CHAPTER 6

EXPERIENCE SAMPLING PLATFORMS

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Up and till now, you have learned what types of research questions we can answer with the experience sampling method (ESM) and how to design a study that is methodologically and ethically sound. The next important step that needs to be taken is the programmation, scheduling, and delivery of the study's content. This is typically done using an Experience Sampling Platform that integrates and allows complex communication between the different hardware (e.g., smartphone, wearable) and software components elements (e.g., dashboard, app) involved. Numerous platforms already exist that allow researchers to operationalize their protocol in the flow of everyday life, which makes it difficult for researchers to decide which platform to use. Instead of attempting to give an exhaustive overview (which would quickly be outdated), this chapter (1) provides considerations on important software and hardware components of ESM platforms, (2) discusses legal and practical challenges that may help guide the choice for a particular platform, and (3) ends with providing a comparison of five excellent ESM platforms currently available. This does not mean that other platforms, not included here, should not be considered when deciding the right platform for your study. Rather, it aims to provide researchers a starting point by highlighting communalities and meaningful differences between platforms.

6.1 The online dashboard

Most central to each ESM platform is its online dashboard. This is a website that can be accessed through a web browser and consists of multiple web pages for implementing ESM-questionnaires, sampling schedules, enrollment of participants, data analytics, and downloading of data. In what follows, each of these modalities are considered.

6.1.1 ESM questionnaires

ESM-questionnaires measure thoughts, experiences, and behavior in real-time (see chapter 4). While the construction of an ESM questionnaire is extensively covered in chapter 4, it is important to note that the questionnaire itself also needs to be programmable. For example, while some questions require a particular response scale option (e.g., multiple choice or slider) this also requires its availability on the online dashboard that is used for the study. Across ESM-platforms, four basic question types are frequently used: modifiable slider questions, checkbox questions, radio questions, and open questions. Modifiable slider questions concern questions in which the dashboard ideally allows for the

anchors and range to be freely adjusted. This, so that the slider can function as either a Likert scale (e.g., ranging from 1 to 7) or a continuous scale (e.g., ranging, from 0 to 100). Next, checkbox and radio question types are used for multiple choice questions. Checkbox questions allow participants to select multiple answer options, whereas radio questions restrict the selection to only one response option. Finally, open questions allow for the possibility of receiving written qualitative feedback from participants.

When considering more complex questionnaires that make use of branching (see chapter 4) or audio-visual stimuli, two important considerations are to be noted. When making use of branching, it is essential to check whether branching can actually be applied. This is important because dashboards do not always offer this feature for all question types (e.g., it might be possible to branch a radio button question type, but not a slider question type). Second, when using audio-visual stimuli (e.g., pictures, videos, or sound clips) it is important to be aware of the potential mobile data costs of these types of questions to participants.

6.1.2 Sampling schedules

In chapter three, four different types of sampling schemes were considered: fixed, random, semi-random, and event-contingent sampling. The first three are signal-contingent, meaning that participants are requested to fill out a questionnaire on a smartphone or wearable each time they receive a push notification ("beep"). Event-contingent sampling, as the word itself explains, is not contingent upon a random beep, but asks participants to initiate a questionnaire each time a predetermined event has occurred (e.g., after smoking a cigarette).

When designing a study that follows signal-contingent sampling (i.e., fixed, random, or semi-random), a survey schedule most often needs to be created on the dashboard from scratch. For example, if a researcher wants to use a semi-random sampling scheme each time point needs to be specified. In a larger-scale study, it may quickly become too time-consuming to do this for each participant individually. Hence, a dashboard that allows one to use a prespecified schedule template, or the ability to copy a created schedule would be preferred. This not only to save time, but also to ensure that all participants receive notifications at the same time. This is advantageous within group settings, where it would be

troublesome if smartphones continuously kept ringing asynchronously (e.g., within group therapy, classrooms, and shared office spaces). Yet, other settings may benefit from (semi)random sampling schedules that differ per participant. In this case, it is hence advised to use a dashboard that offers individualized (semi)random sampling. What this entails, is a feature in which a researcher needs to, instead of individual time points, indicate the length of the time interval in addition to how many notifications should be presented randomly, and different, for each participant.

