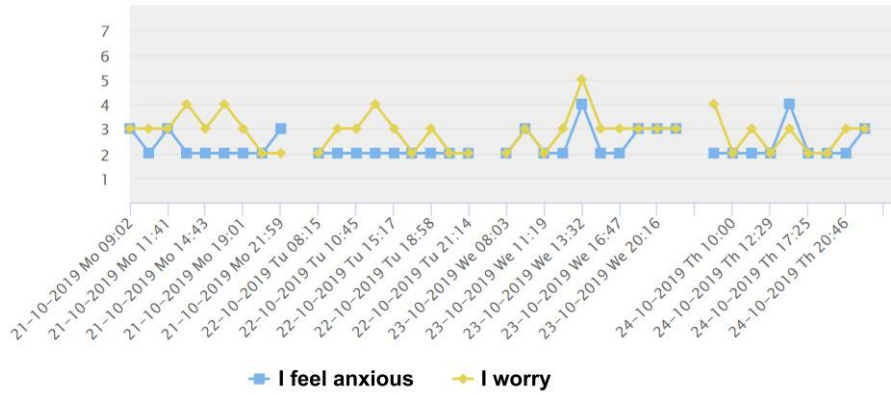


Figure 6.2 An example of the web-based reporting tool displaying the individual items anxiety and worrying.

In addition, the mental health professional and the patient further explored the contextual relation of these individual mood items. They figured out that she worried more at home, probably due to being alone (something she recognized). She worried less being outside, because she experienced more distraction and could focus externally while relaxing (see Figure 6.3).

By using the experience-sampling tool, both the patient and mental health professional got a confirmation of their hypotheses. However, only now it is clear to the patient how much she suffers on her own and how important being outside is to her. She is now going to take steps in her own recovery process. She will visit her friends and colleagues more often, and undertake more outside activities. In addition, they decided to keep using this self-monitoring tool.

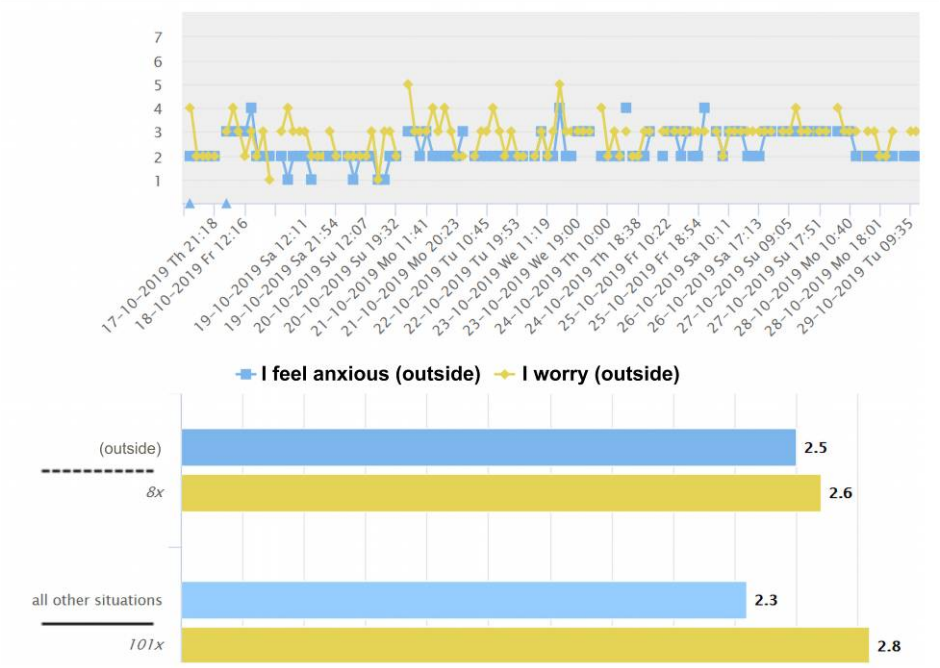


Figure 6.3 An example of the web-based reporting tool depicting the combination between the individual mood items anxiety and worrying, and location, as context variable.

Patient B: sleeping problems

Background

Patient B, a 28-year-old woman, complains of poor sleep in the past six months: lying awake for hours, waking up several times each night and waking up too early in the morning. Consequently, she is tired during most of the day. The patient's sleeping problems started during a stressful period at work in combination with taking care of two young children. She also suffers from worrying thoughts and panic attacks related to her family situation. Her biggest fear is not being able to adequately care for her children due to her fatigue. Threats to drop out at work or to fail caring properly for her children signaled her to consult a mental health professional: enough is enough!

Determine suitability

The mental health professional assumed that this patient had sufficient smartphone skills according to her age. Nevertheless, the mental health professional checked if she possessed a smartphone and was able to use smartphone applications. The patient confirmed this and the mental health professional did not have to assist her with downloading the smartphone application.

Decision to use the ESM tool

The patient wanted to better understand her sleeping problems, what provides or drains her energy during the day and how to gain more control of her life. These questions triggered the decision to introduce an experience-sampling tool, here the PsyMate™, and apply it as a diagnostic tool (detailed functional analyses).

Introduction of the ESM tool

The patient already kept a paper diary, but this provided limited insight. The relation between her symptoms and the circumstances in which they occur remained unclear and lacked detail because only end-of-day recall assessments were available. Therefore, the patient was invited to keep a prospective, structured, digital diary to record her sleep quantity and -quality, and feelings throughout the day. The mental health professional described the functioning of the smartphone application while the patient downloaded it. The mental health professional checked the correct registration procedure. Afterwards, the patient completed the practice questionnaires and asked clarification to ensure that she understood the procedure. Subsequently, the mental health professional and the patient agreed on a one-week monitoring period.

Use of the ESM tool

In practice, the patient used the ESM tool for the whole two-week period between consecutive consultations. In the first week, she completed at least seven assessments per day. This decreased towards the last three days of the monitoring period.

Discussion of the ESM results to support functional analyses

During the next consultation, the mental health professional invited the patient to look at the results, and explore the causes and sustaining factors of her sleeping problems. Before discussing the results, they evaluated the patient's ESM experiences. The smartphone application was fun and simple. Nevertheless, she experienced some burden in completing the questionnaires towards the end of the second week. Next, the mental health professional asked the patient what she was curious about. They started looking at how much time she spent at work and alone (see Figure 6.4). She spent most time with her partner and children, and at home, while she spent 20 per cent of her time both at work and alone.

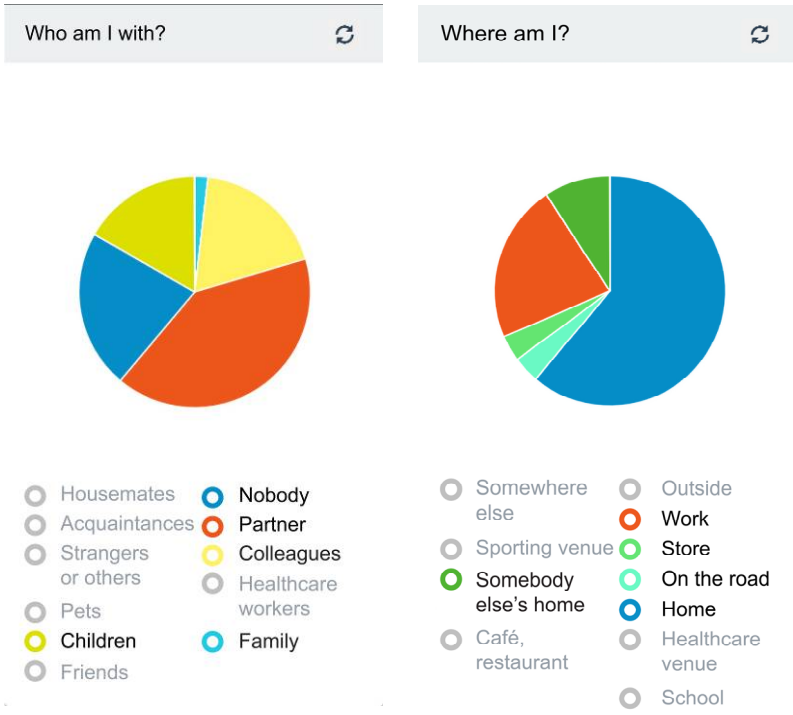


Figure 6.4 An example of the web-based reporting tool displaying the time budgets (e.g., persons present and location).

Then, they assessed the aggregated constructs of positive (i.e., cheerful, relaxed, satisfied, energetic) and negative (i.e., insecure, irritated, down, anxious, lonely) affect. She experienced more negative and less positive affect

at the beginning of the day and at the end of the working hours. This appeared to be due to the anticipation of stressful moments with two young children (see Figure 6.5). They unraveled that she felt insecure and anxious about not being a good mother and partner during these moments.

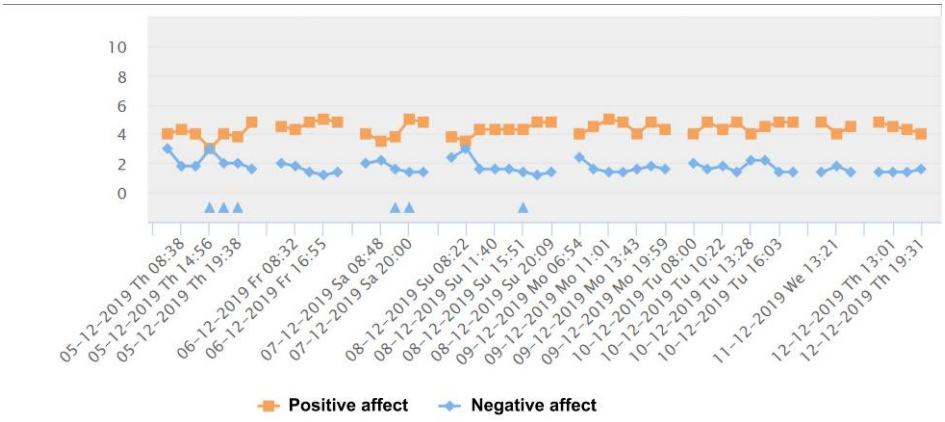


Figure 6.5 An example of the web-based reporting tool displaying the aggregated constructs of positive (i.e., cheerful, relaxed, satisfied, energetic) and negative (i.e., insecure, irritated, down, anxious, lonely) affect.

Eventually, they combined worrying with being alone and being at work. When she was alone, she worried more than in other situations (see Figure 6.6). The patient explained that distraction protects against worrying. In contrast, when she was at work, she worried less because she could focus on her work and her colleagues.

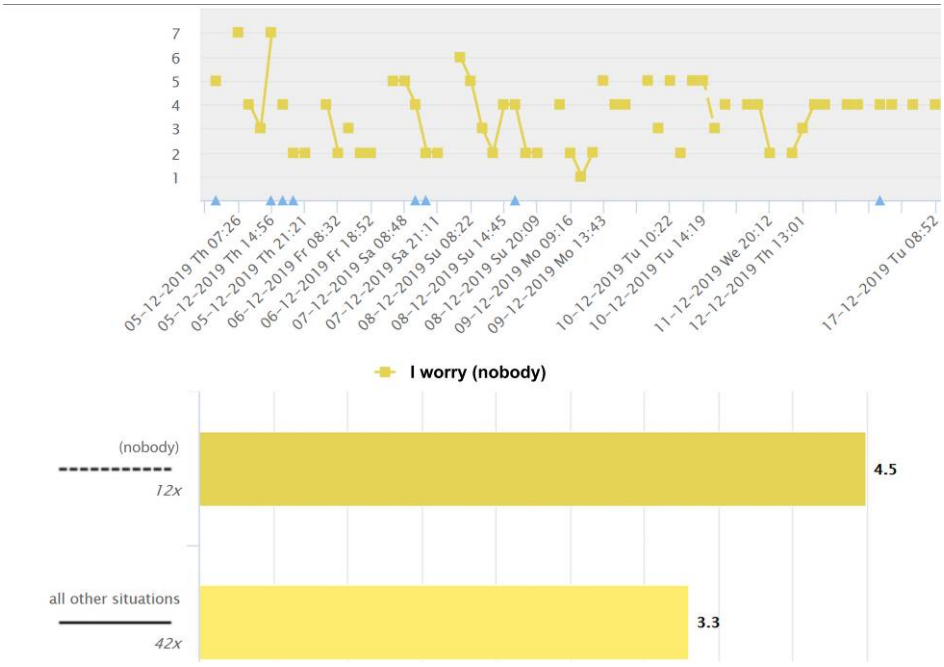


Figure 6.6 An example of the web-based reporting tool depicting the combination between the individual mood items worrying, and persons present, as context variable.

She also wanted to assess the feeling of being satisfied about her day and sleep quantity (see Figure 6.7). They discovered that sleep quantity did not influence her daily life functioning. Furthermore, they found out that she slept less than four hours one third of the days, which was shocking to her.

Consequently, they decided to focus on the sleeping circumstances, which seemed to be influenced by rumination during the day. Something that was not discovered with a less holistic approach. Additionally, they agreed to use the experience-sampling technology as an intervention tool for another two-week period and at the same time fill in a scheme about the antecedents, thoughts, feelings and behavior, including the pros and cons for her thoughts.

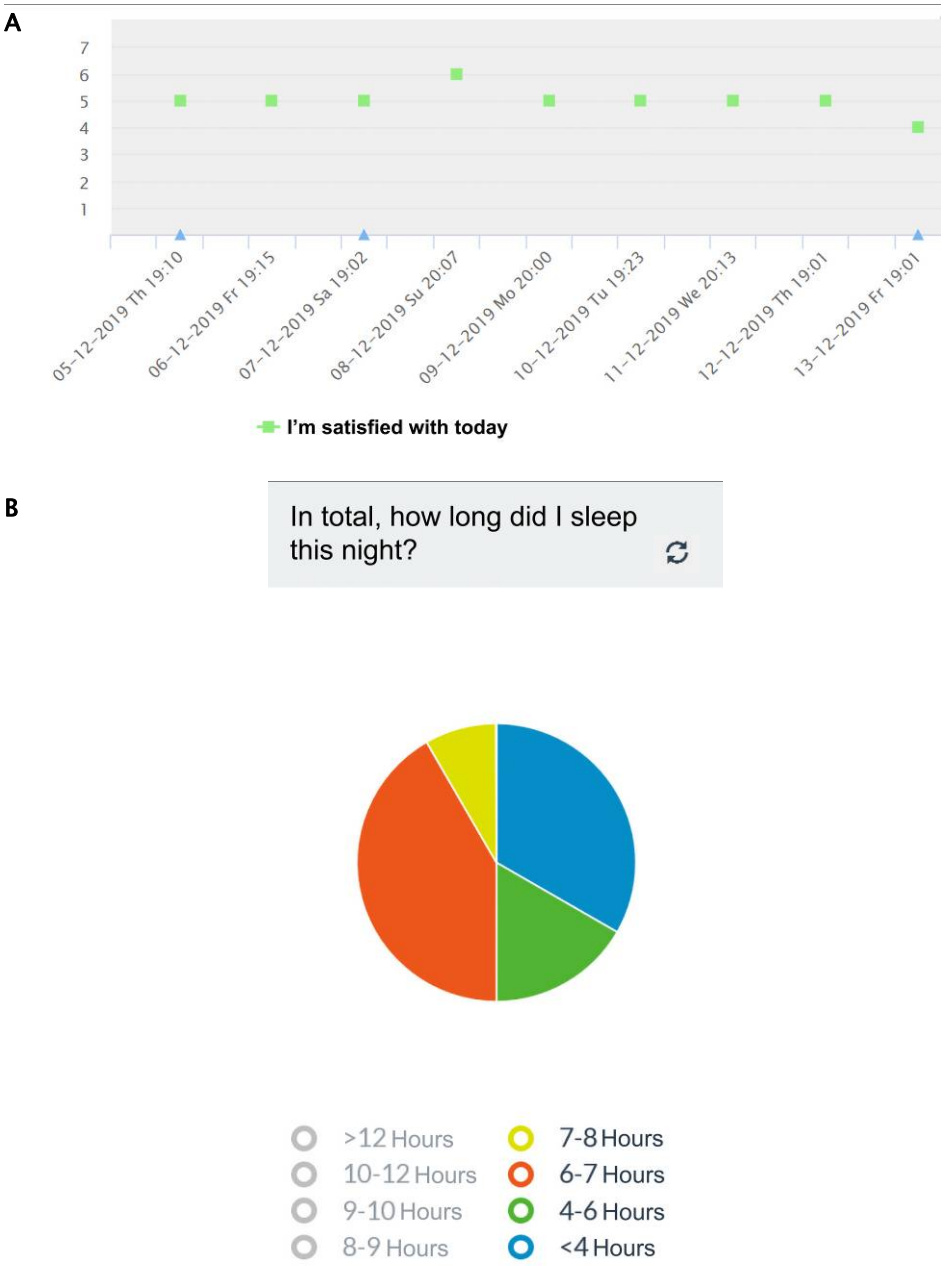


Figure 6.7 An example of the web-based reporting tool depicting the individual item being satisfied about her day, and sleep quantity (i.e., number of hours slept).

Discussion

With the increase of mental health problems worldwide and the rise of daily stressors due to outside events (as the COVID-19 pandemic makes painfully clear), it is crucial to invest in intervention strategies that are sustainable at low cost[53,54]. Equally important and highly required are improvements in intervention efficacy. Allowing the daily life domain to become a visible and tangible part of care is a promising strategy. Wellbeing benefits are achieved through multiple pathways, not by symptom reduction alone[1,3,20]. Reducing loneliness and finding a purpose in life are often as important in recovery from depression as adjusting brain circuits through pharmacotherapy or addressing cognitive behavior patterns through psychotherapy[8,55–57]. Using a combined approach optimizes the chance for successful recovery[5,20,56]. ESM is ideally suited as an ecological, person-centered approach that empowers patients to take an active lead in their own recovery process[28,40,58]. This step-by-step guide describes how to use this technology for detailed functional analyses (FAs) in routine clinical practice.

Clinical implementation does not follow strict rules (allowing flexibility) although the proposed recommendations in this paper provide guidance to improve practice. Correspondingly, FAs are meant to enrich and complement regular care processes, and are not intended as a stand-alone treatment. These processes help to formulate hypotheses about the context of mental suffering (symptom exacerbation), but also describe moments of symptom relief. Although standard assessments often focus on symptom occurrence, adequate description of contextual variability helps to understand the bandwidth of emotions, cognition, perception and behavior, and why they vary over time. The domains included in the assessment of the individual's daily life are broad and comprehensive, and cannot be covered with a single cross-sectional instrument without it becoming to lengthy or burdensome. High frequency sampling of the person's daily life provides the necessary input with minimal effort. Although experience sampling might seem burdensome (especially with assessments eight to ten times a day), evidence supports its feasibility when short ESM questionnaires are used and the purpose is meaningful to patients[40,41,59,60]. High frequency sampling enables participants to quasi-naturally come into the flow of daily life data collection, thereby minimalizing the mental effort needed for data completion[61].

The use of ESM to support detailed FAs is possible in a variety of settings (e.g., outpatient, at the general practitioner's office, in specialist mental

healthcare institutions, in hospitals). One example of its individual merit comes from a patient perspective, were a person took the initiative to monitor her recovery of depression over the course of two years. It helped her fine-tune daily routines to relieve symptoms and increase wellbeing[29]. This example occurred naturally, outside regular care. The application of ESM is not limited to mental health as ESM questionnaires tend to include information that is relevant across different health domains, thereby being transdiagnostic and applicable in somatic healthcare as well[40]. The possibility to add additional (more personalized) items helps to tailor the information to specific needs. It facilitates a broad applicability in patients with psychological, psychosocial and/or physical problems even more. The exact use and implementation of the recommendations, however, need to be further tested in and tailored to these target populations.

Although mHealth applications have benefits, it is important to acknowledge that these tools are not feasible in every situation for every patient. Personal restrictions (e.g., poor eyesight or motor control), work place regulations or patient preferences (as with all interventions) should be considered. Additional barriers and facilitators for the implementation of such innovative tools exist at all levels (e.g., intervention, organizational culture and implementation climate, external policies and incentives, end-users, implementation process)[62,63]. For routine implementation, it is important to be aware of the required skills and knowledge of the healthcare professional as well as their beliefs about the added value of the ESM tool. Other lessons-learned are the importance of providing both theoretical and practical training, thereby demonstrating how the data can be meaningful in treatment, next to ascertain that the healthcare professional has sufficient time and resources to use the tool[32,63].

Taking the abovementioned issues into consideration, specialized nurses, doctor's assistants, social workers, physiotherapists and other health professionals involved in formulating functional analyses collaboratively with their patients can use this step-by-step guide to apply experience-sampling technology in routine care. It can especially be useful for less experienced or novice healthcare professionals. Experienced healthcare professionals can also use this guide to evaluate their approach or adopt the recommendations to embed ESM more successfully in their work processes.

Conclusion

This practical guide provides hands-on instructions and recommendations to embed experience-sampling technology in routine clinical practice. It is important to focus on a collaborative care process while determining who is suitable for the method, deciding to use the technology, introducing the tool, guiding the patient through the exploration process, and discussing the monitoring results. The key recommendation is to include the patient in all phases of the process: in determining suitability, in formulating a clear focus related to the patient's needs and care process, by involving them in formulating hypotheses and in choosing behavioral experiments and change opportunities. During the exploration process, one should be cautious about the interpretation of the results. The exact use and implementation of these recommendations should be tested in various target populations and healthcare settings. Tailoring to the users' needs and skills remains important. Future research should focus on user experiences and the implementation process.

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Appendix 6.A

Sometimes terms for macro- (lifetime perspective) and micro-analysis (momentary perspective) are used interchangeably. We believe that it helps to differentiate between a holistic theory on the macro-level (i.e., why do I have this kind of problems in my life, given my genes, upbringing and learning history) and a functional analysis on the micro-level that tries to understand why problems occur, remain unchanged or exacerbate in daily life[39]. For example, someone becomes an anxious and overly concerned mother due to genetic make-up and life experiences (lifetime perspective). When she presents for treatment, she reports feeling guilty about repeatedly punishing her children harshly, while paradoxically, their disruptive behavior escalates (momentary perspective).

Appendix 6.B

Several experience-sampling tools are available (e.g., RoQua, m-Path, movisensXS, PsyMate™). The PsyMate™ Suite is a set of mHealth tools consisting of a freely available smartphone application for Android and iOS, a cloud-based data management system and an individual web-based reporting tool (www.psymate.eu). The PsyMate™ Suite is intended as a generic development platform with different purposes: monitoring of behavior, mood variability and context; detailed functional analysis; and self-management tools applied in the individual's daily life. The PsyMate™ is grounded in the principles of the Experience Sampling Method (ESM), collecting moment-to-moment assessments during daily life. The data are collected in response to (semi-) random beep signals indicating individuals typically eight to ten times a day during waking hours of a normal day to fill out short self-report questionnaires (beep questionnaires; max. 2 minutes per beep). The beep questionnaires only remain available for a short time period. The beep questionnaire consists of items assessing mood (e.g., cheerful, insecure and relaxed), physical status (e.g., hunger, pain and tiredness) and context (e.g., current activity, location and company). The mood and physical status items are assessed with 7-point Likert scales ranging from not at all (1) to very much (7). The context items are assessed categorically. In addition to the beep questionnaire, users are asked to fill out a morning and evening questionnaire, respectively measuring sleep quality and sleep duration, and appraisal of the day. The team at Maastricht University developed an interactive feedback tool (i.e., web-based reporting tool) to allow users to explore their data through graphs and diagrams. In this way, it allows to see patterns in mood, behavior or the relation between mood and behavior in their daily life (a detailed functional analysis).

Appendix 6.C

Table 6.C. An example of the beep, morning and evening questionnaires.

Beep questionnaire	
Item	**7-point Likert scale or categorical options**
I feel cheerful	1 = not at all, 4 = moderate, 7 = very
I feel insecure	1 = not at all, 4 = moderate, 7 = very
I feel relaxed	1 = not at all, 4 = moderate, 7 = very
I feel irritated	1 = not at all, 4 = moderate, 7 = very
I feel satisfied	1 = not at all, 4 = moderate, 7 = very
I feel down	1 = not at all, 4 = moderate, 7 = very
I feel energetic	1 = not at all, 4 = moderate, 7 = very
I feel anxious	1 = not at all, 4 = moderate, 7 = very
I feel happy	1 = not at all, 4 = moderate, 7 = very
I feel lonely	1 = not at all, 4 = moderate, 7 = very
I am concentrated	1 = not at all, 4 = moderate, 7 = very
I worry	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question 1	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question 2	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question 3	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question 4	1 = not at all, 4 = moderate, 7 = very
Optional additional personal question 5	1 = not at all, 4 = moderate, 7 = very
Who am I with?	Select: partner, children, family, housemates, pets, friends, colleagues, healthcare workers, acquaintances, strangers or others, nobody
I like this social situation	1 = not at all, 4 = moderate, 7 = very
What am I doing?	Select: work, study, housekeeping, self-care, care for others, eating / drinking, travelling / on the road, having a conversation, having online contact, sports, leisure, resting, other, nothing
I would rather be doing something else	1 = not at all, 4 = moderate, 7 = very
I am active	1 = not at all, 4 = moderate, 7 = very
Where am I?	Select: work, school, home, somebody else's home, store, café / restaurant, sporting venue, healthcare venue, on the road, outside, somewhere else
I am hungry	1 = not at all, 4 = moderate, 7 = very
I am tired	1 = not at all, 4 = moderate, 7 = very
I am in pain	1 = not at all, 4 = moderate, 7 = very
I generally feel well	1 = not at all, 4 = moderate, 7 = very
Since the last beep I used	Select: alcohol, medication, coffee / caffeine, smoking / nicotine, cannabis, energy drink, other substances, nothing
This beep disturbed me	1 = not at all, 4 = moderate, 7 = very
Thank you!	

Morning questionnaire	
Item	**7-point Likert scale or categorical options**
How long did it take before I fell asleep last night?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
In total, how long did I sleep this night?	Select: < 4 hours, 4 – 6 hours, 6 – 7 hours, 7 – 8 hours, 8 – 9 hours, 9 – 10 hours, 10 – 12 hours, > 12 hours
How often did I wake up last night?	Select: 0, 1, 2, 3, 4, 5, > 5
How long did I lie awake this morning before getting up?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
I slept well	1 = not at all 4 = moderate 7 = very much
I am looking forward to today	1 = not at all, 4 = moderate, 7 = very
Thank you!	
Evening questionnaire	
Item	**7-point Likert scale or categorical options**
I am satisfied with today	1 = not at all 4 = moderate 7 = very much
I felt accepted today	1 = not at all 4 = moderate 7 = very much
Today was a normal day	1 = not at all 4 = moderate 7 = very much
I felt good about myself	1 = not at all 4 = moderate 7 = very much
Goodnight!	

Chapter 7

The use of an experience-sampling platform to support problem explorations for patients with anxiety or sleeping problems in family medicine – An action research design

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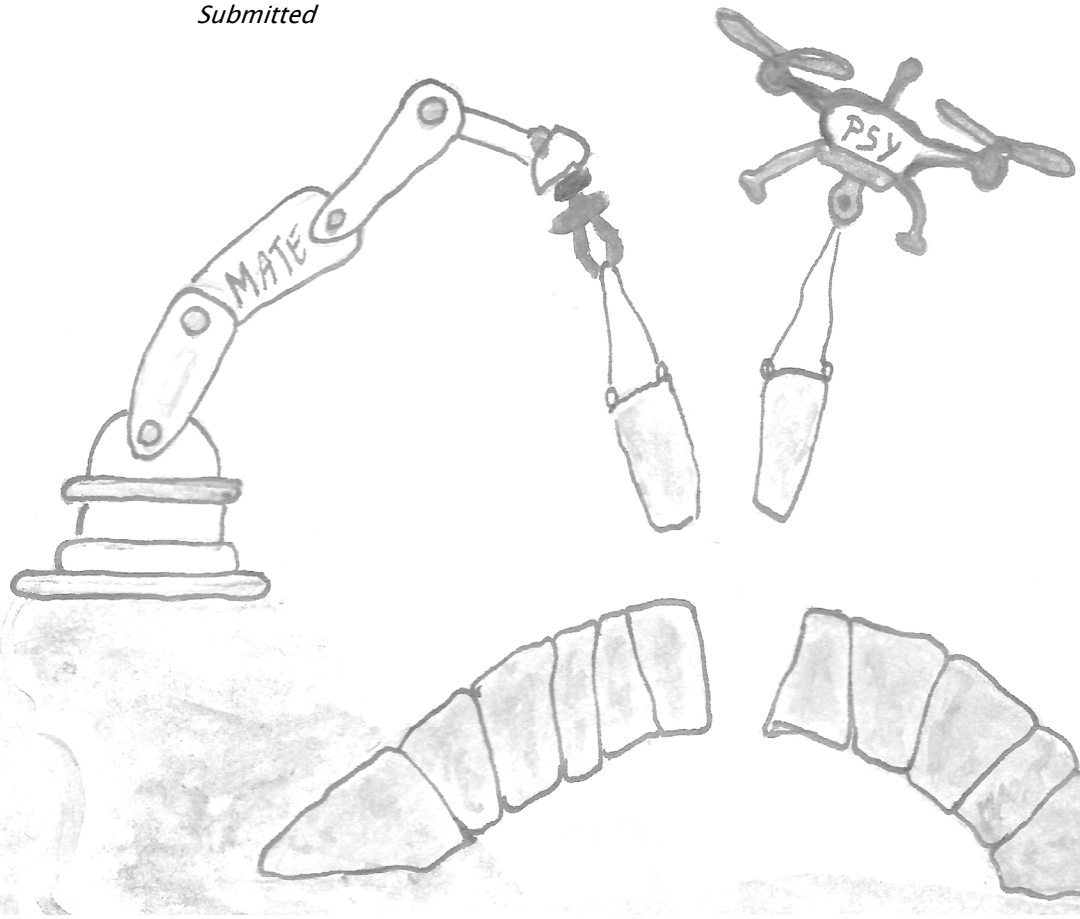
Submitted



Abstract

Background

Current treatment of mental health problems remains challenging. Next to understanding symptom dynamics, we need insight into resilience in daily life. mHealth tools using the Experience Sampling Method (ESM) might provide a solution. ESM is extensively studied in mental health research, but not in family medicine.

Objectives

To discover how psychological assistants (PAs) can use ESM to support problem explorations for patients with anxiety or sleeping problems and to learn about their experiences with using this technology.

Methods

An action research design was used to give PAs and patients the opportunity to experience and learn about how and when they can use ESM. A draft program was developed, based on a needs assessment, and iteratively tested and evaluated by PAs. Data were collected using observations, interviews, patient records and a logbook, and analysed with directed content analysis.

Results

Two PAs were unable to integrate ESM in their work processes. PAs indicated that patient instructions, tailoring the ESM results discussion to the patients' needs and interpreting these results collaboratively helped to integrate the tool into regular practice. Continuous support by the research team was needed to achieve sufficient depth. The added value was increasing awareness about the context of varying vulnerabilities. This provided starting points for treatment.

Conclusion

The iterative action research allowed PAs to learn, but integration remained difficult. When successful, ESM use yielded meaningful insights into personalized vulnerabilities and strengths in varying situations. The ESM tool needs fine-tuning to better fit patients' care processes and PAs' work processes.

Introduction

Worldwide, the prevalence of mental health problems, including anxiety and sleeping problems, in the family medicine population ranges between 20 and 55 per cent[1–8]. Mental disorders cover seven percent of the global disease burden[9]. People with anxiety and sleeping problems experience reduced daily life functioning in different contexts (e.g., at work, at home). They have, for example, trouble concentrating, remembering, and performing daily activities which cause a significant disease burden, as measured in disability-adjusted life years. Despite frequent consultations in family medicine and specialist mental healthcare, current treatment of mental health problems remains challenging. Almost half of the patients with mental health problems relapse within the first year after treatment[10–12].

To prevent this relapse, scholars propose also to focus on other health domains like physical well-being, social participation, personal recovery and quality of life[13–15]. These domains are part of daily life functioning which gains importance in routine clinical care[13,16]. The shifted focus reflects a transition from illness to well-being[13–15]. This requires the development of other assessment strategies. Traditional tools focus on symptom occurrence and need to be supplemented with assessments of the individual's strengths and resilience[13–15,17,18].

Clinical interviews or observations are the strategies of choice in mental health assessment. They provide an integrated summary of risk or symptom occurrence. These snapshots offer insufficient insight into the daily fluctuations in the patients' mood, cognition, perceptions, and behaviour. Consequently, intervention planning is based on inadequate data about the patients' daily life function dynamics[19–21]. Also, patients experience difficulties in generalizing the skills learned during treatment to their daily life. In summary, to improve assessment and treatment, new strategies are required that focus on daily life functioning in different health domains. These strategies collect repeated contextualized data that reflect vulnerable as well as strength moments into the diagnostic process, and help develop treatments that increase the individual's resilience[17]. This provides new opportunities for personalised treatment[22].

Compared to traditional assessments, diaries are an improvement because individuals reflect on their feelings, thoughts, perceptions, and behaviour repeatedly at regular time intervals. The reporting process therefore is prospective. Diaries provide some insight into symptom variability and contextual variation, but individuals often experience summarizing periods (e.g.

a day) as burdensome or forget to complete them[23,24]. Retrospective completion of a large number of reports (so-called parking lot reporting) lacks specificity due to memory biases and recall problems[24,25].

As an alternative, the Experience Sampling Method (ESM) – or Ecological Momentary Assessment – is a structured diary technique in which individuals are asked to complete short, momentary self-reports of feelings, thoughts, experiences and behaviour in the context of their daily life[26,27]. A signalling device (e.g., watch, personal digital assistant, mobile phone) reminds the individual to record their mental state on questionnaires presented at (semi-)random moments within the day, several days a week for several weeks[26,27]. The questionnaire can be fully tailored. ESM allows the study of fluctuations in the individual's subjective experiences (intrapersonal or within-person variability) in the flow of daily life. The procedure is intensive and reactivity can occur due to repeated measurements[28].

Although the feasibility, usability and effectiveness of ESM have been demonstrated in mental health research, across various patient populations and age ranges, studies assessing the use of ESM in daily clinical practice, in general and family medicine in particular, are lacking[29–33]. Previous research demonstrated that several barriers and facilitators influence embedding ESM in routine clinical care. These are related to design aspects[34–37], end users' characteristics[35,36,38,39], and training and instructions for both patients and healthcare professionals[35–37].

A first pilot study, conducted in doctors' practices in the Netherlands, provided insight into bottlenecks that psychological assistants (PAs) experience when embedding ESM in family medicine: (1) only limited time per patient available for consultation, insufficient to adequately introduce the tool and discuss the monitoring results, (2) the PAs had insufficient knowledge and skills to select the target population, introduce the ESM tool and discuss the results, and (3) results presented in the format of the web-based reporting tool were difficult to understand[40]. Consequently, the PAs barely used the ESM tool and were unable to acquire sufficient experience to assess the added value of the tool[40]. As a result, it is unclear how ESM can fit into and improve the work processes of the PAs in family medicine. The aim of the current study was to discover how a specific ESM platform, the PsyMate™, can be embedded as an mHealth tool to support problem explorations for patients with anxiety or sleeping problems in family medicine. Experiences of the PAs and their patients in relation to the PsyMate™ platform were assessed. To solve limitations from the pre-assessments, PAs were trained theoretically and practically and

provided with extra consultation time to introduce the ESM tool and discuss the monitoring results.

We formulated the following research questions:

1) How is the PsyMate™ used as an mHealth tool to support problem explorations for patients with anxiety or sleeping problems who are seen by a psychological assistant in family medicine?
2) How do psychological assistants experience the use of the PsyMate™ to support problem explorations?
3) How do patients in family medicine experience the use of the PsyMate™ to support problem explorations?

Methods

Design

We selected an action research design to allow the PAs and their patients to experience, reflect on, and learn about when and how they can use an ESM tool, in this case the PsyMate™, to support problem explorations (see Figure 7.1). The action research strategy allows to collect in-depth knowledge about the use and experiences of both PAs and patients[41].

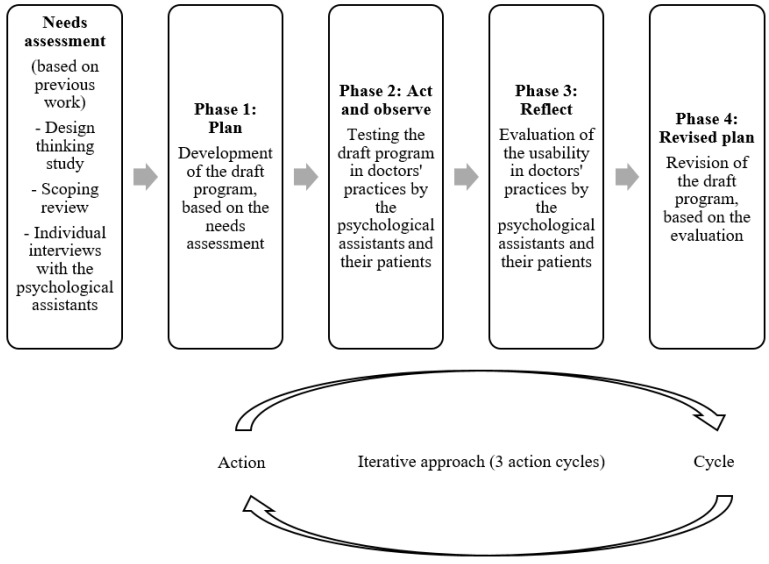


Figure 7.1 Action research design.

Phase 1: Plan

The draft program was developed, based on a needs assessment. This needs assessment had been compiled on the basis of previous research related to the use of electronic diaries in healthcare and the redesign of an ESM tool (the PsyMate™) for family medicine[40,42]. It resulted in three main change objectives: (1) coach the PAs to recognise the importance of daily life functioning, (2) improve the PAs' knowledge about ESM and ESM technology, and (3) improve the PAs' skills to introduce the ESM tool and discuss the ESM results (see Figure 7.2). Based on these change objectives, the authors created a draft program to train the PAs. The design of the web-based reporting tool was not altered, but a manual and an instruction movie were provided.

Phases 2, 3 and 4: Act and observe, reflect and revised plan

The draft program was tested and evaluated in the context of the doctors' practices by the PAs and their patients. The evaluation was performed iteratively through three action research cycles: acting and observing, reflecting and revising (see Figure 7.1). The PAs and their patients had the opportunity to experiment with the ESM tool. The researcher had individual meetings with the PAs and the PAs exchanged experiences and learned from each other in a WhatsApp group. This yielded solutions for the barriers they encountered and if possible, these were implemented by all PAs. Based on their experiences, the draft program was iteratively revised.

Before the PAs started experimenting with the PsyMate™, they got extra time to introduce the ESM tool and discuss the monitoring results with their patient. To better prepare them, they followed a half day theoretical and practical training about the rationale of experience sampling in daily life, how to instruct patients and how to use the PsyMate™. PAs role-played how to select patients, introduce the ESM tool and discuss the ESM results to support problem explorations. In addition, they received a written work instruction about the use of the ESM tool.

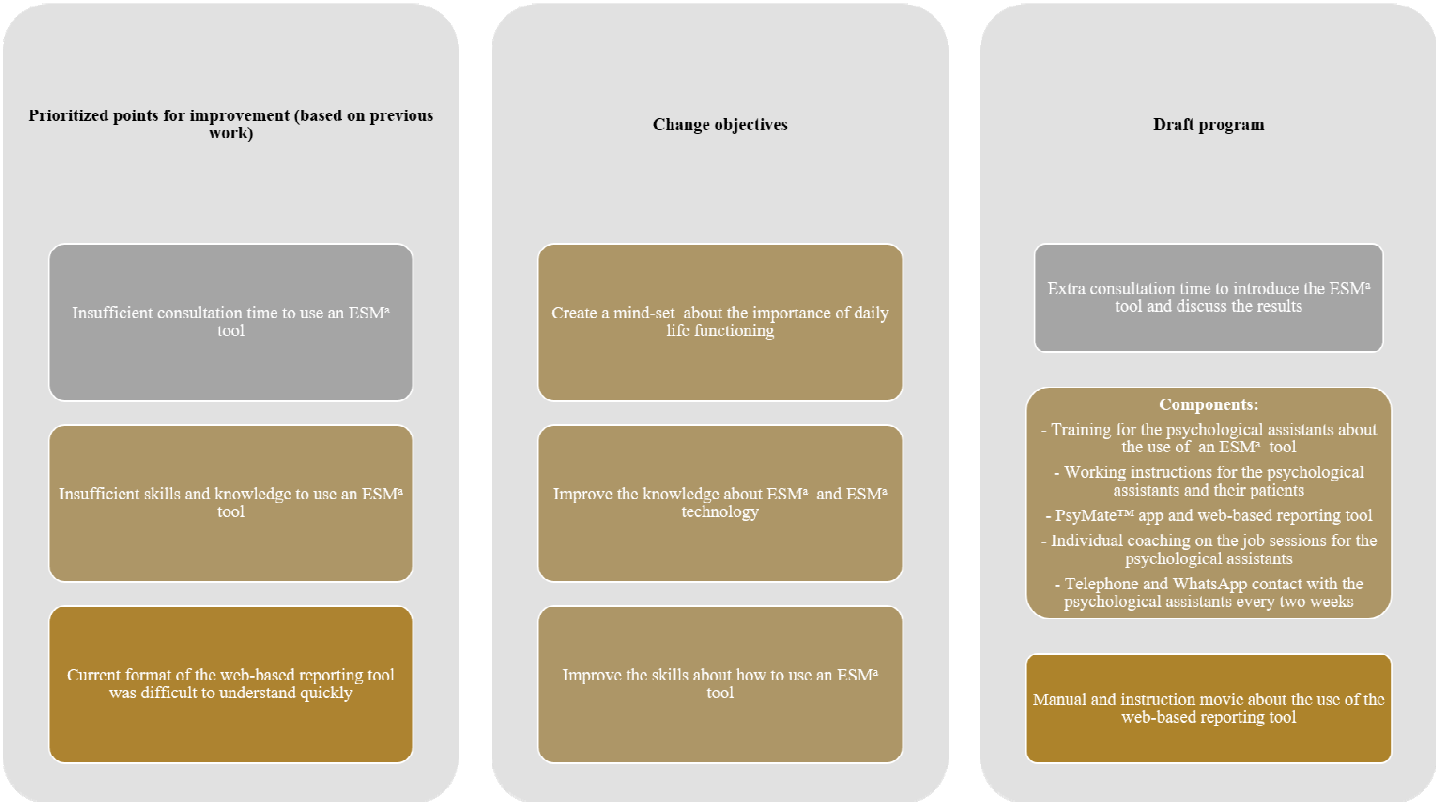


Figure 7.2 Draft program based on needs assessment. *Note.* aESM = Experience Sampling Method

Setting and participants

The study occurred in family physicians' practices in the south of the Netherlands, where most doctors hired PAs to support them with patients who have mental health care needs. PAs support people with psychological, psychosocial and psychosomatic problems, under the final responsibility of the family physician[43,44]. We selected PAs with an interest in mHealth, using convenience sampling through the researchers' networks. PAs were included in the study if they were interested in using mHealth in routine clinical care, had at least two years of experience on the job and had a full understanding of the Dutch language. Patients were recruited by their PAs, who considered ESM useful in the care process, if they had anxiety or sleeping problems, had a smartphone, were open to the use of mHealth during their care process and had sufficient understanding of the Dutch language without needing the presence of an interpreter.