When using event-contingent sampling, two types of questionnaire initiation are to be considered: self-initiated and device-initiated based on passive data. For questionnaires that are self-initiated, the implementation is straightforward. The dashboard needs to make the questionnaire permanently available and accessible (e.g., on the home screen of an ESM app) after which a participant can self-initiate a response when needed. Initiating questionnaires based on device data related to bodily (e.g., increased heart rate) or environmental conditions (e.g., sound or GPS location) is more complicated (see also chapter 12). The challenge here is for the ESM platform to integrate the passively collected sensor data, analyze it, and trigger a questionnaire when a particular condition is met. However, as technology advances, ESM platforms are starting to offer this type of data collection to their sampling schemes (for a recent example see (Hoemann et al., 2020). Researchers should however be mindful that this requires accurate wearable technology and good decision rules which may be tedious to develop. For example, considering heart-rate alone would not be sufficient to provide a questionnaire in those moments that leads up to a panic attack as heart-rate may increase by intensive movement.

6.1.3 Enrollment of participants

Ideally, the ESM dashboard will generate a single study code, scannable QR code, or a web link that allows participants to enroll in the ESM protocol through the platform's smartphone app (discussed later). This is important as some dashboards do not allow this and instead require the researcher to generate an individual code for each participant; which quickly becomes time-consuming. Equally important with respect to the enrollment of participants, is whether the dashboard allows for a flexible, instead of fixed, start of the ESM schedule. The fixed start would concern a starting date that will be the same for all participants, regardless of when they enroll (e.g., first beep on Monday the 15th of June). A

flexible start concerns a starting point relative to the enrollment date (e.g., first beep on the first Monday following enrollment, or the morning after enrolling in the study).

6.1.4 Data analytics

Once people have started their ESM monitoring period, it may be advantageous to keep an overview of participants' involvement. A dashboard that allows for checking compliance, makes it possible to quickly identify data collection problems or risk of drop-out. While a participant can then be contacted by the research team if needed, some dashboards also allow researchers to immediately follow-up with participants via the app itself. Additionally, dashboards that allow for visualization of data make it possible to stimulate compliance by facilitating the provision of visual feedback. Similarly, it allows for the software to be used in more clinically oriented (study) settings. However, it is important to note that the analysis options and visualizations available on a dashboard or app are often limited. Requiring additional development of new onboard analysis tools or visualizations unique to for instance a clinical study is furthermore expensive. For these types of studies, we hence recommend discussing additional development costs with developers well in advance.

6.1.5 Data download

Data collected with an ESM platform is typically stored on a secure database that is managed by the platform provider. However, some platforms offer the opportunity to use your own database for storing data (e.g., RADAR). Yet, this requires significant technical skills to set up and maintain. Platforms that do not allow you to set up your own database instead have a function to export data, which is typically done via the dashboard. This export process concerns aggregating all data into a single data file that can be used for statistical analysis. To ensure the exportation in the required (long-data) format (e.g., .csv file), we recommend researchers to test this process out prior to the start of the study.

6.2 ESM apps

So far, we have discussed important features to consider when selecting an ESM-platform. An ESM platform is, however, much more than just the dashboard. We now turn our attention to the ESM app itself. In this section, we

highlight two important considerations related to ESM apps. Afterward, we consider three advanced app features that may impact compliance.

6.2.1 Native or hybrid

There are two main types of ESM apps: native and hybrid apps. While the former app is developed to function and work with only one type of system software (e.g., android- vs. iOS-only app), the latter is based on web technologies and works cross-platform (i.e., a single app that works on both android and iOS). Native applications are typically faster and can take full advantage of special features unique to the system software it is developed for (Ajayi et al., 2018). This may be relevant to consider with mobile sensing (see chapter 13). However, development and maintenance costs, and hence also subscription fees, are often higher for native apps compared to hybrid apps. This has to do with native apps requiring a unique and more difficult codebase for each system software it is run on, whereas hybrid apps share a single codebase that is generally easier to implement. While performance may favor native apps for those interested in mobile sensing, experts suggest that hybrid apps may eventually be equal to and possibly even outperform native applications as technology advances (Huynh et al., 2017).

6.2.2 Push notifications: a warning

An ESM app uses push notifications to signal participants to fill out a questionnaire, but these may not work seamlessly on all smartphone models and operating systems by default due to hardware- and software-based fragmentation (Han et al., 2012). Smartphones that run on iOS and Android phones cover about 99% of the current market share (Karthick & Binu, 2017) and for both of them there are different operating systems versions in circulation. Similarly, phones run on different hardware (i.e., processors, sensors, graphic cards, etc.). This issue makes that not all smartphones may be compatible with the selected ESM app. It is therefore crucial to test whether the app is compatible with the smartphone of the participant. This furthermore holds especially true for android smartphones, for which manufacturers often develop unique 'skins' for different smartphones. These skins give each smartphone its own unique user-interface. This is why phones running on the same version of android can look and behave differently. These skins can furthermore have an effect on whether push notifications related to an ESM app are allowed by default. When working with android phones, it is

therefore even more important to check whether manual adjustment to app privacy settings is possible and required (i.e., allowing an app to send push notifications). Additionally, updates of the operating system may include changes to default settings. Hence, it is recommended to check whether notifications are still coming through after such updates.