Ethical approval was obtained from the Medical Ethics Review Committee of the academic hospital of Maastricht and Maastricht University (METC 2019-1180). All PAs received written and oral information about the content and procedures of this study. Written informed consent was obtained from all patients.

Experience-sampling platform

The PsyMate™ Suite is an integrated experience-sampling platform (smartphone application, cloud-based data storage and web-based reporting tool). It can be customized for moment-to-moment assessment of mood, cognition, perception, and behaviour in the individual's daily life context. It aims to enable users gaining insight into their daily life functioning. This ESM platform has been developed collaboratively by SmarteHealth and the department of Psychiatry and Neuropsychology of Maastricht University Medical Centre (MUMC+). Individuals can download the PsyMate™ app for free from the Google Play Store or the App Store. Users typically are prompted ten times a day at semi-random moments throughout the day (between 7.30AM and 10.30PM) to fill in a short questionnaire (max. 2 minutes). The standard PsyMate™ beep questionnaire assesses mood (i.e., positive and negative affect), physical status (i.e., hunger, fatigue and pain), and context (i.e., location, activity and persons present) (see Appendix 7.A). Mood and physical status items are rated on 7-point Likert scales (1 = not at all, 4 = moderate, 7 = very much), while context

is assessed categorically. In addition to the within-day repeated beep questionnaires, users complete a morning (assessing sleep quality) and an evening questionnaire (assessing overall appraisal of the day) (see Appendix 7.A).

The web-based reporting tool visualizes the patient's results into graphs and diagrams (see Figure 7.3). Likert scale items are presented in line charts and categorical items in pie charts. After collecting at least one week of data, sufficient data is available to reliably assess how mood and physical status are related to context, for example to see how the environment or daily activities influence mood (problem explorations). This exploration is part of a personalized collaborative process.

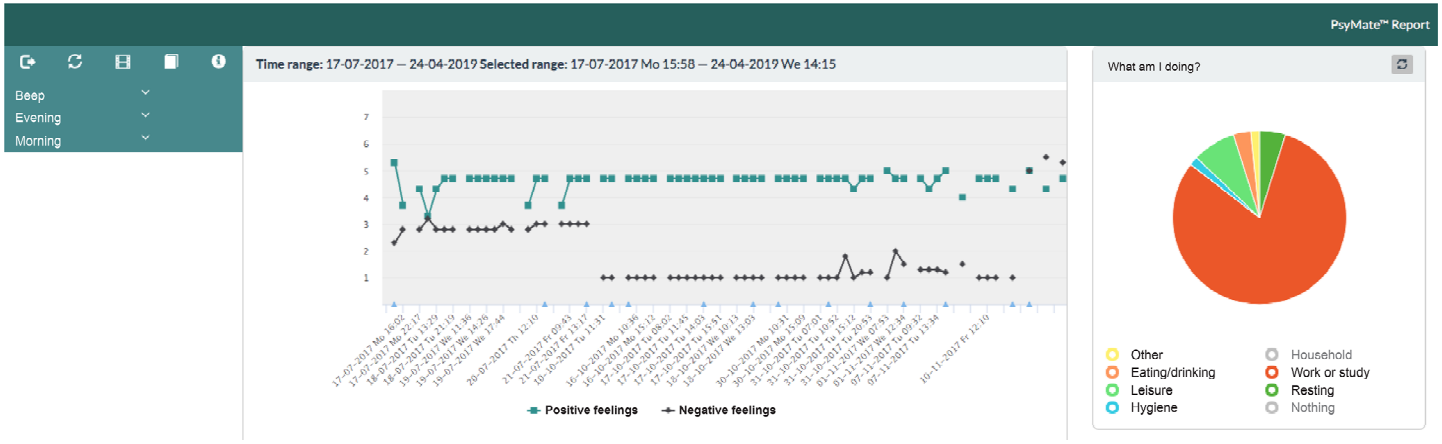


Figure 7.3 An example of the PsyMate™ web-based reporting tool.

Data collection

Data were collected between October 2019 and October 2020. During the 'act and observe' and 'reflect' phases of the action research cycle, the tests and evaluations in the doctors' practices by the PAs and their patients were performed iteratively with ongoing data collection from observations, interviews, patient records and a logbook (see Table 7.1).

Table 7.1 Overview of the research questions and the corresponding data collection method.

Data collection	Use	PA experiences	Patient experiences
Observation of ESM tool introduction	X		
Observation of ESM results discussion	X		
PA interview		X	
Patient interview			X
In-depth interview with PAs (final step)		X	
Patient records	X		
Logbook		X	

Note. PA = psychological assistant. ESM = Experience Sampling Method.

Observations

The PAs asked their patients if the researcher (ND) could observe the consultations in which the ESM tool was introduced and the ESM results were discussed. These consultations were audio-recorded and the observer took field notes.

Interviews

After the observed consultations, the PAs and the patients were interviewed separately about their experiences with the use of the ESM tool. Fourteen interviews (10 patient interviews and 4 PA interviews) were conducted by the researcher (ND). From the original six PAs, one PA was not available for post-observation interviews due to practical reasons, one dropped out during the first half of the project and one was unable to include patients because it was impossible to make room for the use of the ESM tool in the work routines. Patient interviews lasted on average 11 minutes and 15 minutes with the PAs.

We conducted individual in-depth interviews with the PAs as a final, additional step. The idea was to check findings from the observations and the interviews, share experiences regarding the use of ESM technology in the routine clinical care of PAs in family medicine and reflect on the learning

process. Five in-depth interviews were conducted by the researcher (ND). They lasted on average 52 minutes.

Patient records

After the interviews with PAs and patients, the researcher (ND) checked for background data in the patient records. Checks of patient records occurred in the presence of the PA, which allowed to explore the place of target problems in the care process.

Logbook

The researcher (ND) kept a logbook of telephone and WhatsApp contacts with the PAs. It contains information about important problems encountered by the PAs, proposed solutions and decisions taken during this action research.

Data analysis

Observations and interviews were transcribed verbatim and analysed through directed content analysis[45], using the qualitative analysis software Nvivo 12 Plus for Windows. To code the observations and interviews, we combined a deductive and inductive approach. Deductive coding started with an initial coding scheme based on our previous work[40,42]. It consists of three major categories: preconditions, content, and process (see Appendix 7.B). We used inductive coding when data could not be coded using the predetermined codes. New categories or subcategories could be analysed and were added to the initial coding scheme. Two researchers (ND, CvZ) read all transcripts independently and repeatedly to familiarize themselves with the data. A logbook was kept by them to enhance the trustworthiness of the study. Outcomes were discussed until consensus was reached.

Results

Results are described per research question. First, how the PsyMate™ was used as an mHealth tool to support problem explorations in family medicine, then the experiences of the PAs and their patients concerning the PsyMate™'s use.

Participant characteristics

Psychological assistants

Six PAs, all women, with a background in nursing or psychology and an additional two-years training at a University of Applied Sciences, participated in this study. They each worked in 1 to 4 family physicians' practices and had work experience between 3 and 11 years (*Mdn* = 6.00).

Patients

Ten patients, eight women, participated. They were on average 39 years old (range: 19-62 years). For three patients, anxiety problems were the primary complaint. For the other patients, anxiety or sleeping problems were secondary complaints. Five patients consulted for stress-related symptoms and two for other psychological symptoms. One patient was observed during the introduction of the ESM tool but it was not possible to discuss the ESM results with the PA due to the COVID-19 measures.

Use of the PsyMate™ to support problem explorations

The results for the use of the PsyMate™ are summarized in Table 7.2.

Table 7.2 The use of the experience-sampling platform, the PsyMate™, in family medicine.

Main categories	Categories	Subcategories	Frequency
Preconditions	Training for the PA	PA followed the training	6/6
	Instruction	PA used the work instructions	8/10
	Support	PA asked for support by the researcher during the ESM tool introduction and/or result discussion	5/10
		PA used the manual/instruction movie of the web-based reporting tool	0/10
		PA searched for use cases	6/6
Content	Determine suitability	Based on symptoms	10/10
		Based on app and smartphone skills	0/10
	Decide to use the ESM tool	PA's decision based on:	
		- tool applicability	0/10
		- patient characteristics	3/10
		- expected outcome	10/10
		Patient's decision based on:	
		- expected outcome	3/9
		- recommendation of the PA	8/9
		- applicability of the tool	2/9
	Introduce the ESM tool	1. Explain the goals of ESM:	
		- provide insight into symptoms	10/10
		- provide treatment starting point	7/10
		- assess the context of daily life	3/10
		- decide on the monitoring period	10/10
		2. Explain ESM tool (app) functioning	
		- app provides a signal at random moments	7/10
		- patient should not adjust routines	4/10
		- assessments concern just before beep	8/10
		- items should be completed immediately	8/10
		- PA explains app content	10/10
		3. PA and patient together perform download and login procedures	9/10
		4. Patient completes practice questionnaires	9/10
		Required introduction time	*Mdn*: 15 minutes (range: 5-35)
		Embedding in the care process: the materials are provided to the patient	4/10

Table 7.2 (continued)

Main categories	Categories	Subcategories	Frequency
	Use the ESM tool	Duration	*Mdn*: 15 days (range: 11–21)
	Discuss ESM results	PA discusses the patient's experiences	5/9
		Login to PsyMate™ web-based reporting module done by the patient	7/9
		Problem exploration (domains – context – relation between both)	
		– domains and relation between symptoms and context	5/9
		– only context	4/9
		Order of ESM results discussion (inventory of the patient's expectations – exploration of context, mood, combination between both – zoom in on specific questions)	
		– inventory → exploration	3/9
		– only exploration	6/9
		Patient interprets the ESM results	4/9
		ESM results connected to management	7/9
		Required discussion time	*Mdn*: 29 minutes (range: 20–50)

In contrast to the training and work instructions, the PAs only determined suitability based on the patient's symptoms and not on the patient's ability to use a smartphone and apps. Furthermore, we observed that the PAs did not decide to use ESM based on its applicability. Based on the PA interviews, they decided to use the ESM tool mainly on the expected outcome, for example, gaining insight into the relation between the patient's symptoms and the situations in which they occur.

"I had a patient where it came up very naturally, that I thought this might be very illuminating for her. So, there were also minimal costs. It was good to remember the ESM tool during this patient consultation. I already told her: 'I think it is good to get some insight into those days and how you feel. So, we can work on it afterwards.'. And it fitted very nicely into her themes and her story." (Psychological assistant C, psychological assistant interview)

In contrast to the PAs' decision, patients mostly decided to use ESM when it was recommended by their PA, not because of the applicability of the tool or the expected outcome like staying in control and managing anxiety symptoms.

The PAs indicated during the interviews that they introduced the tool during the first or second patient consultation because of a possible relation with the patient's needs. During the observations, the observer noticed that the PAs usually first introduced the ESM tool and how it works, and only later explained its goal and advantages.

"And the advantage of this app is that you can actually complete a questionnaire very often in one day. I used to ask patients or discussed keeping a diary, but then you only complete it two or three moments during the day. This app ensures that you can at least complete it ten times." (Psychological assistant D, observation, explaining the functioning of the ESM tool)

"You can discover when you suffer from your symptoms, is it always equally bad or is it better sometimes? At what moments does it go well? Consequently, we can look at your strengths. You are going to help yourself to regain your strength." (Psychological assistant A, observation, explaining the goal of using an ESM tool)

During the introduction of the ESM tool, the PA initially needed support by the researcher to explain the login procedure. Patients often had questions about the anonymity and the content of the ESM tool, for example the personal items and the web-based reporting tool. During the second iteration, the PAs decided to adapt the way they introduced the ESM tool; they gave a written work instruction to the patient instead of a rather extensive oral introduction. During the third iteration, COVID-19 conditions moved the care process online and PAs paid attention to conducting patient consultations by telephone or video conference.

The number of completed assessments per person ranged between two and eight out of ten assessments per day (*Mdn* = 4.00). Some patients only completed assessments during the week and not in the weekends, or only before and after work and not during the working hours. In some cases, completion also decreased towards the end of the monitoring period.

Based on the in-depth interviews with the PAs, they apply a holistic approach in the problem explorations, taking various life domains such as social and emotional functioning, education, work, activities, and living and housing conditions into account. To shape problem explorations, the PAs used several holistic models, for example Gordon's model of eleven functional health patterns[46] or the "Complaints Circumstances Personality characteristics"-model[47]. Furthermore, they were accustomed to use different instruments like symptom questionnaires and draw schematic representations of the symptoms to explore the patient's vulnerabilities and strengths.

We observed that in only two out of nine cases PAs made up an inventory of the patient's expectations. Most often no specific pre-existing hypotheses were formulated. The PAs focused in most cases only on the exploration of the context (time spent per activity or location, and persons present), mood per day and per beep, and the relation between mood and context. The researcher supported the PAs to interpret the scale of the line graphs and bar charts, the meaning of positive and negative feelings, and the real time level (i.e., results of all completed beep moments).

"What is the first thing you notice here? What do you see yourself? When you look at your scores, what do you get out of it? If you think about completing the app and how you felt last week, which emotion stood out for you?" (Psychological assistant D, observation, discussing the ESM results)

Psychological assistants' experiences

The experiences of the PAs are divided into: (1) added value for the PAs, (2) inclusion and instruction of patients, and (3) experiences with the PsyMate™ web-based reporting tool.

Added value for the psychological assistants

The PAs who had introduced the PsyMate™ to their patients experienced the use of the ESM tool as an addition to their patient consultations. They indicated that the use of the ESM tool can promote patient' self-management and empowerment. Provided that patients are digitally skilled, they can continue to work on their vulnerabilities at home, in-between sessions, thereby creating more intrinsic motivation for their treatment. Some PAs also experienced that the patients got more responsibility, so the working alliance between the PA and the patient changed. Moreover, the high sampling frequency allowed more in-depth explorations and PAs felt able to investigate relations between the patient's vulnerabilities and the conditions in which they occur. Some PAs also experienced that using the ESM tool activated patients and made them more aware of their vulnerabilities and their strengths in the daily life context. Furthermore, some PAs reported that other patients needed the confirmation of their own hypotheses because they did not dare to trust their own insights. The PAs also experienced that using the ESM tool is a good start to invest in strengths and resilience, and focus on responsibility and self-reliance of the patient.

"You can focus on certain topics very well and gain some insight. In this way, you can reflect more during patient consultations, also to find out what helps you and what can you do differently to suffer less from those symptoms." (Psychological assistant A, in-depth interview)

"I think that she knew what she saw there, but that confirmation was needed to believe what the two of us came up with. That she saw that certain symptoms were the results of situations and thoughts. In this case, that confirmation was very nice. She did not dare to rely entirely on her own insights. And I think it certainly delivered that. For me, it was also guesswork, to see if it came or not." (Psychological assistant C, psychological assistant interview)

All PAs indicated that they would recommend the use of the PsyMate™ to colleagues; the PsyMate™ was experienced as a usable, user-friendly and patient-oriented self-help instrument to gain insights into both vulnerabilities and strengths in the context of the patient's daily life.

"I would say: 'Gosh, the PsyMate™ is a nice tool if people want to gain insights themselves, want to learn to act differently, want to do other things to achieve that change, and who are digitally skilled." (Psychological assistant A, in-depth interview)

Inclusion and instruction of patients

The PAs experienced several challenges with regard to including and instructing patients. Two of the six PAs had trouble to include and instruct patients about ESM use within their regular work processes. They struggled to make room for an additional tool in their work routines. They experienced difficulties in integrating the research of this ESM implementation study within their consultations. Some patients were open to use ESM in their care process, but they refused to allow observations and participate in interviews required for the research. During the second iteration, we changed the research protocol and provided the possibility to audio record the session for later coding instead of physical presence of the researcher during the observations. Even then, patients still refused to participate in the research.

Based on the PA interviews and on the logbook entries, some patients refused to use the ESM tool because they had insufficient energy and felt overburdened. Other patients refused to use the tool because they expected difficulties due to assessments during working hours. In the in-depth interviews, the PAs mentioned they might use it with patients having stress-related complaints and gloominess. They were cautious to use it with patients with psychosis sensitivity, autism spectrum disorder, compulsion, personality problems and severe depressive disorders.

"People who have trouble understanding their vulnerabilities because I do not want to reinforce them in how many symptoms they experience. And the people who actually have too little energy to get through their day. I find it much more important that they are able to eat and sleep on time rather than also asking them seven times to do something. Many people find it terrible to having to do something. They would feel more irritated or stuck if their phone rings several

times a day. Then, I think it is a bit early to start using it. If I have the feeling that people are not yet ready to use it or who want to talk first, I will not ask it in the first place. That is because I want to align with their needs." (Psychological assistant C, in-depth interview)

Both the PAs and their patients reported during the interviews that they needed a degree of digital skills and the ability to abstract while using the smartphone application and the web-based reporting tool. Whether patients want to use the ESM tool or not was not age-related. The PAs noticed that it is important that patients want to explore their feelings and want to work on their recovery. During the first iteration, PAs only included patients with anxiety or sleeping problems. Later, they asked to be allowed to use the ESM tool with other patients. A second iteration allowed them to broaden the patient population, but in this study only patients with anxiety or sleeping problems were included.

During the in-depth interviews, the PAs reported that demonstrating the smartphone app to the patient, downloading the app and completing practice questionnaires together with the patient were important elements in introducing the ESM tool. In the second iteration, the PAs provided a written work instruction to the patients. This puts greater responsibilities on the patient. During the third iteration, the PAs conducted patient consultations by telephone or video conference, due to the COVID-19 measures. They reported that the inclusion of patients did not go as smoothly during patient consultations by telephone or video conference, as compared to physical patient consultations.

Experiences with the PsyMate™ web-based reporting tool

The PAs reported that discussing the ESM results using the web-based reporting module engaged patients more in their treatment.

"She has taken all the initiatives herself. She started it herself. That is the biggest motivation to get started at home. It becomes even more her project." (Psychological assistant B, psychological assistant interview)

Furthermore, they experienced conducting more in-depth analyses, however, making conscious choices about the topics to be discussed via the web-based reporting tool was crucial. PAs experienced that discussing the ESM results was a starting point for behavioural change. In addition, by using ESM the PAs got a

more objective picture of the patients' vulnerabilities, but also of their strengths.

"It gives insight into how the patient can cope with their symptoms differently so they can become less prominent. It makes clear how the patient maintains his/her symptoms by doing certain things, meaning that they can do things in a different way, if they want to. You have to practice more to gain experience with reading the feedback quickly. Of course, it is also an art to let patients read that feedback themselves. You just have to practice those things to make it as efficient and effective as possible." (Psychological assistant D, in-depth interview)

Nonetheless, some PAs found it difficult to extend the use of the reporting tool because they adhered too much to the scores. This is a limitation of the current format of the web-based reporting tool. Support from the researcher helped them on the right track. They liked that they could search and work together with their patients to interpret the ESM results. But, PAs also had patients who did not register moments when they felt well, not even after discussing the ESM results and explaining the need of monitoring in every situation.
"It has not yielded what she wanted to know. It did not encourage her afterwards to monitor moments when she feels well. It is not yet easy to broaden its use; getting stuck to the scores. How can I engage patients in a better way?" (Psychological assistant A, psychological assistant interview)

Patients' experiences

The experiences of patients are ordered into: (1) added value for patients, (2) experiences with the PsyMate™ app, and (3) experiences with the PsyMate™ web-based reporting tool.

Added value for patients

The added value of using the ESM tool for patients was based on the goal of the ESM tool and the expected outcome, for example, staying in control and managing sleeping problems. Patients experienced getting insight into their symptoms and strengths, and the ESM tool provided starting points for their treatment because they could make connections between their mood and the corresponding context. Furthermore, they reported becoming more aware of their feelings, thoughts and behaviour while completing the ESM

questionnaires. They experienced the possibility for better self-reflection; they could see how their feelings and behaviour changed in different situations, where the bottlenecks were and for which areas they could use help. Moreover, their thoughts or hypotheses got confirmed, with greater objectivity.

"When I felt irritated, I started thinking about why I felt irritated, because I had to complete that item. Then you start thinking for a moment about why I felt irritated or why I was worrying or why I slept badly. Usually, you just go on with the day and ignore that, so now you are a bit more conscious about it." (Patient E, patient interview)

Experiences with the PsyMate™ app

Patient experiences with the PsyMate™ smartphone app can be divided into five themes: content, functionalities, look-and-feel, burden and technical issues. Regarding the content of items, patients experienced difficulties interpreting "It was a normal day" or "I like this social situation". About functionalities, they liked that they could tailor the app to their situation by adding personal questions. Although the introduction lasted on average 20 minutes, the patients appreciated that they could start using the app without a lengthy instruction. Moreover, they experienced the concise items as a strength. The patients suggested to add the possibility to contact their healthcare professional, and to add exercises or tips. They enjoyed the ease of use, the reminders and the semi-random beep moments because they could monitor their mood or physical status in different situations and not only at work.

"I found it useful that I got a reminder every time, so I did not have to think about completing it several times a day. I really liked that. And I really liked the items. And the morning and evening questionnaire. I found it nice and convenient to use it that way." (Patient H, patient interview)

With respect to the look-and-feel, patients reported that the PsyMate™ was a simple and functional tool to monitor their vulnerabilities and strengths. However, they would like to add in-app feedback. Some patients were burdened by the number or the sound of the beeps, the time scheme and their eagerness not to miss beeps. They suggested to provide a possibility to adjust the time schedule. Regarding technical issues, some patients experienced problems with an invasive battery saver mode, especially on Android devices.

"Well, at first I thought that it would work for me. But, later on I felt like it actually became a burden rather than that it helped me. I found it difficult to complete the questionnaires every time, for example when I was eating. I cannot complete it when I am at work. It was really only when I had time to complete it. I rather perceived it as burdensome." (Patient G, patient interview)

Experiences with the PsyMate™ web-based reporting tool

The patient experiences with the PsyMate™ web-based reporting tool are in line with the experiences of the PAs. Patients also appreciated the possibility of in-depth analyses and complimented on the ease of use and the clear overview of the results.

"I can say that I found it very clear. That you can select exactly what you wanted to see. Very clear, a good overview. You could also see the ups and downs very well. I really liked that. I found it especially interesting to see how I felt during the last three weeks, to see what I filled in. I thought that was interesting to see. Sometimes, if something happened on that day, I could recall 'oh yes, that is how I felt' when I looked at the results. The charts were easy to read. I found them very clear." (Patient H, patient interview)

However, they sometimes had difficulties interpreting the graphs and diagrams. Consequently, they argued that some analytic or computer skills are required to use the PsyMate™ web-based reporting tool.

"I often see graphs. I can read and interpret the graphs reasonably well. However, I can imagine that there are people who do not fully understand them because it is a different way of looking at certain things. It would be helpful if the psychological assistant would know more about the layout. Or maybe a short description on the web-based reporting tool with regard to the initial values so people do not get overwhelmed by the bunch of buttons, some basic functionalities that show what is important. First, what you would like to see and only then you can start developing a table. This way, you do not get too much information at once and do not wonder what the different buttons are for." (Patient B, patient interview)

Discussion

The aim of the current study was to discover how experience-sampling technology is used to support problem explorations for patients with anxiety or sleeping problems, who are seen by a psychological assistant (PA) in family medicine. Furthermore, the experiences of the patients and the PAs in using ESM have been explored. This was assessed using an action research design.

Although four of the six PAs actually used the ESM tool, and PAs and patients experienced the added value of its use to support problem explorations, the PAs encountered difficulties to integrate this tool into their work processes. Patients sometimes encountered difficulties integrating it into their daily life activities, such as work. Where integration succeeded, the PAs were able to determine suitability of patients, to decide to use the ESM tool and to introduce the ESM tool to the patients. They experienced most difficulties in the discussion of the ESM results. Some patients and PAs experienced difficulties reading and interpreting their results in the web-based reporting tool. Consequently, support by the researcher was needed to achieve sufficient skills to read and interpret the ESM results using the web-based reporting tool. Therefore, the web-based reporting tool needs further fine-tuning to better align with the work processes of PAs and the care needs of patients, in addition to providing a manual and an instruction movie. A more intuitive, user-friendly interface that automatically generates personalized feedback might facilitate the integration of the tool into daily clinical practice[48]. This way, the data can become more transparent and simple to grasp. We also learned that the implementation of an ESM tool requires more than only giving a training for the PAs.

The iterative approach of the action research design supported the PAs in reflecting on their work routines and learn how to use ESM. To achieve this, learning from each other and coaching by a researcher were necessary. Using the ESM tool in routine clinical care required a growth process for PAs. These findings were in line with experiences from another action research study that examined the embedding of an activity tracker in specialized mental healthcare[49]. The target population were patients with chronic somatic symptom disorders and their psychosomatic therapists. They indicated that reflection sessions with the researcher, and learning from and with each other helped to implement the activity tracker into daily clinical practice[49]. Furthermore, previous research demonstrated that it is important to not only pay attention to the characteristics of the tool, but also to the end users'

characteristics, the innovation climate in the implementing organization, and the external policies and incentives[42,50,51]. We addressed some areas such as the innovative climate of the family physicians' practices, determining suitability and providing training and work instructions on how and when to use the ESM tool. In our study, the PAs got a one-hour extension of the consultation time to introduce the ESM tool and discuss the ESM results. Furthermore, the PAs reported the importance of support by colleagues, especially the family physician, with regard to the use of the ESM tool. We also noticed that the ESM tool should not deviate too much from the standard care process. With regard to determining suitability, the PAs and their patients reported how important it is to have sufficient digital skills to use the ESM tool, especially the web-based reporting tool. We learned that PAs had to accustom themselves with the use of the tools before presenting them to patients. However, they did not use the digital skills criterion when including patients. Technical support was provided by the researcher and a help desk might be necessary for problems exceeding the clinician's skills. We would advise to setup help desks and user communities to facilitate adoption. Our action research strategy with iterations taught us that training, work instructions and use cases are necessary aids for achieving the learning curve. But we did not focus on, for example, securing future financial investments for telehealth. Future research needs to include these areas as well.

Although the COVID-19 pandemic created momentum for the use of mHealth in family medicine, the findings of this study showed that a face-to-face briefing including a hands-on demonstration of the ESM tool to the patient, including completing practice questionnaires, helped to integrate it into routine clinical care. The remote instruction and demonstration were not successful. Meurs and colleagues also found that existing applications have been scaled up rapidly, but thorough implementation in the work routines is often lacking[52]. So, it will take time for mHealth tools to become a natural part of routine practice.

Strengths and limitations

For the interpretation of the results of this study, three limitations are important. First, the PAs and patients were both recruited using convenience sampling, potentially resulting in selection bias. Only the most intrinsically motivated PAs with interest in using mHealth during patient consultations participated in the study. They are probably not representative of all family physicians' practices. The experiences and perspectives of more critical users

and sceptics were missed. However, the design strategy may benefit from such recruitment because at this stage active involvement is required to improve the program and its implementation. In addition, patients are not representative of the general patient population, either. But we ascertained that the PAs, based on their clinical expertise, were free to ask the patients who they thought could benefit from ESM in their care process, thereby resembling the situation in routine clinical care.

Second, a limited number of PAs and patients were included in this study. Patients who did not start using the ESM tool after the PA asked them, were not included in this study. This potentially overestimates the effect. Therefore, the findings cannot be generalized to all PAs and patients with anxiety or sleeping problems in family medicine, and either professionals and patients in other healthcare settings. Future research should include other healthcare professionals and patients, including patients who are reluctant to use the ESM tool.

Third, the study ended after a third action research cycle due to the COVID-19 measures. Consequently, data saturation was not achieved. Another action research cycle would have provided us with more insights into the learning process of the PAs regarding the use of an ESM tool during routine patient consultations.

This action research study has several strengths. First, the iterative action research cycles ensured the active involvement of the end users in the test- and evaluation phase. The research team and PAs collaborated closely. This way, the findings of this study are more likely to be incorporated into routine clinical care. Second, the draft program as well as the initial coding scheme were based on change objectives, which in turn were based on prioritized points for improvement that resulted from previous research. The training for the PAs and the work instructions for both PAs and patients provided guidance on the use and embedding of an ESM tool in work routines and could be further adjusted during the act and observe, and reflect phases. Third, the implementation barriers encountered during our previous study, more specifically providing extra time, and training and instructions, were optimized. Although a manual and an instruction movie were added about the use of the web-based reporting tool, these were not used and the reporting tool remained a barrier in this study. By countering barriers, this action research approach provided more genuine and in-depth knowledge about the use of an ESM tool in family medicine and experiences regarding its use by PAs and their patients.

To ensure data triangulation, different data collection sources were used. Two researchers independently performed the data analyses to ensure consistency of coding. To enhance the credibility of the study, the research team reflected on the design, data collection, data analyses and lessons learned[52]. To increase the transferability of the study, a description of the design, the setting and participants, the data collection methods and the data analyses was provided[53].

Conclusion

The action research approach provided meaningful insights into the use and experiences of both psychological assistants and patients suffering from anxiety or sleeping problems and about the implementation of an ESM tool in family medicine. It remains a challenge to integrate ESM into existing work routines. If the integration succeeds, psychological assistants and their patients gain more in-depth insights into the variability that occurs as a result of interaction between mood, physical status and context. The psychological assistants felt able to extensively explore not only the patients' vulnerabilities but also their strengths, thereby improving patient empowerment. To ensure a better fit between needs of patients, work processes of psychological assistants and the ESM tool, fine-tuning of the web-based reporting tool is needed. In conclusion, it is a growth process for the psychological assistants to become familiar with the use of an ESM tool within their work routines. To get accustomed, the psychological assistants need extra time and the opportunity to learn from each other, and receive coaching from a researcher or help desk during the implementation process, in addition to necessary adaptations of the ESM tool.

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Appendix 7.A

Experience-sampling platform: beep, morning and evening questionnaire (standard assessment protocol).

Beep questionnaire	
Item	**7-point Likert scale or categorical options**
I feel cheerful	1 = not at all, 4 = moderate, 7 = very much
I feel insecure	1 = not at all, 4 = moderate, 7 = very much
I feel relaxed	1 = not at all, 4 = moderate, 7 = very much
I feel irritated	1 = not at all, 4 = moderate, 7 = very much
I feel satisfied	1 = not at all, 4 = moderate, 7 = very much
I feel down	1 = not at all, 4 = moderate, 7 = very much
I feel energetic	1 = not at all, 4 = moderate, 7 = very much
I feel anxious	1 = not at all, 4 = moderate, 7 = very much
I feel happy	1 = not at all, 4 = moderate, 7 = very much
I feel lonely	1 = not at all, 4 = moderate, 7 = very much
I am concentrated	1 = not at all, 4 = moderate, 7 = very much
I worry	1 = not at all, 4 = moderate, 7 = very much
Optional additional personal question 1	1 = not at all, 4 = moderate, 7 = very much
Optional additional personal question 2	1 = not at all, 4 = moderate, 7 = very much
Optional additional personal question 3	1 = not at all, 4 = moderate, 7 = very much
Optional additional personal question 4	1 = not at all, 4 = moderate, 7 = very much
Optional additional personal question 5	1 = not at all, 4 = moderate, 7 = very much
Who am I with?	Select: partner, children, family, housemates, pets, friends, colleagues, healthcare workers, acquaintances, strangers or others, nobody
I like this social situation	1 = not at all, 4 = moderate, 7 = very much
What am I doing?	Select: work, study, housekeeping, self-care, care for others, eating / drinking, travelling / on the road, having a conversation, having online contact, sports, leisure, resting, other, nothing
I would rather be doing something else	1 = not at all, 4 = moderate, 7 = very much
I am active	1 = not at all, 4 = moderate, 7 = very much
Where am I?	Select: work, school, home, somebody else's home, store, café / restaurant, sporting venue, healthcare venue, on the road, outside, somewhere else
I am hungry	1 = not at all, 4 = moderate, 7 = very much
I am tired	1 = not at all, 4 = moderate, 7 = very much
I am in pain	1 = not at all, 4 = moderate, 7 = very much
I generally feel well	1 = not at all, 4 = moderate, 7 = very much
Since the last beep I used	Select: alcohol, medication, coffee / caffeine, smoking / nicotine, cannabis, energy drink, other substances, nothing
This beep disturbed me	1 = not at all, 4 = moderate, 7 = very much
Morning questionnaire	
Item	**7-point Likert scale or categorical options**
How long did it take before I fell asleep last night?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
In total, how long did I sleep this night?	Select: < 4 hours, 4 – 6 hours, 6 – 7 hours, 7 – 8 hours, 8 – 9 hours, 9 – 10 hours, 10 – 12 hours, > 12 hours

How often did I wake up last night?	Select: 0, 1, 2, 3, 4, 5, > 5
How long did I lie awake this morning before getting up?	Select: 0 – 5 minutes, 5 – 15 minutes, 15 – 30 minutes, 30 – 45 minutes, 45 minutes – 1 hour, 1 – 2 hours, 2 – 4 hours, > 4 hours
I slept well	1 = not at all 4 = moderate 7 = very much
I am looking forward to today	1 = not at all, 4 = moderate, 7 = very much
Evening questionnaire	
Item	**7-point Likert scale or categorical options**
I am satisfied with today	1 = not at all 4 = moderate 7 = very much
I felt accepted today	1 = not at all 4 = moderate 7 = very much
Today was a normal day	1 = not at all 4 = moderate 7 = very much
I felt good about myself	1 = not at all 4 = moderate 7 = very much

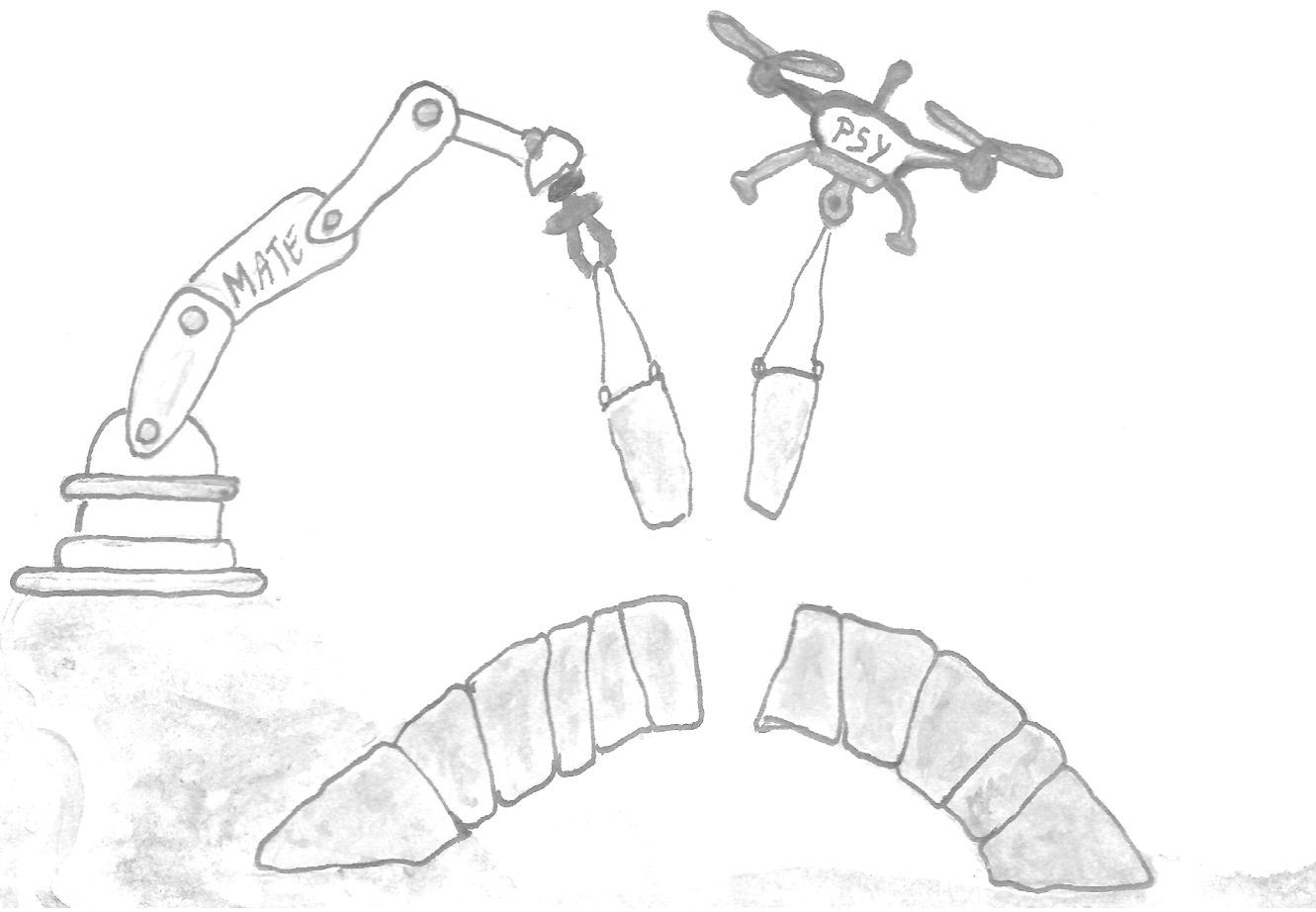
Appendix 7.B

Main category	Category	Subcategory
Preconditions	Training for the psychological assistants	Format Content
	Instruction	How did they use the work instruction?
	Support	Support by the researcher Support by the work instruction Support by the manual/instruction movie of the web-based reporting tool Support by use cases
Content	Determine suitability	Based on symptoms Based on app and smartphone skills
	Decide to use the ESM tool	Psychological assistant's decision - based on the applicability of the tool - based on the expected outcome
		Patient's decision - based on the expected outcome - based on the recommendation of the psychological assistant - based on the applicability of the tool
	Introduce the ESM tool	1. Explaining the goal of using an ESM tool - providing insight into the patient's symptoms - providing starting points for treatment - in the context of the patient's daily life - deciding on the monitoring period
		2. Explaining the functioning of the tool - the app provides a signal at random moments - the patient should not adjust his/her daily life rhythm to the app - the items concern the moment before the beep - the items should be completed immediately
		3. The psychological assistant and the patient perform the download and login procedure together
		4. The patient completes practice questionnaires
		Required introduction time
		Embedding the care process: the materials are provided to the patient
	Use the ESM tool (monitoring period)	

	Discuss the ESM results	1. The psychological assistant discusses the patient's experiences - applicability of the tool - expected outcome
		The log in in the PsyMate™ web-based reporting module is done by - the psychological assistant - the patient
		Problem exploration elements - domains - context - relation between symptoms and context
		Order of the ESM results discussion 2. inventory of the patient's expectations 3. exploration of time budgets (context), mood per day and per beep, combination between mood and context 4. zoom in on specific questions
		The ESM results are interpreted by - the psychological assistant - the patient
		The ESM results get connected to the management
		Required discussion time
	Added value for the patient	
	Estimated added value for the patient according to the psychological assistant	
	Added value for the psychological assistant	
Process	Experiences with using the PsyMate™ app (patient)	Content Look-and-feel Burden
	Experiences with using the PsyMate™ web-based reporting tool (patient)	Content Look-and-feel Burden
	Experiences with using the PsyMate™ web-based reporting tool (psychological assistant)	Content Look-and-feel Burden
	Knowledge and skills	Experience with reading graphs and diagrams to interpret the web-based reporting tool (psychological assistant) Experience with reading graphs and diagrams to interpret the web-based reporting tool (patient) Make conscious choices regarding the use of the web-based reporting tool

Chapter 8

General discussion



General discussion

The main objective of this thesis was to explore the continued development and implementation of an experience-sampling platform, the PsyMate™. The PsyMate™ was proposed as an mHealth tool to support problem explorations with patients suffering from mental health problems in family medicine. This thesis is divided into three parts, including five studies. In **part I**, the current practice about the use of electronic diaries in healthcare was explored in a scoping review. In **part II**, because cognition assessments were underdeveloped in experience sampling, but relevant for the family medicine field, the feasibility of experience-sampling technology was assessed in two pilot studies by administering two newly developed objective cognition tasks. In **part III**, the actual development and implementation of experience-sampling technology in family medicine was explored.

This final chapter summarizes the main findings and describes methodological considerations. Furthermore, lessons learned are defined, and implications for daily clinical practice, future research and education are discussed. This chapter ends with a general conclusion.

Summary of main findings

Part I: Exploring current practice

A scoping review was conducted to explore the current practice about factors that influence the use of electronic diaries in healthcare (**Chapter 2**). In line with the Consolidated Framework for Implementation Research (CFIR[1]), the use of electronic diaries is influenced by the device and app design (i.e., visually appealing tool with reminders, clear in-app data visualization, and automated data transfer, requiring minimal user demands), the end user profile (i.e., smartphone experience, intrinsic motivation, clear rationale to monitor own behavior) and the implementation process (i.e., theoretical and practical training). Two CFIR domains provided no empirical confirmation in the scoping review: the setting or organizational context in which electronic diaries are implemented (inner setting), and the implementation climate, for instance,

external pressure to use electronic diaries in routine clinical care due to guidelines, reimbursement and legislation (outer setting)[1]. The successful implementation of electronic diaries in daily clinical practice requires an integrated approach that includes all CFIR factors[1–6]. In conclusion, our analysis recommends that healthcare professionals or organizations focus on the software, hardware and target population as well as the structural, political and cultural organizational context, the implementation climate and the implementation process, when implementing innovative tools. No firm conclusions could be drawn on required, useful and effective features of electronic diaries. More prospective, longitudinal studies are needed using mixed methods study designs to better understand crucial factors required for sustainable implementation of innovative tools.