6.2.3 Helpful app features

Three app features can benefit ESM research: sound intensity and duration, font size, and offline notification. First, the sound intensity and duration of push notifications can be increased on some apps which makes it easier for participants to notice them in noisy environments. Second, it may be helpful to check whether the font size of the text displayed within the app is adjustable so that every participant can comfortably read the questions or information provided on the app. Third, when sampling in remote areas, or at moments when people may have low connectivity (e.g., commuting to work on the train), it may be helpful to use an app that is capable of functioning offline.

6.3 Wearables

Wearables concern technologies that can be worn. In the context of ESM these technologies are most commonly used for passively collecting physiological data (e.g., heart-rate and galvanic skin response) and movement (e.g., accelerometer data and relative geographical position). Wearables can come in many different forms and shapes. For the measurement of heart rate, there are for instance smartwatches (Tison et al., 2018), rings (Magno et al., 2019), chest patches (Liu et al., 2018), and even earpieces (L. Wang et al., 2017). The scope of what is possible concerning measurement with wearables is covered in detail in chapter 13.

While the dashboard and ESM app are prototypical for each ESM platform, the inclusion of one or more wearables is not. Currently, only a limited number of providers are capable of integrating data from a wearable. This point is mainly of importance when one wants to trigger questionnaires based on data collected from a wearable (i.e., a particular type of event-contingent sampling). When this does not apply, one may use commercially available wearables and aggregate the data of both ESM questionnaires and passively collected data using external software such as R or Python. However, when using commercially made

wearables, one should be wary of how certain measures are calculated. For instance, a wearable may claim to measure or indicate a level of stress, without users being able to see how this 'stress' is calculated. This, as the computation of stress may be hidden and under the protection of intellectual property rights by the developer. Similarly, raw data may not necessarily be available from commercially developed devices.

6.4 Legal considerations

Related to ESM software and hardware, there are laws that need to be taken into consideration. This concerns laws on data privacy and use of electronic devices, as well as the use of ESM in the context of clinical settings.

6.4.1 Data privacy and electronic devices

Chapter 5 addressed the highly personal and often sensitive nature of ESM data, which brings responsibility regarding data privacy and protection. ESM platforms based in the EU will by default be required to be in line with the European Union's General Data Protection Regulations (GDPR, https://gdpr-info.eu/) that came into effect in 2018. While researchers outside of the EU do not need to adhere to GDPR, they will often also have country-specific laws that they need to adhere to (Greenleaf, 2017). This implies that the choice of a platform may also be determined by the data privacy laws in the country in which an ESM study is conducted. For example, GDPR demands that any data collected on EU-citizens needs to be stored on a database that is in line with GDPR regulation.

As we use electronic devices in ESM research, be it wearables or smartphones, they are subject to laws related to parameters on health, safety, and environmental protection standards. For example, electronic devices sold within the EU need to have a CE marking, which indicates conformity with EU legislation surrounding the parameters mentioned above. This CE marking is not to be confused with the China Export marking, which is highly similar (figure 6.1).

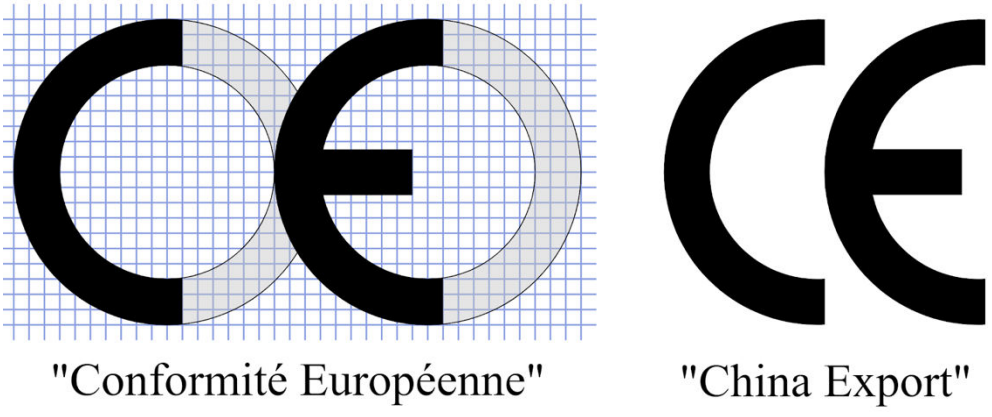

Figure 6.1. CE vs. China Export markings. Image retrieved from https://upload.wikimedia.org/wikipedia/commons/2/2b/Comparison_of_two_used_CE_marks.svg