Part II: Cognition in daily life

The Experience Sampling Method (ESM) was primarily developed to assess changes in affect and behavior, and to relate these to context. In family medicine, patients often formulate worries about cognitive decline. Because cognition assessments were underdeveloped in experience sampling, two quantitative studies were conducted to assess cognitive performance in daily life (**Chapters 3 and 4**). They explored two newly developed cognition tasks, measuring respectively information processing speed (mDSST), and concentration and visuospatial working memory (mVSWMT). These were implemented in an experience-sampling paradigm. The feasibility of both momentary cognition tasks was critically assessed. The tasks seem promising in healthy individuals. They experienced the cognition tasks as pleasant, motivating and engaging (competitive). Correlational relationships were found between mood, context, and objective cognitive performance. For example, healthy individuals performed less well cognitively while being distracted. The ESM assessment strategy does not allow to determine causal inferences. It is, therefore, impossible to tell whether being distracted leads to a decrease in cognitive performance or that people are less inclined to participate in momentary cognition assessments on buzzy moments. The mDSST proved age-sensitive, with older individuals performing less well. The mDSST also seemed more sensitive to capture between- and within-person variability, compared to the mVSWMT. Furthermore, mVSWMT-scores were affected by specific response strategies that were unrelated to intended cognition assessments, resulting in biases. Key recommendations for improving the design are: to involve a

multidisciplinary team and end users in the development of momentary cognition assessments, to adjust the difficulty level to the individual's abilities to improve motivation and prevent frustration, and to make assessments competitive to stimulate sustainable engagement.

Part III: Continued development and implementation of experience-sampling technology in family medicine

In the last three chapters (**Chapters 5-7**), we explored the continued development and implementation of experience-sampling technology in family medicine. A design thinking study describes the customizing process of experience-sampling technology, the PsyMate™, for its application in problem explorations for patients who are seen by psychological assistants in family medicine (**Chapter 5**). Several barriers and facilitators were described: (1) insufficient consultation time to properly introduce the app and discuss the monitoring results (inner setting), (2) insufficient skills and knowledge to adequately use the platform during patient consultations (individual characteristics), and (3) the web-based reporting tool proved too difficult for some to understand and interpret (intervention characteristics). Facilitators were: (1) the regional consortium of family physicians stimulates eHealth and other innovations under the 'Blue Care' (Blauwe Zorg) label (inner and outer setting), (2) the end users were satisfied with the app content and suggested improvements for (motivational) functionalities (intervention characteristics), and (3) the telephone support of the researcher every three weeks and the WhatsApp group were experienced as an added value (process). The study concludes that implementing an experience-sampling platform could be considered a technological and behavioral innovation that requires a mind shift in the way psychological assistants work. This requires theoretical as well as practical training.

To provide support for clinicians on relevant aspects to use ESM in daily clinical practice, **Chapter 6** contains a step-by-step guide. The manual describes how and when to use experience-sampling technology to support problem explorations, thereby integrating empirical knowledge and expert experiences, and providing real-world examples. Relevant stages are: (1) determine suitability, (2) decide to use ESM in the clinical process, (3) introduce the ESM tool, (4) practicalities related to the use of the ESM tool, and (5) discuss the results to support problem explorations. We recommended to focus on a

collaborative care process, thereby involving the patient, while going through every relevant stage: to determine suitability, to formulate a clear focus related to the patient's needs and care process, to formulate hypotheses, and to choose behavioral experiments and change opportunities. Both mental health professionals and patients have to be aware of the correlational nature of the data and be cautious while discussing results. The monitoring data helps to formulate hypotheses on what is going on (problem explorations) and these can be challenged using interventions.

The results of these studies were used as input for action research, to test and evaluate the experience-sampling technology in family medicine and learn about the user experiences of patients and psychological assistants (**Chapter 7**). We chose this design to give psychological assistants and their patients the opportunity to experience and learn about the applicability of the experience-sampling platform. The organizational barriers, identified in chapter 5, were improved: (1) the psychological assistants' session-duration increased by half an hour to introduce the app and discuss the monitoring results (inner setting), (2) the psychological assistants received a half-day theoretical and practical training, work instructions using a manual and an instruction card, and coaching-on-the-job sessions (individual characteristics), and (3) a manual and an instruction movie about the use of the web-based reporting tool were added (intervention characteristics). The study showed that it remained difficult to embed experience-sampling technology in family medicine. Explaining the goal and functioning of the platform to the patient, demonstrating it to the patient and completing practice questionnaires, tailoring the discussion of the results to the individual's needs and interpreting these results together helped to integrate the PsyMate™ into routine clinical care. The added value of this momentary assessment approach to support problem explorations during patient consultations was experienced by both psychological assistants and their patients. However, the tool and implementation procedures need further fine-tuning to adequately fit the needs of patients and the work processes of psychological assistants. To conclude, becoming acquainted with this momentary assessment approach can also be considered a growth process, that requires time for learning and understanding as well as adaptation of routines. Learning from each other and coaching are necessary.

Methodological considerations

In this section some overall methodological considerations are discussed: the study designs used, the participants, and the transferability, data triangulation, and credibility.

Study designs used

For each part in this thesis, the research designs were selected to match the research question and stage of the research. This led to a variety of designs: a scoping review and various (mainly) qualitative studies, using design thinking and action research. We used primarily qualitative designs because it was needed to gain in-depth insights into the continued development and implementation of an experience-sampling platform in family medicine[7]. This research enables the generation of rich data and yields a comprehensive understanding, taking into account different contexts[7].

In **Chapter 2**, a scoping review was conducted to explore the factors that influence the use of electronic diaries in healthcare. There is a possible risk of selection bias; articles may have been missed since the research topic was often not the primary aim of the included studies and most articles were filtered in a first stage based on title screening. However, the broad, sensitive search and additional hand search may minimize this bias. Furthermore, we did not perform a study quality assessment since the aim was to map the existing empirical knowledge and identify any gaps about the factors that influence the use of electronic diaries. This way, we could not draw any firm conclusions regarding the useful characteristics of electronic diaries based on quantified outcomes. In addition, we did not intend to give a summary of the existing literature or compare results. We rather provided an overview of the existing knowledge and gaps concerning the factors that influence the use of electronic diaries in healthcare.

In **Chapters 3 and 4**, we conducted two pilot studies to assess the feasibility of experience-sampling technology by administering two newly developed cognition tasks. These studies did not investigate the concurrent validity with traditional neuropsychological assessments. Furthermore, we could not draw firm conclusions regarding the efficacy and effectiveness of this momentary cognition assessments because of the small sample size. But, the design choices for daily life cognition assessments provide an important first step to disentangle the contextual variability of mood and objective cognitive

performance. Additional research is needed to fine-tune the momentary cognition assessment tools before they can reliably be implemented in regular daily clinical practice.

In **Chapter 5**, co-creation sessions, applying the nominal group technique[8], empathy mapping[9], moderated user testing[10], the MoSCoW method[11], and semi-structured interviews were used to explore how the PsyMate™ could be optimized to fit with the needs of the psychological assistants and their patients in family medicine. Co-creation refers to the active involvement of end users in various stages of the production process[12–15]. A trade-off must be sought between stakeholders who want to have a feeling of (psychological) mastery over the tool, and the technological feasibility of implementing changes and previous scientific experiences of the research team. For example, the psychological assistants and their patients sometimes asked for less frequent assessments, but experience and scientific evidence learns that more intensive monitoring keeps patients in the flow and eventually decreases the cognitive burden. The research team attended the co-creation sessions to be able to make quick iterations in the continued development process of the experience-sampling platform.

In **Chapter 7**, we used an action research approach to give both psychological assistants and their patients the opportunity to experience and learn about when and how they can use an experience-sampling platform to support problem explorations in family medicine[16,17]. This approach was chosen for its iterative nature and the active involvement of the intended end users[16,17]. In action research, healthcare professionals usually have a greater say in the development process, while the researchers have a more supporting role[16–18]. However, in our study the researchers took a more leading role because the psychological assistants asked for more coaching on when and how to use the ESM tool. The experiences of both psychological assistants and their patients were discussed with the research and development team. Moreover, the combination of co-creation sessions, observations and semi-structured interviews allowed to iteratively broaden and deepen the findings[19]. Furthermore, by observing patient consultations in different family physicians' practices, and interviewing both psychological assistants and their patients a more thorough understanding was ensured. A researcher was always present during patient consultations which could increase the risk of information bias. By physically attending these consultations, the researcher was able to coach the psychological assistant on the job and answer the questions of the patients. In addition, the researcher could deepen the interviews afterwards. Audio-

recording was used when the researcher was not able to physically attend the patient consultation or when the patient objected.

In this thesis, we did not perform a process evaluation or study the (cost-)effectiveness of the experience-sampling platform in healthcare. Because the steps performed in this thesis are a prerequisite to be able to perform these next steps in future research.

Participants

For the feasibility studies (**Chapters 3 and 4**), mainly young, healthy and highly educated adults were recruited by means of snowball sampling, meaning that these findings cannot be generalized to, for example, older adults or individuals with lower education and patients.

The studies related to the continued development and implementation of the PsyMate™ in family medicine were primarily executed in various family physicians' practices in the South of the Netherlands (**Chapter 5 and 7**). The psychological assistants were recruited by means of convenience sampling, using the network of the research team. Only the most intrinsically motivated psychological assistants, so-called early adopters, participated due to their previously expressed interest in eHealth and to collect in-depth knowledge about the use and implementation of an experience-sampling platform in routine clinical care. This sample is not representative of family physicians' practices in general, thereby resulting in a potential selection and information bias. The perspectives and experiences of more critical users and the skeptics are missed. Nonetheless, we ascertained that the psychological assistants differed in background, education, years of experience and work processes.

Furthermore, patient involvement is important to ensure a close fit between platform and eHealth development, and end users[20]. Design thinking principles can guide this process[21,22]. Due to practical reasons patients were not involved in the design thinking study because getting started with the PsyMate™ was already challenging for the psychological assistants (**Chapter 5**). The psychological assistants were considered the primary users and expressed their experiences. But, we may have missed important information from the patient perspective regarding the continued development and use of the PsyMate™. The patient perspective was more clearly taken into account in the action research study (**Chapter 7**).

For the action research (**Chapter 7**), patients with anxiety or sleeping problems were recruited by means of convenience sampling, via their

psychological assistants. They were involved during the test and evaluate phases. Although the plan phase was based on the results of the design thinking study, we could have involved patients earlier, resulting in more meaningful adjustments of the ESM tool and a more sustainable implementation[21,22]. We were able to tackle several barriers described in the design thinking study. But, despite of providing a manual and an instruction movie, some patients and psychological assistants still experienced difficulties reading and interpreting the ESM results via the web-based reporting tool. Consequently, the web-based reporting tool needs further fine-tuning to better fit the psychological assistants' work routines and the patients' care needs.

Furthermore, for all studies, psychological assistants, patients as well as healthy individuals had to be able to use a smartphone with the PsyMate™. Individuals who were hesitant or skeptic about smartphone use might have refused participation. In addition, participants might experience ESM use as burdensome, which may conflict with workplace regulations. Personal restrictions or patient preferences might also interfere with the use of these tools.

Transferability, data triangulation and credibility

In the studies presented in this thesis, attention was paid to transferability, data triangulation and credibility. Although transferability is not a main goal in qualitative research, the design, setting and participants, procedure and data collection methods were described thoroughly to allow readers to evaluate if and how the results apply in other contexts or settings[23]. Furthermore, to improve the transferability of our findings, convenience and snowball sampling were used to include the experiences from different relevant stakeholders. However, our findings cannot be generalized to professionals and patients in other healthcare settings outside the family medicine setting, and other psychological assistants and patients with anxiety or sleeping problems.

To ensure data triangulation, field notes were collected, and observations and interviews were transcribed. Different data collection methods were combined to check for deviant perspectives. In addition, two researchers performed the qualitative analyses independently of each other and discussed the results until consensus was reached.

To enhance the credibility of the findings, debriefing sessions were held with the research team. The co-creation sessions, interviews and observations were executed by experienced interviewers who frequently checked the

meaning of the answers[24,25]. Methodological triangulation, more specifically combining data from literature, co-creation sessions, semi-structured interviews, and observations, also contributes to a more comprehensive understanding of the findings and enhances the credibility and validity of these findings. Furthermore, the same research team conducted the co-creation sessions, semi-structured interviews, and observations, and provided coaching and training. This might be a potential confounder for the design thinking study and the action research study. The expertise of the research team might have influenced the process to obtain the desired results. In addition, the research team had two roles: researcher and trainer. The research team had the double task to critically evaluate and study the PsyMate™ Suite, while also continuously developing and implementing the tool. Optimistic bias was minimized by regular self-reflection on distinguishing the role of advocate or researcher and potential biases. Finally, one of the supervisors also had the role of developer. This was not the case for the other supervisors, and we tried to monitor this process as much as possible.

Lessons learned

This thesis offers insights into the implementation of experience-sampling technology, the PsyMate™, to support problem explorations for patients with anxiety, depression, cognitive decline or sleeping problems, seen by psychological assistants in family medicine.

To assess the lessons learned, we use the Consolidated Framework for Implementation Research (CFIR[1]), which we also used in our design thinking study and scoping review. The lessons learned may not only be relevant for the setting of our study but also for the implementation of other eHealth tools. The CFIR describes five domains in the implementation of complex interventions: (1) intervention characteristics (e.g., relative advantage and design quality), (2) outer setting (e.g., peer pressure, external policies and incentives), (3) inner setting (e.g., implementation climate and team culture), (4) individual characteristics (e.g., beliefs and knowledge), and (5) implementation process (e.g., reflecting and evaluating, and stakeholder engagement)[1] (see Figure 8.1).

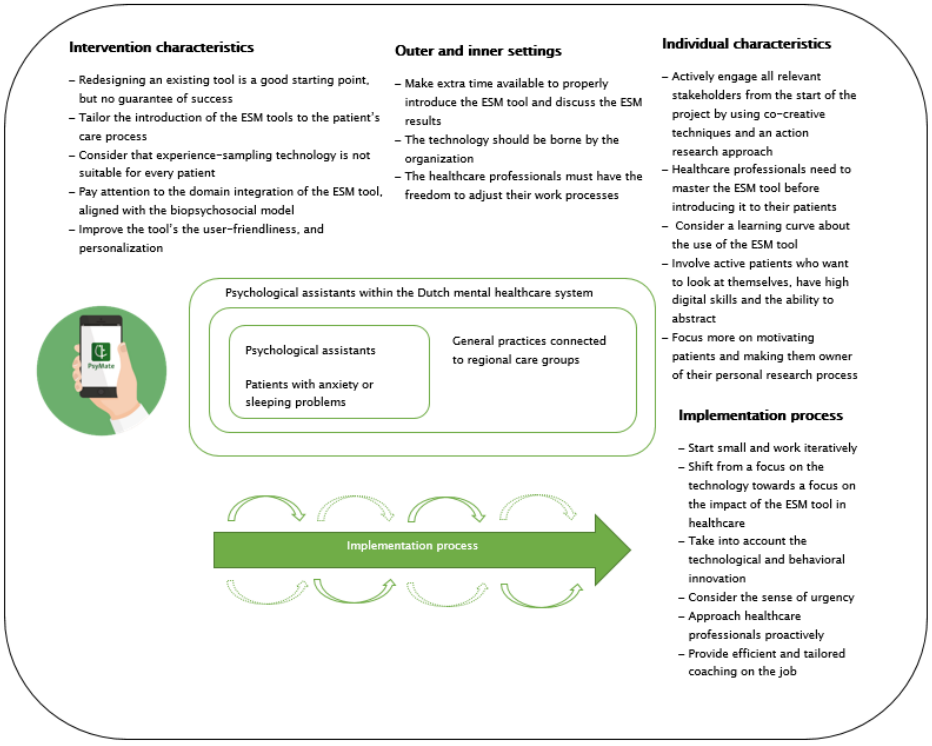


Figure 8.1 Overview of factors identified in this thesis that influence the use and implementation of experience-sampling technology in family medicine (chapters 5-7).

Intervention characteristics

Aspects of the intervention, the PsyMate™ or other eHealth tools, may influence the implementation and dissemination of technology in a new setting, i.e. the work environment of healthcare professionals.

In contrast to most new health apps that are uploaded daily to the Google Play store or the App store, the PsyMate™ was an existing app with a sound scientific basis. It is a platform (smartphone application, web-based reporting tool and cloud-based data storage) for collecting data following the experience-sampling principles. This overarching research field has a rich knowledge base of 50 years, of which more than 40 years in Maastricht. The experience-sampling principles have been implemented, evaluated, and fine-tuned worldwide in patient-related research as well as in clinical settings both in mental and somatic health. Some of these studies used the PsyMate™ app for ESM data collection. The studies in this thesis could rely on a robust platform

and focus on the integration of the PsyMate™ tool in family medicine and in the work processes of the psychological assistants. This remained challenging and illustrated that work routines required for ESM and the PsyMate™ are really different from regular practice in the field. For example, the existing web-based reporting tool seems sufficient feasible and usable in research but not in daily clinical practice.

The introduction of the tool and tailoring to the patient needs to assess his/her vulnerabilities and strengths required coaching. We experienced that a natural and matter-of-fact introduction of the ESM tool enhances patient engagement: this is how we do things here; we use the PsyMate™ to improve how we can help. For some patients, the tool was intuitive and they picked up the necessary routines quasi-automatically. Other patients needed a hands-on explanation. As a standard, we advise a briefing session in which the tool is demonstrated to the patient and practice questionnaires are completed collaboratively. During this face-to-face contact a dialogue about goals unfolds and worries can be tackled.

In this thesis, psychological assistants used the PsyMate™ to support problem explorations for patients suffering from mental health problems in family medicine. Over the past years, the biopsychosocial[26] approach was emphasized again and positive health[27] was introduced regionally in the family physicians' practices to focus more on the patient's strengths and resilience. The comprehensive, generic descriptions of daily life adaptation cannot be covered with a single cross-sectional instrument. Although the ESM tool supports this holistic approach, its integration in daily clinical practice does not come naturally. We also learned that use cases, based on real-world examples (chapter 6) helped to integrate the tool into routine clinical care.

Many attractive apps with interesting features are on the market nowadays; from year to year more end users adopt this technology. They increasingly expect certain features and functionalities[28,29]. Continual investments are needed to keep the tool operational, matching changing regulations (privacy, medical device, and data security), and incorporate new insights, improve the intuitiveness of use and user-friendliness (e.g., instruction screens in the form of infographics, that substitute extensive introductions by healthcare professionals). In addition, users want to personalize the tool (e.g., the possibility to (de-)activate items to better match their personal profile or adjust the sampling scheme to fit the individual's waking hours). The availability of these customizations developed together with end users might improve the prolonged use of the ESM tool. For example, a more intuitive, user-friendly

interface for the PsyMate™ web-based reporting tool that automatically generates personalized feedback will improve data transparency and simplify adoption for both healthcare professionals and their patients. Another possibility would be a more narrative representation of the data in which we retain the exploration and engagement of the end users. We are looking into this more narrative representation in a project to adapt the PsyMate™ to people who are visually impaired. A narrative version of the web-based reporting tool can make feedback more accessible for individuals who are visually impaired, but can also lower accessibility thresholds for, for instance, people with less abstract reasoning skills. Furthermore, passive monitoring using smartphones or wearables (e.g., activity trackers to map physical activity) might supplement active ESM monitoring in future implementations[30,31], herewith reducing burden. Moreover, AI algorithms or machine learning techniques can be used to further personalize the ESM questionnaires by smart enabling or disabling items. Customization, however, is no panacea. Experience in our studies teaches us that giving end users too much freedom is an inefficient way to improve user engagement. In addition, gamification elements can be explored to personalize the experience-sampling technology, thereby improving the motivation for continued use[32].

Outer and inner setting

Successful implementation is subject to aspects of the outer setting (e.g., peer pressure, external policies, and incentives) and characteristics of the broader organizational environment (e.g., implementation climate and team culture). This was confirmed in our research.

Throughout the studies presented in this thesis, we learned that it is important to have sufficient time to properly introduce the ESM tool and discuss the ESM results collaboratively. Furthermore, support for the introduction of the ESM tool by the primary care holding organizations (i.e., regional care groups) is insufficient. Individual family physicians who supervise the psychological assistants should also be motivated. The whole team of colleagues, including the family physicians, need to be engaged from the start of the development process in order to enhance its uptake and use in daily clinical practice. If these barriers related to the inner setting are not eliminated, the implementation is doomed to fail. For example, implementations will be unsuccessful if psychological assistants have to use several new assessment strategies at the same time without enough time to learn and to embed them in working

routines. In the action research study, we lobbied the stakeholders and deliberately made sure that the psychological assistants got extra time to introduce the ESM tool and discuss the ESM results and they were free to decide which patients they thought could benefit from ESM in their care process.

In a modern well-organized and efficient care system, deviations from the standard work routine are difficult. Healthcare professionals follow protocols and there is limited room for experimentation and learning. However, implementation of innovative tools takes time and managerial support is crucial for healthcare professionals to invest time to learn and implement new practices. We included real-world examples and insights from research on barriers and facilitators in eHealth[33,34]. An iterative action research approach, that involves both healthcare professionals and their patients, ensures a better chance of sustainable implementation of innovative tools[16].

Individual characteristics

The next domain in the CFIR model describes end user characteristics (e.g., beliefs and knowledge). In this study, healthcare professionals and their patients, were the end users of the ESM implementation.