6.4.2 Clinical use of ESM software, a medical device?

Both the EU and US have strict laws surrounding medical devices with different definitions:

> EU [Regulation (EU) 2017/745 on Medical Devices (MDR), article 2(1)] (OJ L 117): "medical device means any instrument, apparatus, appliance, software, implant, reagent, material or other article intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the following specific medical purposes: diagnosis, prevention, monitoring, prediction, prognosis, treatment or alleviation of disease, diagnosis, monitoring, treatment, alleviation of, or compensation for, an injury or disability, investigation, replacement or modification of the anatomy or of a physiological or pathological process or state, providing information by means of in vitro examination of specimens derived from the human body, including organ, blood and tissue donations, and which does not achieve its principal intended action by pharmacological, immunological or metabolic means, in or on the human body, but which may be assisted in its function by such means…".
>
> US [Federal Food, Drug, and Cosmetic Act, section 201(h)] "An instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is: recognized in the official National Formulary, or the

> United States Pharmacopoeia, or any supplement to them, intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or intended to affect the structure or any function of the body of man or other animals, and which does not achieve its primary intended purposes through chemical action within or on the body of man or other animals and which does not achieve its primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of its primary intended purposes…".

At first sight, the use of ESM in clinical practice matches both EU and US definitions. However, and as with many laws, exemptions are possible. For example, the federal drug administration (legal body in the US) states that whilst some software may meet the definition of a medical device, it intends to exercise enforcement discretion when the software poses a low risk to the public (US Food and Drug Administration, 2019). This in itself is a vague statement, as the words 'intends' and 'low risk' are vague. However, they do provide examples under which we also find diagnosis and treatment of psychiatric conditions (US Food and Drug Administration, 2019, p22). It is currently unclear whether or not the same exemption intention applies to the clinical use of ESM software within the EU. Yet, app stores are full of mental health apps (other than ESM) that fit the medical device definition. None of these, to the best of our knowledge, are classified as medical device software. Hence, it seems to suggest, similar to within the US, there is an equal amount of vagueness surrounding the applicability of medical device regulation on clinically used mental health apps (which may include ESM software).

6.5 Sustainability of ESM software and hardware

The different elements of an ESM platform consist of various types of hardware. This includes the collection of elements (i.e., physical objects) that make up smartphones, wearables, laptops, databases, and servers. Each of these devices in turn runs on its own system software (e.g., Windows, Mac, Android, and iOS.). System software provides a platform for the use of other types of software, such as for instance application software (i.e., apps, database management software, etc.). System software therefore acts as an interface

between hardware and apps. This implies that when system software updates, application software may need to be updated as well.

System software is typically backed by major multinationals (e.g., Microsoft/Apple). These multinationals employ a solid workforce whose task it is to continuously improve the system software. In contrast, application software is often not backed by a multinational or even a company per se. The updating of application software in order to remain compatible with updated system software is a vital element of sustainability. When application software is managed by a single individual, this requires considerable investment which may threaten the sustainability of the platform. Similarly, without support for new developments, the application software may quickly become outdated. An ESM platform should therefore preferably involve a multidisciplinary team of programmers, researchers, and medical health professionals in order to stay operational as well as innovative.

6.6 Recommended ESM platforms

Up until this point we have described different relevant elements and considerations when deciding upon the right ESM platform for a study. In this section, we compare five excellent ESM platforms: m-Path (https://m-path.io/landing/), Movisens (https://www.movisens.com/en/), RADAR (https://radar-base.org/), SEMA3 (https://sema3.com/), and Expiwell (https://www.expiwell.com/). These platforms have been selected based on merit, geographical location in light of legislation and perceived sustainability.

6.6.1 Overview ESM platform features

In the table below we provide an overview of the selected platforms. The content within the table is based on personal correspondence with representatives of each of the platforms (November 2020 - January 2021). When interested in an alternative ESM platform, you can use this table to see how that platform would compare against the five platforms considered here.