Since innovative tools are more likely to be implemented in routine clinical care when stakeholders are actively engaged, we involved both psychological assistants and their patients from the start of the project. Co-creative techniques were used to improve the active involvement of all relevant stakeholders. These techniques are more frequently used in design and business, but are also applicable in research[35]. We used co-creative techniques such as empathy mapping[9], personas[9] and the MoSCoW method[11]. Researchers need training and support to choose and perform the adequate techniques[36,37]. This project was part of the Brightlands Innovation Program LIME (Limburg Measures; limeconnect.nl), a program that facilitates smarter measurement methods and more efficient data collection for better care and health, funded by the Province of Limburg, Zuyd University of Applied Sciences, and Maastricht University, the Netherlands. A co-creation team, consisting of two co-creation experts, supported the research teams and developed a Co-creation Impact Compass for healthcare researchers[36]. In addition, we used the participation ladder to determine the degree of stakeholder involvement in every project phase, ranging from mere informing them to giving them full control[38]. Stakeholders participated mostly to the full extent of the participation ladder. We searched for a good balance between stakeholders' maximized freedom of

choice to increase their intrinsic motivation and limitations due to scientifically proven findings imputed by the research team. Therefore, given that experience-sampling design principles have a long backing in research, some proposed adjustments (e.g., less frequent assessments) collected during co-creation were known not to work (falsified in previous research) and consequently were not implemented.

Healthcare professionals

We learned that it is important to value the professionalism and expertise of the psychological assistants to achieve a sustainable implementation. However, it is also recommended that healthcare professionals master the eHealth tool before introducing it to the patient. Therefore, they need to gain skills and knowledge on when and how to use the tool in patient consultations. The action research strategy learned us that the introduction of the ESM tool has to be intuitive to support use by patients. The learning curve is important and should be short. Also, is important that tools can be used in different target populations, to allow them to become routine. We initially restricted the target population to patients with anxiety or sleeping problems. We hoped this would focus psychological assistants to refer patients. But after an initiation phase, the psychological assistants spontaneously expanded the target population to also include, for example, patients with addiction problems or patients with acquired brain injury. This shows that healthcare professionals learned the generic potential of ESM.

Patients

We also learned that it is important to engage patients from the start of the project. But, this was not easy since we used a mediating strategy where the psychological assistants and not the researchers managed the contact with patients. The psychological assistants decided to primarily recruit patients who wanted to explore personal strengths and weaknesses and incorporate these in their recovery process. We observed that the web-based reporting tool required specific skills of psychological assistants and patients: digital skills and the ability to abstract reasoning. Positive experiences with active, motivated patients were crucial for the motivation of psychological assistants. In contrast to classic questionnaires or diaries that are often binge-completed in the waiting room, the living situations of persons are very diverse. Workplace regulations, patient preferences (e.g., not wanting to gain insight into

underlying patterns or psychological mechanisms) or personal restrictions (e.g., poor motor control) need to be considered. Consequently, this technology is neither a one-size-fits-all solution, nor a stand-alone treatment that can be applied to every patient in every situation. The question remains who benefits from using the ESM tool. It is important to focus on motivating patients and explaining them the advantages. We need to train patients and make patients owner of their personal research process (user-scientist). This approach can improve the adoption and implementation of eHealth. Another participatory action research study demonstrated the importance of involving a patient expert as an educator and coach of the researchers[37].

Implementation process

The last domain describes activities related to the implementation process (e.g., reflecting and evaluating, and stakeholder engagement).

The transition from pilot to implementation and upscaling eHealth to regular clinical practice is described as a barrier[39]. Different implementation strategies exist, but it is difficult to choose the method that optimally fits the implementation phase and context[1,40,41]. Throughout the project, we used the CFIR[1] to analyze the barriers and facilitators encountered during the redesign process to use and implement the ESM tool in family medicine. In our action research study, we tried to optimize potential barriers related to the device, the inner setting and the individual characteristics. The eHealth monitor 2019 confirmed the importance of shifting the focus from the technology to the impact in healthcare[39]. eHealth tools must therefore be tailored to the end users, thereby requiring a transformation in which care processes and digital tools are aligned[39]. Furthermore, the eHealth monitor 2013 already pointed out that practice and training are not sufficient for sustainable implementation of eHealth tools in healthcare. A mind shift in the way of working is also necessary[42]. So, if we want self-management support with eHealth tools to improve care, a cultural change is required among healthcare professionals and management. Successful implementation of these tools goes beyond technology, it is also a behavioral innovation[42]. Technology is not an end in itself; it is a means to an end.

An increasing workload, the scarcity of staff and the high administrative burden in modern care, creates a sense of urgency for the use of eHealth as part of healthcare[39]. Throughout our project, we learned that both psychological assistants and their patients must acquire first-hand experiences

in using ESM in routine clinical care. Therefore, engaging end users, including early adopters, from the start of the development process is important to ensure a close fit between the ESM tool and its end users. We advise to approach them proactively and build a working alliance between users and the research team.

The COVID-19 pandemic created momentum for the use of eHealth in family medicine. The sense of urgency was large and many people were able to experience the added value, which is a prerequisite for implementation. However, we learned during the action research study that remote instruction and demonstration of the ESM tool were not successful. Some existing applications have been scaled up rapidly, but thorough implementation in existing work routines often remains lacking[43]. So, it will take time for eHealth tools to become natural part of routine practice.

We learned during the design thinking study and action research study that efficient and tailored coaching on the job is needed to achieve sustainable implementation of the ESM tool in routine clinical care. Short communication lines such as mail, WhatsApp and telephone contact are important to enhance the engagement of the healthcare professionals and create a community in which they could learn from each other.

After use and implementation, the next step is to evaluate the effectiveness of new assessment strategies or interventions. Classic RCTs might be less feasible for the evaluation of innovative tools because of difficulties in the inclusion of a randomly assigned control group and the need to freeze interventions[44–46]. Technological developments iterate quickly and often tools have to be redesigned after the formal evaluation, requiring a new evaluation cycle[46]. Therefore, alternative approaches such as process evaluations or realist evaluations are proposed to evaluate these complex interventions[47].

Implications and recommendations

Based on the summary of the main findings, the methodological considerations and the lessons learned, as described above, the implications and recommendations for daily clinical practice, future research and education will be discussed.

Daily clinical practice

To implement experience-sampling technology in daily clinical practice, we suggest to:

- be aware that the implementation is influenced by various factors. Attention has to be paid to the intervention and device characteristics, external factors, characteristics of the implementing organization, end users' characteristics and the implementation process;
- consider the sense of urgency concerning the use of the ESM tool in daily clinical practice;
- consider that the use and implementation of experience-sampling technology is a growth process, in which the healthcare professionals need to adapt their work processes, requiring the necessary resources and a mind shift in the way of working. Furthermore, both psychological assistants and their patients must experience the added value;
- not only pay attention to the content and functionalities of the tool, but also to provide the rationale for using such technology during patient consultations;
- tailor the use of experience-sampling technology to the patient's needs, wishes and care process, aligned with the biopsychosocial model[26] and process of clinical reasoning;
- train patients and make them owner of their personal research process;
- tailor and test the exact use and implementation in the specific population and healthcare setting, based on the need assessment of both healthcare professionals and their patients;
- start with early adopters to create a community in which they can share experiences, reflect on and learn from each other and be good examples for other professionals;
- think about the support of an external coach, contact point or helpdesk.

Future research

Based on the findings presented and research themes emerging in this thesis, we suggest to:

- focus on bridging the gap between research and daily clinical practice in implementation studies by applying co-creative techniques and an action research approach, including the active involvement of all relevant stakeholders;

- use the participation ladder to consider how to engage patients at different and meaningful levels (i.e., informing, consulting, engaging, co-designing and co-producing);
- explore strategies to enable and support healthcare professionals towards actual behavioral change by testing and evaluating the feasibility of experience-sampling technology with different patient populations;
- evaluate the effect of the use of experience-sampling technology to improve sustainable implementation;
- investigate the opportunity of supplementing active self-monitoring with passive self-monitoring via smartphones or wearables (e.g., physical activity or heart rate variability)[30,31] or using artificial intelligence algorithms or machine learning techniques to personalize the ESM questionnaire;
- explore in co-creation with the end users the possibility of adding reward gamification elements (e.g., goal setting, e-community function) and in-app feedback (e.g., progress of beeps, average mood during the day) that is easy to read and interpret to increase the motivation for sustainable use of experience-sampling technology[32].

Education

Based on the findings presented in this thesis, we suggest to:

- get acquainted with eHealth during their medical or clinical training in which it is especially important to pay attention to its use in daily clinical practice and patient involvement;
- provide use cases, based on real-world examples, to illustrate when and how to use the eHealth tool in routine clinical care to support problem explorations in patients suffering from mental health problems;
- invest in both theoretical and practical training of the healthcare students and healthcare professionals, in which they can experience and learn from each other about the use of the eHealth tool in existing work routines.

General conclusion

The studies in this thesis have contributed to understand and support the use of experience-sampling technology, the PsyMate™, in daily clinical practice. The studies show that is challenging to embed experience-sampling technology in

family medicine. The PsyMate™ and implementation procedures need further fine-tuning to adequately fit the needs of patients and the work processes of psychological assistants. Becoming acquainted with the momentary assessment approach can be considered a growth process, that requires time for learning and understanding as well as adaptation of routines. Learning from each other and coaching are necessary. Various lessons learned and recommendations have been articulated, for which the experience-sampling platform, the PsyMate™, needs further research to empower future healthcare professionals, patients, and healthy individuals to use it in daily routines.

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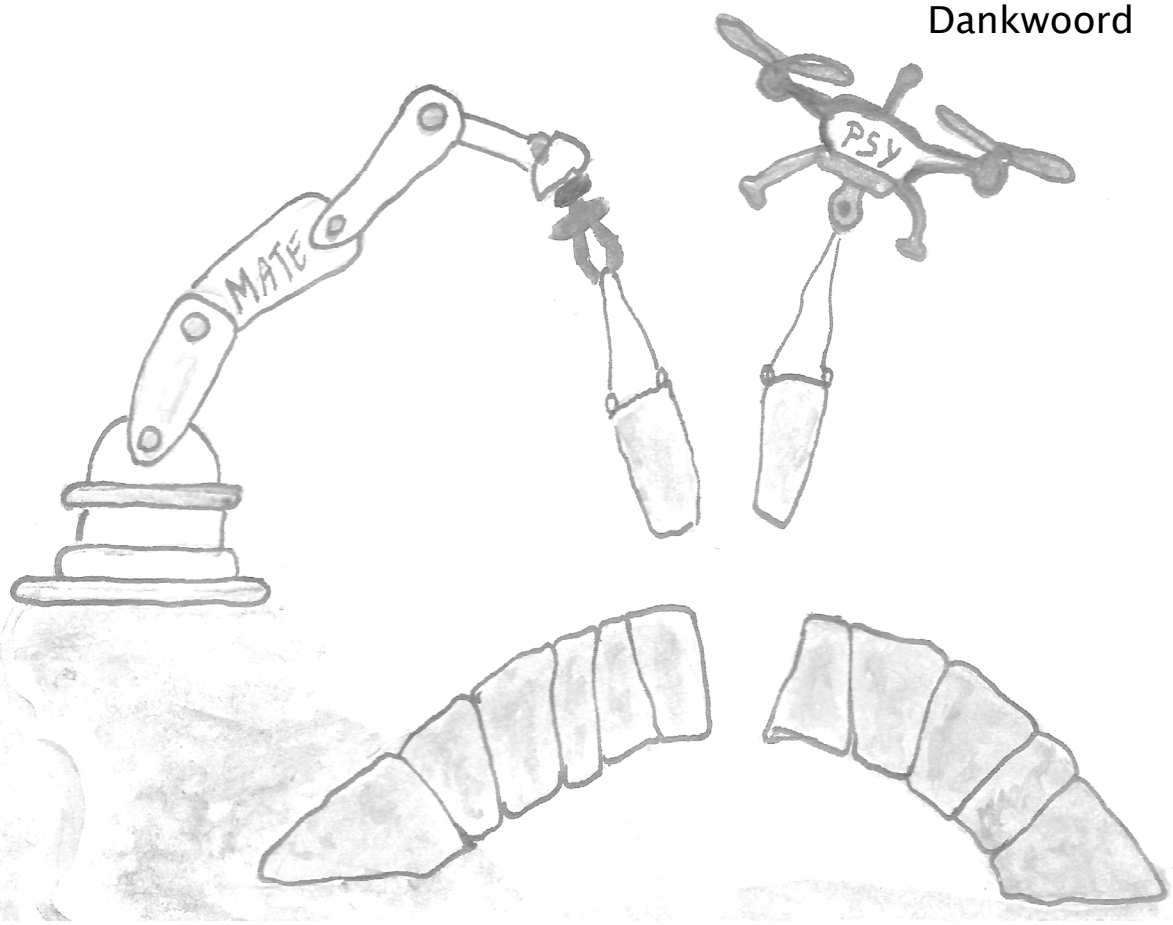
Addendum



Summary

In modern healthcare, a shift occurs from an exclusive focus on symptom reduction to include physical well-being, social participation, personal recovery and quality of life. This aligns with the multidimensional experience of health. This refocus asks for new assessment technologies. Standard self-report assessments such as diaries only aim at detecting vulnerabilities and offer insufficient insight into mental health variation reflecting adaptation dynamics in the flow of daily life due to measurement frequency and the related degree of retrospection.

In family medicine, many patients present with diffuse/fuzzy problems: pain, anxiety, depression and worries about cognitive decline. Also, therapeutic challenges exist for patients needing lifestyle changes: stop smoking or reduce drinking, adopt new dietary routines and increase mobility. For all these domains, standard assessments that focus on symptom detection are insufficient. They lack information about the contextual fluctuations of the individual's mental state or performances, and therefore the person's abilities under different circumstances.

mHealth tools based on the Experience Sampling Method (ESM) such as the PsyMate™ are proposed as an alternative to standard self-report assessments (clinical observations, interviews or questionnaires). ESM allows momentary assessments of mood, cognition, perception, and behavior in the context of daily life, thereby monitoring vulnerabilities as well as strengths and resilience. The PsyMate™ is extensively studied in academic research, across patient populations with psychiatric and somatic disorders, and different age ranges. However, there is a gap in empirical knowledge about the feasibility (i.e., the extent to which experience-sampling technology is easy to use) and the usability (i.e., the extent to which experience-sampling technology can be embedded in family medicine) of experience-sampling technology in family medicine. Therefore, the main objective of this thesis was to explore the continued development and implementation of an experience-sampling platform, the PsyMate™. The PsyMate™ was proposed as an mHealth tool to support problem explorations for patients suffering from mental health problems in family medicine. The current applications of ESM target primarily affect, perception (pain) and behavior. Assessment of cognitive functioning still is an unexplored field. Patients with psychosocial problems often experience

difficulties remembering, concentrating, planning, and organizing. The patient's cognitive abilities determine whether he/she can cope with the demands of everyday life. Therefore, the secondary objective of this thesis was to improve the assessment of cognitive performance in daily life. With our results, we aim to contribute to bridging the gap between academic research and routine clinical care.

To achieve these objectives, this thesis has three parts. **Part I** explores the current practice of using electronic diaries in healthcare. **Part II** assesses the feasibility of experience-sampling technology by administering two newly developed objective momentary cognition tasks. **Part III** explores the continued development and implementation process of experience-sampling technology to support problem explorations in family medicine.

Chapter 1 is an introduction of the topic of this thesis. It describes the transition from illness to well-being in mental healthcare, incorporating a broader perspective on the health concept that includes various health domains in addition to symptom reduction. The chapter then outlines the standard self-report assessments (questionnaires and diaries) used in healthcare to collect subjective information about symptoms, daily life functioning, participation and quality of life. It reviews the advantages and disadvantages of self-report assessments. Afterwards, mHealth tools using the Experience Sampling Method are proposed as an alternative. The PsyMate™ is an example of an experience-sampling platform to map the patient's daily life functioning. It is mostly used in research settings and challenges regarding the implementation of mHealth tools in family medicine are discussed. The chapter concludes with the thesis aims, research questions and thesis outline.

Exploring current practice

Chapter 2 outlines the current empirical knowledge about factors that influence the use of electronic diaries in healthcare, in a scoping review. Here, 'electronic diaries' are defined as repeated individual psychosocial or physical data collection using measurement tools on a smartphone or on a computer. 'Use' is defined as the repeated recording of information in electronic diaries by patients or healthy individuals for at least one week. The literature published between January 2000 and December 2018 was screened. Data were analyzed

through directed content analysis, using the Consolidated Framework for Implementation Research (CFIR). The CFIR consists of five categories: (1) key attributes of the electronic diary device, (2) economic, political and social context of the organization, (3) internal architecture of the organization and implementation climate, (4) characteristics of the individuals who use the electronic diary and (5) activities related to the implementation process. The findings of this study indicated that electronic diary use could be influenced by the technology (i.e., reminders, attractive designs, tailored and clear data visualization), the end user (i.e., smartphone experience, intrinsic motivation to change behavior) and the implementation process (i.e., theoretical and practical training). However, most included studies did not take into account the structural, political and cultural organizational context, and the implementation climate Therefore, the findings of this study suggested to investigate an integrated approach for experience-sampling technology including these aspects. Researchers might use longitudinal and mixed methods study designs to examine the causal relationships between all relevant factors.

Cognition in daily life

Chapter 3 describes the feasibility of an experience-sampling platform, the PsyMate™, by administering a newly developed objective cognition task in healthy individuals. Forty healthy individuals tested a symbol substitution task measuring information processing speed for six consecutive days. The feasibility was assessed by multilevel regression analyses, with the number of trials performed in a 30-second interval (speed) and the percentage of correct trials (accuracy) as cognition outcome measures. The participants indicated that this symbol task was easy and pleasant to perform. This was also visible in the high degree of accuracy (97%). Cognitive performance varied over time, with a slight increase in trials in the first days of the monitoring period (adaptation period) and more trials completed towards the end of the day (within-day fluctuations). Moreover, momentary cognition was related to mood, more specifically feeling cheerful, irritated and anxious, and context in terms of distraction and location. Healthy individuals completed more trials and made fewer mistakes when they felt cheerful. They completed more trials when they felt irritated whereas they made more mistakes when they felt anxious. Healthy individuals also completed fewer trials and made more mistakes when they felt

distracted. To conclude, the findings indicated that an experience-sampling platform is feasible to apply momentary cognition tasks in healthy individuals.

Chapter 4 extends the study described in Chapter 3. An additional objective cognition task, measuring concentration and visuospatial working memory, had been developed. The chapter describes the feasibility and validity of an experience-sampling platform, the PsyMate™, by administering these two cognition tasks in a new sample of healthy individuals. In total, 49 healthy individuals with an age range between 19 and 73 years old tested both momentary cognition tasks for 6 consecutive days. The feasibility and the validity were assessed by descriptive statistics and multilevel regression analyses, with the numbers of trials performed in a 30-second interval (speed) and the percentage of correct trials (accuracy) for the symbol substitution task, and correct/incorrect for the visuospatial working memory task as cognition outcome measures. The participants reported positive experiences with the tasks and felt motivated to perform well. However, the visuospatial working memory task was too difficult, as reflected in the low number of correct scores (37%). Momentary cognitive performance was related to the context, specifically being in company and feeling distracted. Healthy individuals made more mistakes in the visuospatial working memory task when they were in company and felt distracted. They also completed fewer trials in the symbol substitution task when they were in company and felt distracted. Older individuals completed fewer trials in the symbol substitution task. In addition, healthy individuals made more mistakes in the symbol substitution task when being distracted. This study thus confirmed that the PsyMate™ is feasible to apply momentary cognition tasks in daily life. However, these tasks need further fine-tuning. This study also concluded that more research is needed to demonstrate the validity and usability of short objective cognition tasks in daily clinical practice.

Continued development and implementation of experience-sampling technology in family medicine

Chapter 5 describes the co-creative redesign process of the PsyMate™ to adjust the tool to the needs of the psychological assistants to support problem explorations for patients suffering from mental health problems in family medicine. Phases from the design thinking framework, understand, explore and materialize, were used to redesign the experience-sampling platform. In co-

creation with two groups of fifteen psychological assistants, we gathered information about patient characteristics and current eHealth use. Next, the content and functionalities of the PsyMate™ were further developed in co-creation with five psychological assistants. Finally, four psychological assistants tested the adjusted PsyMate™ in daily clinical practice for four months. The data were analyzed using content analysis. We gained meaningful insights into the needs and desires of the psychological assistants in family medicine. The important user requirements were the motivational functionalities, the technological performance and the instructions about the use of the PsyMate™, especially the introduction and results discussion within their work processes. The psychological assistants encountered severe barriers related to the use and uptake of the PsyMate™: (1) insufficient consultation time to introduce the platform and discuss the results, (2) insufficient skills and knowledge to use the tool to support problem explorations during patient consultations, and (3) the web-based reporting tool proved too difficult to read and interpret quickly. Despite these severe barriers, the implementation of an experience-sampling platform in family medicine seemed promising, but the PsyMate™ needed further fine-tuning to fit with the daily routines of the psychological assistants. In conclusion, implementing this technology was not only a technological innovation, but also a behavioral innovation. We recommended to focus on the usefulness of this platform in family medicine and to include patient experiences in future research.