Table 6.1. Overview of presented ESM platforms [a]

	m-Path	**Movisens**	**RADAR**	**SEMA3**	**Expiwell**
Online dashboard					
Slider questions	Yes	Yes	Yes	Yes	Yes
Checkbox	Yes	Yes	Yes	Yes	Yes
Radio buttons	Yes	Yes	Yes	Yes	Yes
Open questions	Yes	Yes	Yes	Yes	Yes
Picture stimuli	Yes	Yes	I.D.	I.D.	Yes
Video stimuli	Yes	Yes	No	No	Yes
Audio stimuli	Yes	Yes	Yes	No	Yes
Branching	Yes	P.	Yes	Yes	Yes
Signal-contingent: fixed and (semi)random	Yes	Yes	Yes	Yes	Yes
Signal-contingent: individualized (semi)random	Yes	Yes	I.D.	Yes	Yes
Event-contingent: initiated by passively collected data	I.D.	Yes	I.D.	No	No
Event-contingent: self-initiated	Yes	Yes	Yes	Yes	Yes
Templates	Yes	Yes	Yes	Yes	Yes
Data visualization	Yes	P.	No	Yes	Yes
Compliance check	Yes	Yes	Yes	Yes	Yes
Data download	Yes	Yes	Yes	Yes	Yes
ESM app					
Native/Hybrid	Native	Native	Native	Hybrid	Hybrid
Operating system compatibility	Android/iOS	Android	Android/iOS	Android/iOS	Android/iOS
Adjustable notification sound & durations	Yes	Yes	No	Yes	No
Adjustable text size and font	Yes	Yes	No	No	Yes
Offline	P.	Yes	P.	Yes	Yes
Data communication	Yes	Yes	No	Yes	Yes
Mobile sensing	I.D.	Yes	Yes	No	No

Table 6.1, continued

	m-Path	Movisens	RADAR	SEMA3	Expiwell
Wearable					
Integrated data	No	Yes	Yes	No	No
Legal					
GDPR compliant	Yes	Yes	Yes	P.	Yes
CE marking	No	P.	No	No	No
MDR compliant	No	No	No	No	No
510(k)	No	No	No	No	No
Other	No	No	No	Legal framework Australia	No
Profile					
Founding date	2019	2009	2016	2013	2015
Country	Belgium	Germany	UK	AUS	US
Number of paid employees	4	16	U.	5	U.
Number of active users	175+	850+	U.	250+	2100+
Cost[b]					
Free	Yes	Yes	Yes	Yes	Yes
Premium	Yes	Yes	No	No	yes

Note: U. = undefined, P. = partial, I.D. = in development.
[a] *For additional ESM platforms, please see: https://docs.google.com/spreadsheets/d/18R9x9Qbl9tADJGpJBJID_T9EWZeQ_4W3OFdn3iKRU7U/edit#gid=204277638*
[b] *Free versions may be limited. Similarly, premium prices may vary depending on study design and are furthermore subject to change. Hence, they are not specified in this table. For free version restrictions, as well as official prices of premium versions, please consult the original platform websites.*

6.6.2 Practical advice

Each platform outlined above has unique characteristics that go beyond the scope of basic ESM. For example, using m-Path one can create questionnaires that change dynamically based on user input, as well as provide psychoeducation and exercises on a separate window inside the app. It is furthermore the only platform that allows users to create, save and share content (e.g., questionnaires and EMIs) with one another. Comparably, Movisens is currently the only platform to offer wearables that are developed in-house and RADAR is the only

platform that allows users to set-up their own database for data collection. Whilst these additional features make each platform different, it is here important to stay close to the core of what is required for the basic application of ESM that will fit most research projects. Noteworthy is then that whilst the platforms share similar features for basic application of ESM, the user interface of different platform components (e.g., dashboard, app, wearable) differs substantially. Just as one can be a proponent of iOS or Android, one can prefer one ESM platform over another. Ultimately, this means that the choice for a platform is also one of personal preference, secondary to research design, budget, and legal restrictions. When multiple platforms fit within budget and envisioned research design, it is hence recommended to pilot the platforms first.

6.7 Conclusion

In this chapter we provided insight into the different programming elements important for setting up an ESM study, as well as associated legal considerations and software sustainability elements. At the end of the chapter this information was aggregated into a table which was used to provide an overview of five excellent ESM platforms. With this chapter we hope to have provided enough information for you to find a platform that will fit your aspired needs perfectly.