Chapter 6 describes a step-by-step guide on how and when to use experience-sampling technology to support problem explorations in daily clinical practice. We integrated empirical knowledge from the literature with expert experiences, and provided real-world examples and recommendations to facilitate the use and implementation of experience-sampling technology in routine clinical care. The step-by-step guide describes the relevant stages to apply this technology: (1) determine suitability, (2) decide to use the experience-sampling tool, (3) introduce the experience-sampling tool, (4) use the experience-sampling tool, and (5) discuss the ESM results to support problem explorations. We noticed that it is useful to focus on a collaborative care process between the healthcare professional and the patient in every relevant stage. Moreover, we suggested to be cautious about the interpretation of the monitoring results because the data is in essence probabilistic, leading at best to hypotheses on what is going on. To conclude, we recommended to tailor the recommendations to the end users' needs and skills, and test them in different target populations and healthcare

settings. More research is also needed to investigate end user experiences and the implementation process.
The findings of the aforementioned studies were used as input for the action research, described in **Chapter 7**, which aimed to test and evaluate the experience-sampling technology in family medicine, and learn about the experiences with its use of both patients and their psychological assistants. The PsyMate™ was tested, evaluated and adjusted in collaboration with psychological assistants and their patients with anxiety or sleeping problems. Organizational barriers identified in Chapter 5 were optimized. The findings of this study demonstrated that it remained difficult to integrate experience-sampling technology into existing work routines. However, when the integration succeeded, it yielded meaningful insights into the relation between mood or physical status and the situations in which they occur for both patients and their psychological assistants. When compared to conventional consultations, the psychological assistants felt able to conduct more in-depth problem explorations about the patients' vulnerabilities and strengths in different situations, thereby promoting patient empowerment. The findings of this study also indicated that demonstrating the tool to the patient and completing practice questionnaires together, tailoring the discussion of the monitoring results to the patient's care process and interpreting these results together helped to integrate the PsyMate™ into the existing work processes of psychological assistants in family medicine. To ensure a better fit between the patients' care processes, the work processes of the psychological assistants and the tool, the tool needs further fine-tuning. This study concluded that it is a growth process for psychological assistants to become familiar with the use of the PsyMate™ within their daily routines. To achieve this growth process, the action research was a good study design to learn from each other, and to coach psychological assistants.

Chapter 8 summarizes the main findings of each part of the project and discusses overall methodological considerations about the study designs used, the participants, and the transferability, data triangulation and credibility of the results. It then discusses the lessons learned for mHealth implementation in daily clinical practice and research. This chapter ends with a summary of implications and recommendations for daily clinical practice, future research and education. The general discussion chapter reflects on the factors that influence the use and implementation of an experience-sampling platform, the PsyMate™, in routine clinical care. Its implementation did not only include

technological changes, but also behavioral changes. It required both theoretical and practical training for the psychological assistants in family medicine. Throughout the project, we noticed that it was meaningful to involve relevant stakeholders early in the development and implementation process to assess their wishes and needs. Moreover, we observed that it was useful to realize short communication lines, coaching on the job sessions and opportunities for the psychological assistants to share experiences and learn from each other. Providing sufficient time and resources seemed a precondition to ensure that the psychological assistants were ready for the uptake and use of innovative technologies. The findings presented in this thesis indicated that the psychological assistants as well as the regional care group need to realize that implementation of an experience-sampling platform takes time. Getting familiar with this technology is a growth process.

Samenvatting

In de moderne gezondheidszorg vindt een verschuiving plaats van een exclusieve focus op symptoomvermindering naar een inclusieve focus op lichamelijk welzijn, maatschappelijke participatie, persoonlijk herstel en kwaliteit van leven. Deze heroriëntering naar een multidimensionale benadering van gezondheid vraagt om nieuwe beoordelingstechnieken. Standaard zelfrapportages zoals dagboeken zijn enkel gericht op het opsporen van kwetsbaarheden en bieden door de meetfrequentie en de daarmee samenhangende mate van retrospectie onvoldoende inzicht in de variatie van de geestelijke gezondheid. Met name op het gebied van inzicht in adaptatiedynamieken in het dagelijks leven schieten zelfrapportages te kort.

In de huisartsengeneeskunde presenteren veel patiënten zich met vage klachten: pijn, angst, somberheid en zorgen over cognitieve achteruitgang. Ook zijn er therapeutische uitdagingen voor patiënten waarbij die veranderingen in hun levensstijl noodzakelijk zijn: stoppen met roken of minder drinken, nieuwe eetroutines aannemen en mobiliteit vergroten. Voor al deze domeinen zijn standaardbeoordelingen gericht op symptoomdetectie onvoldoende. Ze missen informatie over de contextuele fluctuaties van de mentale toestand of prestaties van het individu, en dus de capaciteiten van de persoon in verschillende omstandigheden.

mHealth instrumenten gebaseerd op de Experience Sampling Methode (ESM), zoals de PsyMate™, worden voorgesteld als alternatief voor standaard zelfrapportagebeoordelingen en aanvullend aan klinische observaties en interviews. ESM maakt momentane beoordelingen van stemming, cognitie, perceptie en gedrag mogelijk in de context van het dagelijks leven, waarbij kwetsbaarheden, sterke punten en veerkracht worden gemeten. De PsyMate™ werd uitgebreid bestudeerd in academisch onderzoek, bij patiëntenpopulaties met psychiatrische en lichamelijke aandoeningen, en verschillende leeftijdsgroepen. Er is echter een kloof in empirische kennis over de haalbaarheid (d.w.z. de mate waarin experience-sampling technologie gemakkelijk te gebruiken is) en de bruikbaarheid (d.w.z. de mate waarin experience-sampling technologie ingebed kan worden) van experience-sampling technologie in de huisartsenpraktijk. Het hoofddoel van dit proefschrift was het onderzoeken van de doorontwikkeling en implementatie van een experience-sampling platform, de PsyMate™. De PsyMate™ werd

voorgesteld als een mHealth instrument ter ondersteuning van de klachtenanalyse voor patiënten met psychische problemen in de huisartsenpraktijk. De huidige toepassingen van ESM richten zich voornamelijk op stemming, perceptie (pijn) en gedrag. Het beoordelen van het cognitief functioneren is nog onontgonnen terrein. Patiënten met psychosociale problemen ervaren vaak moeilijkheden met herinneren, concentreren, plannen en organiseren. De cognitieve mogelijkheden van de patiënt bepalen of hij/zij kan omgaan met de eisen van het dagelijks leven. Het secundaire doel van dit proefschrift was daarom het verbeteren van de beoordeling van cognitieve prestaties in het dagelijks leven. Met onze resultaten willen we bijdragen aan het overbruggen van de kloof tussen academisch onderzoek en de klinische praktijk.

Om deze doelstellingen te bereiken, bestaat dit proefschrift uit drie delen. **Deel I** onderzoekt het huidig gebruik van elektronische dagboeken in de gezondheidszorg. **Deel II** evalueert de haalbaarheid van experience-sampling technologie voor het meten van objectieve cognitie in het dagelijks leven door twee nieuw ontwikkelde objectieve, momentane cognitietaken te testen. **Deel III** onderzoekt het doorontwikkelings- en implementatieproces van experience-sampling technologie ter ondersteuning van de klachtenanalyse in de huisartsenpraktijk.

Hoofdstuk 1 is een inleiding op het onderwerp van dit proefschrift. Het beschrijft de overgang van ziekte naar welbevinden in de gezondheidszorg, met een breder perspectief op het gezondheidsconcept dat naast symptoom-vermindering ook verschillende andere gezondheidsdomeinen omvat. Het hoofdstuk schetst vervolgens de standaard zelfrapportages (vragenlijsten en dagboeken) die in de zorg gebruikt worden om subjectieve informatie te verzamelen over symptomen, functioneren in het dagelijks leven, maatschappelijke betrokkenheid en kwaliteit van leven. Het geeft een overzicht van de voor- en nadelen van zelfrapportages. Daarna worden als alternatief mHealth instrumenten voorgesteld die gebruikmaken van de Experience Sampling Methode. De PsyMate™ is een voorbeeld van een experience-sampling platform om het functioneren in het dagelijks leven van de patiënt in kaart te brengen. Het wordt meestal gebruikt in onderzoek en uitdagingen in de implementatie van mHealth instrumenten in de huisartsenpraktijk worden besproken. Het hoofdstuk sluit af met de doelstellingen, de onderzoeksvragen en de structuur van het proefschrift.

Het verkennen van de huidige praktijk

Hoofdstuk 2 schetst de huidige empirische kennis over factoren die het gebruik van elektronische dagboeken in de zorg beïnvloeden, in een scoping review. Hier worden 'elektronische dagboeken' gedefinieerd als herhaalde individuele psychosociale of fysieke gegevensverzameling met behulp van meetinstrumenten op een smartphone of een computer. 'Gebruik' wordt gedefinieerd als het herhaaldelijk registreren van informatie in elektronische dagboeken door patiënten of gezonde personen gedurende ten minste een week. De literatuur die gepubliceerd werd tussen januari 2000 en december 2018 werd gescreend. Gegevens werden geanalyseerd door middel van gerichte inhoudsanalyse (directed content analysis), door gebruik te maken van het Consolidated Framework for Implementation Research (CFIR). Het CFIR bestaat uit vijf categorieën: (1) de belangrijkste kenmerken van het elektronisch dagboek, (2) de economische, politieke en sociale context van de organisatie, (3) de interne structuur van de organisatie en het implementatieklimaat, (4) de karakteristieken van de individuen die het elektronisch dagboek gebruiken en (5) activiteiten met betrekking tot het implementatieproces. De resultaten van deze studie gaven aan dat het gebruik van elektronische dagboeken beïnvloed wordt door de technologie (d.w.z. herinneringen, aantrekkelijke designs, op maat gemaakte en duidelijke datavisualisatie), de eindgebruiker (d.w.z. ervaring in het gebruik van een smartphone, intrinsieke motivatie om gedrag te veranderen) en het implementatieproces (d.w.z. theoretische en praktische training). De meeste geïncludeerde studies hielden echter geen rekening met de structurele, politieke en culturele organisatorische context en het implementatieklimaat. De resultaten van deze studie suggereerden daarom het onderzoeken van een geïntegreerde benadering voor experience-sampling technologie, inclusief deze aspecten. Onderzoekers kunnen longitudinale en studiedesigns met een mix aan methoden (mixed methods study designs) gebruiken om de causale relaties tussen alle relevante factoren te onderzoeken.

Cognitie in het dagelijks leven

Hoofdstuk 3 beschrijft de haalbaarheid van een experience-sampling platform, de PsyMate™, door een nieuw ontwikkelde objectieve cognitietaak te testen bij gezonde individuen. Veertig gezonde individuen testten zes opeenvolgende dagen een symbooltaak waarbij informatieverwerkingssnelheid gemeten werd.

De haalbaarheid werd beoordeeld door multilevel regressieanalyse, met het aantal behaalde trials in een interval van 30 seconden (snelheid) en het percentage correcte trials (nauwkeurigheid) als uitkomstmaten voor cognitie. De deelnemers gaven aan dat deze symbooltaak gemakkelijk en plezierig was om uit te voeren. Dit was ook zichtbaar in de hoge mate van nauwkeurigheid (97%). Cognitieve prestaties varieerden over tijd, met een lichte toename in het aantal behaalde trials in de eerste dagen van de monitoringperiode (aanpassingsperiode) en meer voltooide trials tegen het einde van de dag (fluctuaties binnen de dag). Bovendien was momentane cognitie gerelateerd aan stemming, meer specifiek zich opgewekt, geïrriteerd en angstig voelen, en context in de zin van afleiding en locatie. Gezonde individuen voltooiden meer trials en maakten minder fouten wanneer ze zich opgewekt voelden. Ze voltooiden meer trials wanneer ze zich geïrriteerd voelden, terwijl ze meer fouten maakten wanneer ze zich angstig voelden. Gezonde individuen voltooiden ook minder trials en maakten meer fouten wanneer ze afgeleid waren. Concluderend gaven de resultaten aan dat een experience-sampling platform haalbaar is om momentane cognitietaken toe te passen bij gezonde individuen.

Hoofdstuk 4 is een uitbreiding van de studie beschreven in Hoofdstuk 3. Er werd een aanvullende objectieve cognitietaak ontwikkeld die concentratie en visueel-ruimtelijk werkgeheugen meet. Het hoofdstuk beschrijft de haalbaarheid en validiteit van een experience-sampling platform, de PsyMate™, door deze twee cognitietaken te laten testen door een nieuwe steekproef van gezonde individuen. In totaal testten 49 gezonde individuen met een leeftijd tussen 19 en 73 jaar beide momentane cognitietaken gedurende 6 opeenvolgende dagen. De haalbaarheid en validiteit werden beoordeeld met beschrijvende statistiek en multilevel regressieanalyse, met het aantal behaalde trials in een interval van 30 seconden (snelheid) en het percentage correcte trials (nauwkeurigheid) voor de symbooltaak, en juist/onjuist voor de visueel-ruimtelijke werkgeheugentaak als uitkomstmaten voor cognitie. De deelnemers rapporteerden positieve ervaringen met de taken en voelden zich gemotiveerd om goed te presteren. De visueel-ruimtelijke werkgeheugentaak was echter te moeilijk, zoals blijkt uit het laag aantal correcte scores (37%). Momentane cognitieve prestaties waren gerelateerd aan de context, meer specifiek in gezelschap zijn en afgeleid zijn. Gezonde individuen maakten meer fouten in de visueel-ruimtelijke werkgeheugentaak wanneer ze in gezelschap waren en afgeleid waren. Ze voltooiden ook minder trials in de symbooltaak wanneer ze

in gezelschap waren en afgeleid waren. Oudere individuen voltooiden minder trials in de symbooltaak. Bovendien maakten gezonde individuen meer fouten in de symbooltaak wanneer ze afgeleid waren. Deze studie bevestigde dus dat de PsyMate™ haalbaar is om momentane cognitietaken in het dagelijks leven toe te passen. Deze taken moeten echter nog verfijnd worden. Deze studie concludeerde ook dat er meer onderzoek nodig is om de validiteit en bruikbaarheid van korte, objectieve cognitietaken in de dagelijkse klinische praktijk aan te tonen.

Doorontwikkeling en implementatie van experience-sampling technologie in de huisartsenpraktijk

Hoofdstuk 5 beschrijft het co-creatieve redesign proces van de PsyMate™ om het platform aan te passen aan de behoeften van de praktijkondersteuners GGZ (POH-GGZ) ter ondersteuning van de klachtenanalyse voor patiënten met psychische problemen in de huisartsenpraktijk. Fasen uit het design thinking framework – begrijpen, verkennen en materialiseren – werden gebruikt om het experience-sampling platform aan te passen. In co-creatie met twee groepen van vijftien POH-GGZ hebben we informatie verzameld over patiëntkenmerken en het huidige eHealth gebruik. Vervolgens zijn in co-creatie met vijf POH-GGZ de inhoud en functionaliteiten van de PsyMate™ doorontwikkeld. Ten slotte testten vier POH-GGZ de aangepaste PsyMate™ gedurende vier maanden in de dagelijkse klinische praktijk. De gegevens werden geanalyseerd met behulp van inhoudsanalyse. We kregen zinvolle inzichten in de behoeften en wensen van de POH-GGZ in de huisartsenpraktijk. De belangrijkste gebruikerseisen waren de motiverende functionaliteiten, de technologische prestaties en de instructies over het gebruik van de PsyMate™, met name de introductie en resultaatbespreking binnen hun werkprocessen. De POH-GGZ ondervonden ernstige barrières met betrekking tot het gebruik en de acceptatie van de PsyMate™: (1) onvoldoende consulttijd om het platform te introduceren en de resultaten te bespreken, (2) onvoldoende vaardigheden en kennis om het platform te gebruiken ter ondersteuning van de klachtenanalyse tijdens patiëntconsulten, en (3) de web-based rapportagemodule bleek te moeilijk om snel te lezen en te interpreteren. Ondanks deze barrières leek de implementatie van een experience-sampling platform in de huisartsenpraktijk veelbelovend, maar de PsyMate™ moet verder verfijnd worden om te passen bij de dagelijkse routines van de POH-GGZ. Concluderend, het implementeren van deze

technologie was niet alleen een technologische innovatie, maar ook een gedragsinnovatie. We raden aan om te focussen op de bruikbaarheid van dit platform in de huisartsenpraktijk en om de ervaringen van patiënten mee te nemen in toekomstig onderzoek.

Hoofdstuk 6 beschrijft een stapsgewijze handleiding over hoe en wanneer experience-sampling technologie gebruikt kan worden ter ondersteuning van de klachtenanalyse in de dagelijkse klinische praktijk. We hebben empirische kennis uit de literatuur geïntegreerd met ervaringen van experten, en hebben praktijkvoorbeelden en aanbevelingen gegeven om het gebruik en de implementatie van experience-sampling technologie in routinematige klinische zorg te vergemakkelijken. De stapsgewijze handleiding beschrijft de relevante stappen om deze technologie toe te passen: (1) bepaal de geschiktheid, (2) beslis om de experience-sampling technologie te gebruiken, (3) introduceer de experience-sampling technologie, (4) gebruik de experience-sampling technologie, en (5) bespreek de ESM resultaten ter ondersteuning van de klachtenanalyse. We merkten dat het zinvol was om in elke relevante stap te focussen op een gezamenlijk zorgproces tussen de zorgprofessional en de patiënt. Bovendien stelden we voor om voorzichtig te zijn met de interpretatie van de monitoringresultaten omdat de data in wezen probabilistisch is en op zijn best leidt tot hypothesen om het gesprek op gaan te brengen over wat er aan hand is. Tot slot, adviseerden we om de aanbevelingen af te stemmen op de behoeften en vaardigheden van de eindgebruikers en deze te testen in verschillende doelgroepen en zorginstellingen. Er is meer onderzoek nodig om de ervaringen van eindgebruikers en het implementatieproces in kaart te brengen.

De bevindingen van de bovengenoemde studies werden gebruikt als input voor het actieonderzoek, beschreven in **Hoofdstuk 7**, dat als doel had de experience-sampling technologie in de huisartsenpraktijk te testen en te evalueren, en om meer te weten te komen over de ervaringen in het gebruik van zowel patiënten als hun POH-GGZ. De PsyMate™ werd getest, geëvalueerd en aangepast in samenwerking met POH-GGZ en hun patiënten met angst- of slaapproblemen. De organisatorische barrières geïdentificeerd in Hoofdstuk 5 werden geoptimaliseerd. De bevindingen van deze studie toonden aan dat het moeilijk bleef om experience-sampling technologie te integreren in bestaande werkroutines. Wanneer de integratie echter wel lukte, leverde dit voor zowel patiënten als hun POH-GGZ zinvolle inzichten op in de relatie tussen stemming

of fysieke toestand en de situaties waarin deze zich voordoen. In vergelijking met conventionele consulten, voelden de POH-GGZ zich in staat om meer diepgaande klachtenanalyses uit te voeren over de kwetsbaarheden en sterktes van de patiënt in verschillende situaties, waardoor het zetten van de patiënt in zijn/haar kracht bevorderd werd. De resultaten van deze studie gaven ook aan dat het demonstreren van het platform aan de patiënt en het samen invullen van de oefenvragenlijsten, het afstemmen van de bespreking van de monitoringresultaten op het zorgproces van de patiënt en het samen interpreteren van deze gegevens hielpen om de PsyMate™ te integreren in de bestaande werkprocessen van de POH-GGZ in de huisartsenpraktijk. Om te zorgen voor een betere aansluiting tussen de zorgprocessen van de patiënt, de werkprocessen van de POH-GGZ en het platform, moet het platform verder worden verfijnd. Deze studie concludeerde dat het een groeiproces is voor POH-GGZ om vertrouwd te raken met het gebruik van de PsyMate™ in hun dagelijkse routines. Om dit groeiproces te realiseren was het actieonderzoek een goede onderzoeksopzet om van elkaar te leren en POH-GGZ te coachen.

Hoofdstuk 8 vat de belangrijkste bevindingen uit elk deel van het project samen en bespreekt algemene methodologische overwegingen over de gebruikte onderzoeksopzet, de deelnemers, en de overdraagbaarheid, datatriangulatie en geloofwaardigheid van de resultaten. Vervolgens worden de geleerde lessen besproken voor de implementatie van mHealth in de dagelijkse klinische praktijk en onderzoek. Dit hoofdstuk eindigt met een samenvatting van implicaties en aanbevelingen voor de dagelijkse klinische praktijk, toekomstig onderzoek en onderwijs. Het algemene discussiehoofdstuk reflecteert op de factoren die van invloed zijn op het gebruik en de implementatie van een experience-sampling platform, de PsyMate™, in routinematige klinische zorg. De implementatie omvatte niet alleen technologische veranderingen, maar ook gedragsveranderingen. Het vereiste zowel theoretische als praktische training van de POH-GGZ in de huisartsenpraktijk. Gedurende het hele project merkten we dat het zinvol was om relevante stakeholders vroeg in het ontwikkel- en implementatieproces te betrekken om hun wensen en behoeften te inventariseren. Bovendien constateerden we dat het nuttig was om korte communicatielijnen, coaching sessies in de praktijk en mogelijkheden voor de POH-GGZ om ervaringen uit te wisselen en van elkaar te leren te realiseren. Het aanbieden van voldoende tijd en middelen leek een voorwaarde om ervoor te zorgen dat de POH-GGZ klaar waren voor de opname en het gebruik van innovatieve technologieën. De bevindingen in dit proefschrift geven aan dat

zowel de POH-GGZ als de regionale zorggroep zich moeten realiseren dat de implementatie van een experience-sampling platform tijd kost. Vertrouwd raken met deze technologie is een groeiproces.

Impact

This impact chapter describes the scientific and societal impact of the findings presented in this thesis. Furthermore, we discuss the relevance of the findings per stakeholder. Finally, we describe the dissemination activities performed during this doctoral project.

Aim and main conclusions

The main aim of this thesis was to explore the continued development and implementation of an experience-sampling platform, the PsyMate™. The PsyMate™ was proposed as an mHealth tool to support problem explorations for patients suffering from mental health problems in family medicine. This thesis has three parts, including five studies. **Part I** explored the current practice about the use of electronic diaries in healthcare. Electronic diary use relies on the content and design of the tool, external policies and incentives for use, the implementation climate in the organization, the end users' beliefs and attitudes, and activities related to the implementation process. **Part II** assessed the feasibility of experience-sampling technology by administering two newly developed objective cognition tasks measuring respectively information processing speed, and visuospatial working memory and concentration in healthy individuals. Experience-sampling technology is feasible for the application of momentary cognition tasks in the daily life of healthy individuals. They reported positive experiences with these tasks and felt motivated to perform well. **Part III** explored the continued development and implementation of an experience-sampling platform to support problem explorations for patients suffering from mental health problems in family medicine. Embedding an mHealth tool to support the exploration of core problems and resilience in family medicine seems promising, yet challenging. Fine-tuning of the technology of the PsyMate™ remains essential to ensure an optimal fit with the end users' wishes, needs and routines. Some required improvements were technological, but we also recommended to provide both theoretical and practical training, and coaching on the job sessions for psychological assistants. In addition, we concluded that it was important that the organization provides the adequate resources (e.g., time, financial reimbursements) to support psychological assistants with embedding experience-sampling technology in existing work routines.

Scientific impact

Mapping the factors that influence the use of electronic diaries in healthcare contributes to the understanding of the essential elements for future implementation. The scoping review concluded that design aspects, end users' characteristics, and training and instructions determine electronic diary use (**Chapter 2**). Two articles in this thesis describe the development and evaluation of new momentary cognition tasks to supplement health domains not covered in the original set of universal ESM items (**Chapter 3 and 4**). The findings of these studies contribute to the knowledge about the feasibility of experience-sampling technology. Fuzzy memory problems are important worries for many patients consulting family physicians. With the design thinking study, we showed how to approach a redesign process of an experience-sampling platform in a concrete and systematic way, using co-creation methods (**Chapter 5**). The redesign process led to meaningful insights into the needs and work routines in family medicine. In implementation research, attention needs not only be payed to the technological barriers, but also to organizational, practical and end users' barriers. To discover how and when an experience-sampling platform can be embedded in routine clinical care, we opted for an action research approach to engage end users, in line with their needs and daily routines (**Chapter 7**). We tried to collect in-depth knowledge by optimizing the barriers encountered in the design thinking study. This study design is not often used in daily clinical practice because there are many barriers and the researchers have insufficient knowledge and skills about the clinical reasoning process. The action research study yielded meaningful insights into the use and experiences of psychological assistants and their patients, and the implementation of experience-sampling technology in family medicine. It also allowed the psychological assistants and their patients to experience and learn about when and how they could use experience-sampling technology to support problem explorations in family medicine. These research designs were needed to understand why experience-sampling technology would (not) be used in routine clinical care. The iterative approach ensured the active involvement of the end users, resulting in a close collaboration between the research team and the end users. However, this was not easy because getting started with the ESM tool was already challenging for the psychological assistants and we used a mediating strategy where the psychological assistants managed the contact with patients. Although end user involvement was only partly successful in our project, the findings of the studies described in this

thesis are more likely to be incorporated into daily clinical practice and provide valuable evidence for the prospective implementation of experience-sampling technology or other mHealth tools in daily clinical practice.

Societal impact

This studies described in this thesis investigated the use and implementation of experience-sampling technology as a method to support problem explorations in family medicine, thereby focusing on the patients' vulnerabilities as well as strengths and resilience, in order to reduce the burden of psychosocial problems.

Worldwide, the prevalence of mental health problems in the family medicine population ranges between 20 and 55 per cent[1–8]. Mental disorders cover seven percent of the global disease burden[9]. People suffering from mental health problems experience reduced daily life functioning in different contexts (e.g., at work, at home). Despite frequent consultations in family medicine and specialist mental healthcare, current treatment of mental health problems remains challenging. Almost half of the patients with mental health problems relapse within the first year after treatment[10–12]. To prevent this relapse, scholars propose to focus on other health domains that are part of daily life functioning[13–15]. This requires the development of other assessment strategies, for example experience-sampling technology. However, although psychological assistants and patients experienced the added value of its use to support problem explorations in family medicine, experience-sampling technology was not taken for granted. Psychological assistants experienced difficulties to integrate the ESM tool into existing work processes and patients experienced difficulties to integrate it into their daily life activities. When integration succeeded, psychological assistants and their patients gained more in-depth insights into patterns of contextual variability and resilience, thereby improving patient empowerment. These findings demonstrate the importance of paying more attention to eHealth use and implementation in daily clinical practice in order to improve the actual use of the many tools that are updated daily in the Google Play Store or the App Store, thereby reducing the burden of mental health problems. Currently, a lot of attention is payed to the development of these tools[16–19]. The findings presented in this thesis contribute to the understanding, knowledge and skills to actually use and implement

experience-sampling technology or other mHealth tools in daily clinical practice.

Target population and other stakeholders

The findings presented in this thesis may be relevant to individuals suffering from mental health problems, family physicians and their psychological assistants, healthcare students, researchers, technology manufacturers and health insurance companies. This thesis was part of the Brightlands Innovation Program LIME (Limburg Measures; limeconnect.nl), a program that facilitates smarter measurement methods and more efficient data collection for better care and health, funded by the Province of Limburg, Zuyd University of Applied Sciences, and Maastricht University, the Netherlands.

Individuals suffering from mental health problems

The knowledge we have gained in this doctoral project can be an added value for individuals suffering from mental health problems. The PsyMate™ was re-designed with patients suffering from mental health problems in family medicine. The findings of this project demonstrated that the use of an experience-sampling platform is not taken for granted by patients. Individuals suffering from mental health problems who tried the PsyMate™ app, experienced it as a functional, easy to use and simple tool to monitor their vulnerabilities and strengths. However, the web-based reporting tool was too difficult for some to read and interpret quickly. The findings of this project also indicated that the PsyMate™ is feasible to assess objective cognitive performance in the daily life of healthy individuals. These findings create opportunities to gain insight into momentary cognitive functioning of healthy individuals. Gaining this insight could help healthy individuals or patients navigate and adjust daily life challenges. It may provide starting points for dealing with cognitive deficits that are individually relevant in the context of daily life. In the future, this might also be relevant to improve prevention and treatment for individuals with neurological conditions (e.g., mild cognitive impairment, Parkinson's disease, early dementia).

Family physicians and their psychological assistants

Although only psychological assistants participated in this project, the findings may be relevant to several healthcare professionals in mental healthcare as well as in somatic care, assuming that patients will get better if you pay more attention to their self-reliance. However, the use and implementation of experience-sampling technology still remains a challenge. It is not taken for granted by psychological assistants. Although severe barriers were encountered related to its uptake and use, the psychological assistants who successfully implemented the PsyMate™, experienced its added value, as it allowed in-depth problem explorations and promoted patient empowerment. The findings presented in this thesis demonstrate that the treatment can be a more collaborative process. The step-by-step guide for using experience-sampling technology in daily clinical practice that has been developed as a part of this thesis, may be helpful to healthcare professionals, as it depicts real-world examples and provides recommendations to facilitate its use (**Chapter 6**). Healthcare professionals can also benefit from the lessons learned from our action research study, through the theoretical and practical training for healthcare professionals (**Chapter 7**).

Healthcare students

The findings presented in this thesis can be used to create awareness among healthcare students about the development, use and implementation of experience-sampling technology in daily clinical practice. Although technology availability and use increase in healthcare, knowledge about the uptake and use of eHealth is limited in the course curricula of healthcare education[20]. To integrate more eHealth into the course curricula, healthcare students need to get acquainted with eHealth during their medical or clinical training in which it is especially important to pay attention to its use in daily clinical practice and patient involvement. Furthermore, providing use cases, based on real-world examples, might help healthcare students to develop abilities on when and how to use eHealth in daily clinical practice. For example, Maastricht University recently started with a major in Digital Technology and Care for health sciences students to educate students in bridging the gap between information technology and routine clinical care. Open University also incorporated a course

on e-mental health interventions for psychology students. Both curricula focus on the uptake and implementation of eHealth.

Researchers

The findings presented in this thesis contribute to the empirical knowledge about the development, use and implementation of experience-sampling technology in routine clinical care, more specifically family medicine. It is also a first step towards embedding the use of an experience-sampling platform in daily clinical practice in general and family medicine in particular. The findings provide insight into the advantages and challenges of the different study designs and co-creation methods used in our research. The findings emphasize the importance to conduct a thorough needs assessment, to involve relevant stakeholders in the redesign process of an experience-sampling tool by using co-creative techniques, and to test and evaluate its use in an iterative way with the intended end users. When using co-creative techniques, it is important to look for a trade-off between stakeholders who want to have a feeling of (psychological) mastery, and the technological feasibility of implementing changes and scientific experience of the researchers. Moreover, healthcare professionals usually have a greater say in the development process of an action research study, while the research team has a more supporting role[21–23]. But, healthcare professionals might also ask for more coaching on when and how to use experience-sampling technology or other mHealth tools, so the research team has to take a more leading role. The design and findings of the studies can be used as a starting point in future research focusing on experience-sampling technology or other mHealth tools, its use in other healthcare settings and its cost-effectiveness.

Within LIME, this doctoral project was, along with another doctoral project (the MISS Activity), part of the main theme 'Personalized Wearables'. The findings presented in this thesis are in line with the findings from the other doctoral project, demonstrating the importance of using other research designs to investigate the use and implementation of eHealth in daily clinical practice[24–26].

Technology manufacturers

To develop a specific protocol that fits with research or care practices, the PsyMate™ is available for purchase via the technology manufacturer. The findings might be useful for technology manufacturers when developing an experience-sampling platform for individuals suffering from mental health problems. Furthermore, the findings presented in this thesis indicate that it might be useful to establish more collaborations between technology manufacturers, researchers and healthcare professionals when developing eHealth tools.

Health insurance companies

The findings presented in this thesis might encourage health insurance companies, policymakers, healthcare professionals, individuals suffering from mental health problems, technology manufacturers and researchers to collaborate more when developing and implementing eHealth in routine clinical care. Health insurance companies recognize the opportunities of eHealth applications to, among others, keep healthcare affordable and accessible and, where possible, bring it closer to the patient[27]. As co-funders of healthcare, they play a role in scaling up eHealth and focus on the (cost-)effectiveness of eHealth initiatives[27]. Demonstrating that the use of eHealth applications is well-integrated into routine clinical care is a prerequisite for (cost-)effective eHealth applications.

Dissemination

Findings of this thesis were nationally shared in symposia and via (co-creative) workshops with the general population, patients, experts by experience, healthcare professionals and researchers. They were also mentioned in a radio broadcast on RTV Maastricht. Findings of this thesis were disseminated via posters, oral presentations and workshops at national and international conferences on mental health, Experience Sampling Method and digital healthcare. This project received a golden gnome as one of the three nominees for the Innovation PRoF 2018 Award; for innovative projects in the broad domain of healthcare applications and care innovation. Promotion of a better understanding and positive attitude of potential future healthcare professionals

can rely on findings presented in this thesis. They were made available through lectures, tutorials and workshops at Maastricht University and Zuyd University of Applied Sciences. Furthermore, findings of this thesis were published in international peer-reviewed journals. This project was part of the Brightlands Innovation Program LIME (Limburg Measures; limeconnect.nl), a program that facilitates smarter measurement methods and more efficient data collection for better care and health, funded by the Province of Limburg, Zuyd University of Applied Sciences, and Maastricht University, the Netherlands. Table 1 provides an overview of the dissemination activities performed during this doctoral project.

Table 1 Dissemination activities within education, healthcare and research.

Presentations	Daniels N. The use of the PsyMate™ to support detailed functional analyses in family medicine – an action research design. LAM; October 2020; Online (oral presentation). Daniels N, Ummels D. Hoe een wearable werkbaar wordt: ervaringsverhaal na doorontwikkeling van wearables en apps. Limburg Meet(ing); December 2019; Heerlen, The Netherlands (oral presentation). Daniels N, Hochstenbach L, van Zelst C, Bokhoven M, Delespaul P, Beurskens A. Successful long-term engagement in self-monitoring using e-diaries: a scoping review. MHeNs Annual Research Day; October 2019; Maastricht, The Netherlands (poster presentation). Daniels N, Daemen M. De Experience Sampling Methode: inzicht en interventies in het dagelijks leven. Jaarcongres kinder- en jeugdpsychiatrie; October 2019; Bussum, The Netherlands (workshop). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. SAA; June 2019; Syracuse, New York, the United States of America (oral presentation). Daniels N, Verhagen S, Bartels S, Tans S, Borkelmans K, de Vugt M, Delespaul P. Cognition in daily life: how to unravel momentary variation? SAA; June 2019; Syracuse, New York, the United States of America (poster presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. ENMESH; June 2019; Lisbon, Portugal (oral presentation). Daniels N, van Zelst C. PsyMate: wat kan je ermee? Landelijke week van de psychiatrie, afsluitingsdag; March 2019; Utrecht, The Netherlands (workshop). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. 3rd ESM network meeting; November 2018; Heerlen, The Netherlands (poster presentation).

	Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. MHeNs Annual Research Day; November 2018; Maastricht, The Netherlands (poster presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. CAPHRI Research Day; November 2018; Valkenburg, The Netherlands (poster presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. ISOQOL; October 2018; Dublin, Ireland (poster presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. BrainTrain Symposium; September 2018; Maastricht, The Netherlands (poster presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. PCPM – Primary Care PsyMate. PRoF 2018 Award Symposium; May 2018; Ghent, Belgium (oral presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. The value of co-creation: boosting the optimization of PsyMate™ in primary mental healthcare. MHeNs Annual Research Day; November 2017; Maastricht, The Netherlands (oral presentation). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. The value of co-creation: collaboration with primary mental healthcare professionals to boost the optimization of an ESM application in clinical practice. 2nd ESM network meeting; November 2017; Groningen, The Netherlands (oral presentation). Delespaul P, Verhagem S, Daniels N. Wat wil jij beter kunnen? Naar een persoonlijke hulpverlening… 13de Psychosecongres; November 2017; Zwolle, The Netherlands (workshop). Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Bridging the gap between research and daily practice: optimization of PsyMate™ in primary mental healthcare (PMHC). CAPHRI Research Day; November 2017; Valkenburg, The Netherlands (poster presentation).
Nominations	Innovation PRoF 2018 Award
Multimedia	Radio broadcast on RTV Maastricht: https://www.rtvmaastricht.nl/tv/bet-beleg-tv/116027988
Lectures	Daniels N. Co-creatie in de dagelijkse praktijk: ervaringen met verschillende methodieken. Bachelor track Health Sciences, major Digital Technology and Care, course Design Thinking and Digital Healthcare Technology, Maastricht University; November 2020; Online.
Education	208 students from different disciplines of Zuyd University of Applied Sciences and Maastricht University: Communication and Multimedia Design, People and Business Management, Business Economics, Physiotherapy, Primary Care Assistant Practitioner Mental Health, Psychology, and Mental Health

Publications in international peer-reviewed journals	Daniëls NEM, Hochstenbach LMJ, van Bokhoven MA, Beurskens AJHM and Delespaul PAEG (2019). Implementing Experience Sampling Technology for Functional Analysis in Family Medicine – A Design Thinking Approach. Frontiers in Psychology 10:2782. doi: 10.3389/fpsyg.2019.02782 Verhagen SJW*, Daniëls NEM*, Bartels SL, Tans S, Borkelmans KWH, de Vugt ME, et al. (2019). Measuring within-day cognitive performance using the experience sampling method: A pilot study in a healthy population. PLoS ONE 14(12): e0226409. doi: 10.1371/journal.pone.0226409 Daniëls NEM*, Bartels SL*, Verhagen SJW, Van Knippenberg RJM., De Vugt ME and Delespaul PAEG (2020). Digital assessment of working memory and processing speed in everyday life: Feasibility, validation, and lessons-learned. Internet Interventions 19:100300. doi: 10.1016/j.invent.2019.100300 Daniëls NEM, Hochstenbach LMJ, van Zelst C, van Bokhoven MA, Delespaul PAEG and Beurskens AJHM (2021). Factors That Influence the Use of Electronic Diaries in Health Care: Scoping Review. JMIR mHealth and uHealth 9(6):e19536. doi: 10.2196/19536
Book chapters	Daniëls NEM, Verhagen SJW and Delespaul PAEG (2020). mHealth binnen herstelnetwerken. In Niels Mulder, Jaap van Weeghel, Philippe Delespaul, Frist Bovenberg, Bram Berkvens, Eva Leeman, Hans Kroon, Tom van Mierlo, Gerdie Kienhorst (Eds.), Netwerkpsychiatrie: samenwerken aan herstel en gezondheid (pp. 161-168). Amsterdam, Nederland: Boom uitgevers Amsterdam BV

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About the author

Naomi Daniëls was born on April 5, 1991 in Bilzen, Belgium. After graduating from secondary school at Heilig Graf Institute Bilzen in 2009, Naomi studied Biological Psychology at Maastricht University. During the third year of the bachelor, she successfully applied for the MaRBLE program. She investigated the relationship between self-esteem, and narcissistic and psychopathic personality traits in children. In 2012, she received her bachelor's degree by completing her bachelor thesis about this topic. Afterwards, Naomi was enrolled in the one-year Master's program Neuropsychology. Naomi graduated in 2013 by completing her first master thesis about visual and auditory sensory processing, and autistic traits in children. Subsequently, Naomi was enrolled in the Master's program Mental Health, childhood and adolescence track. In 2014, she received her second master's degree by completing her second master thesis about the implementation of Routine Outcome Monitoring.

Immediately after, she started working as a project manager at Faresa and as a teacher at Maastricht University. Since then, she also works as a clinical psychologist at Faresa. Alongside with her work as clinical psychologist, she started her PhD trajectory at Maastricht University in 2017 that resulted in this thesis. This was a collaborative project of the Department of Psychiatry and Neuropsychology (MHeNS, Maastricht University), the Department of Family Medicine (CAPHRI, Maastricht University) and the Research Centre for Autonomy and Participation of Persons with a Chronic Illness (Zuyd University of Applied Sciences) This thesis was part of the Brightlands Innovation Program LIME (Limburg Meet), a program that facilitates smarter measurement methods and more efficient data collection for better care and health.

She is currently working as a clinical psychologist at Faresa and as an expert at Inventia, a multidisciplinary research center for expert witness research in families, high conflict parenting and parental alienation.

List of publications

International peer-reviewed publications

Daniëls NEM, Hochstenbach LMJ, van Bokhoven MA, Beurskens AJHM and Delespaul PAEG (2019). Implementing Experience Sampling Technology for Functional Analysis in Family Medicine – A Design Thinking Approach. Frontiers in Psychology. 10:2782. doi: 10.3389/fpsyg.2019.02782

Verhagen SJW*, Daniëls NEM*, Bartels SL, Tans S, Borkelmans KWH, de Vugt ME, et al. (2019). Measuring within-day cognitive performance using the experience sampling method: A pilot study in a healthy population. PLoS ONE. 14(12): e0226409. doi: 10.1371/journal.pone.0226409

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Daniëls NEM, Beurskens AJHM, van Zelst C, Delespaul PAEG and van Bokhoven MA (2021). The use of an experience-sampling platform to support problem explorations for patients with anxiety or sleeping problems in family medicine – An action research design. International Journal of Clinical Practice. Manuscript submitted for publication.

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Oral presentations

Daniels N. The use of the PsyMate™ to support detailed functional analyses in family medicine – an action research design. LAM; October 2020; Online.

Daniels N, Ummels D. Hoe een wearable werkbaar wordt: ervaringsverhaal na doorontwikkeling van wearables en apps. Limburg Meet(ing); December 2019; Heerlen, The Netherlands.

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Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. SAA; June 2019; Syracuse, New York, the United States of America.

Daniels N, Hochstenbach L, Bokhoven M, Beurskens A, Delespaul P. Re-design of PsyMate™ for family medicine: design thinking in co-creation with health care professionals. ENMESH; June 2019; Lisbon, Portugal.

Daniels N, van Zelst C. PsyMate: wat kan je ermee? Landelijke week van de psychiatrie, afsluitingsdag; March 2019; Utrecht, The Netherlands.

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healthcare. MHeNs Annual Research Day; November 2017; Maastricht, The Netherlands.

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Delespaul P, Verhagem S, Daniels N. Wat wil jij beter kunnen? Naar een persoonlijke hulpverlening… 13de Psychosecongres; November 2017; Zwolle, The Netherlands.

Poster presentations

Daniels N, Hochstenbach L, van Zelst C, Bokhoven M, Delespaul P, Beurskens A. Successful long-term engagement in self-monitoring using e-diaries: a scoping review. MHeNs Annual Research Day; October 2019; Maastricht, The Netherlands.

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