

# Trends in Ambulatory Self-Report: The Role of Momentary Experience in Psychosomatic Medicine

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In this article, we review the differences between momentary, retrospective, and trait self-report techniques and discuss the unique role that ambulatory reports of momentary experience play in psychosomatic medicine. After a brief historical review of self-report techniques, we discuss the latest perspective that links ambulatory self-reports to a qualitatively different conscious self—the “experiencing self”—which is functionally and neuroanatomically different from the “remembering” and “believing” selves measured through retrospective and trait questionnaires. The experiencing self functions to navigate current environments and is relatively more tied to the salience network and corporeal information from the body that regulates autonomic processes. As evidence, we review research showing that experiences measured through ambulatory assessment have stronger associations with cardiovascular reactivity, cortisol response, immune system function, and threat/reward biomarkers compared with memories or beliefs. By contrast, memories and beliefs play important roles in decision making and long-term planning, but they are less tied to bodily processes and more tied to default/long-term memory networks, which minimizes their sensitivity for certain research questions. We conclude with specific recommendations for using self-report questionnaires in psychosomatic medicine and suggest that intensive ambulatory assessment of experiences may provide greater sensitivity for connecting psychological with biologic processes. **Key words:** ecological momentary assessment, Positive and Negative Affect Schedule, emotion, memory bias, stress, questionnaires.

AA = ambulatory assessment; ANS = autonomic nervous system; CA/SAL = core affect/salience network; D/LTM = default/long-term memory network; HAM-D = Hamilton Rating Scale for Depression; HPA = hypothalamic-pituitary-adrenal axis; IM = immune system; PDA = personal digital assistant; STM = short-term memory; 5-HTTLPR = 5-hydroxytryptamine transporter gene-linked polymorphic region.

## INTRODUCTION

Self-reports are ubiquitous in psychosomatic medicine and related fields like behavioral medicine and health psychology. It is a rare study that does not have participants verbally describe something, whether it be their emotions, physical symptoms, health behaviors, or other patient-reported outcomes. Traditional reporting formats require people to report their experiences from memory through the use of trait or retrospective questionnaires. By contrast, momentary self-report techniques, such as ambulatory assessment (AA), allow people to report experiences that are happening in real time across multiple moments in their daily lives. In this article, we review the core differences between trait, retrospective, and ambulatory self-report techniques and highlight the powerful role that ambulatory self-reports of experience play in psychosomatic research.

We start with a brief review of self-report techniques and then propose that scientific understanding of self-reports has progressed from simply documenting how ambulatory self-reports may be less biased by memory than traditional self-reports to recognizing that self-reports evoke different types of constructed experience—the self in the moment (the experi-

encing self), the self through time (the remembering self), and the belief-based self (the believing self) (1–4). Moreover, each state of subjective construction (experiences, memories, and beliefs) serves a unique function (e.g., for navigating current environments, decision-making and long-term planning) that, in part, is based on its unique pattern of underlying neurobiology. From this perspective, the experiencing self measured through AA plays an important role in connecting psychological processes to bodily processes (cardiovascular, hormonal, and immune). We review evidence showing that ambulatory reports of daily experiences often show stronger connections with autonomic, hormonal, and immune system processes than do corresponding retrospective and trait self-report measures. By contrast, the remembering and believing selves measured through traditional self-reports play important roles in health decisions. We end with five practical recommendations for choosing self-report techniques in psychosomatic medicine.

## TRAIT, RETROSPECTIVE, AND AMBULATORY SELF-REPORT TECHNIQUES

Trait and retrospective self-report questionnaires, which we collectively call traditional self-report techniques, rely on a memory-based reporting format in which people are asked to remember and summarize experiences, often over long periods (weeks, months, or a lifetime). At the highest level of abstraction are trait questionnaires (also called global questionnaires) in which people are asked to remember and aggregate experiences over the widest time frame—one’s lifetime. Trait questionnaires are used to assess personality, temperament, and emotional style (e.g., the Neuroticism, Extraversion, Openness Personality Inventory – Revised; the Buss-Perry Aggression Questionnaire) (5,6). For example, the neuroticism scale of the Neuroticism, Extraversion, Openness Personality Inventory – Revised instructs respondents to rate the extent to which they agree or disagree with general statements like “I often feel tense and jittery” or “I often get angry at the way people treat me” (5). Likewise, in the trait format of a widely used affect measure—the Positive and Negative Affect Schedule—individuals rate the extent they *generally feel* 20

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high-activation emotions like “enthusiastic,” “nervous,” and so on (7). Trait questionnaires are popular and easy to use, and perhaps because of these factors, they have been the primary way of looking for connections between psychological concepts and underlying biology (cf., Kagan (8)). Other traditional self-report procedures are explicitly retrospective in nature; they ask people to remember their prior experiences over a particular time frame. For example, the Center for Epidemiologic Studies Depression scale requires respondents to reflect on their emotions and behaviors *during the past week* (9). Some of the most common health inventories use a 1- to 4-week retrospective timeline (36-Item Short Form Health Survey) (10) (for discussion of recall time frames in patient-reported outcomes, see Stull et al. (11)).

By contrast, momentary self-report procedures have people describe their thoughts, feelings, or behaviors as they are happening in real time (or close to real time). Momentary self-report procedures can be done in the laboratory (12,13), but they are more commonly conducted over many time points in naturalistic settings using a class of procedures called experience sampling methods (14), ecological momentary assessment (15), or, increasingly, AA (16) ([www.ambulatory-assessment.org](http://www.ambulatory-assessment.org)). (For a recent handbook on these methods, see Mehl and Conner (17).) Although early procedures collected data using paper-and-pencil surveys sometimes combined with audible pagers (18,19) and later, data were collected with palmtop computers and personal digital assistants (PDAs) (20–23), today, advances in Internet and mobile technology enable efficient data collection through daily Internet diaries, mobile phones, and smartphones (24). Ambulatory self-report procedures have been used in psychosomatic medicine and related health fields to measure a variety of experiences and behaviors including emotions, pain, fatigue, coping, and daily stress (25–29) as well as health behaviors like smoking and alcohol use (30,31). For more detailed reviews of AA methods in these areas, see references (32–35).

### EVOLVING THEMES IN THE SCIENCE OF SELF-REPORT: RELATIONSHIP AMONG TRAIT, RETROSPECTIVE, AND AMBULATORY SELF-REPORTS

Following the introduction of AA techniques, scientific understanding of their differences from traditional memory-based reports has evolved. In this section, we review three conceptual themes that characterize an understanding of their relation. The core differences, assumptions, and recommendations of each theme are shown in Table 1. Although we discuss the three themes separately and in loose chronological order, these groupings are more conceptual than historical because there is overlap in their publication dates.

#### Ambulatory Self-Reports Are Less Biased Than Traditional Self-Reports

Soon after their development, AA procedures came to be seen as the more valid measure of experience compared with

traditional memory-based procedures. (For a history of AA, see Wilhelm et al. (36).) Researchers believed that intensive momentary reporting allowed them to obtain an “objective” account of activities and experiences as they unfold for a respondent over time, whereas traditional self-reports gave them a reconstructed and potentially fallible account of prior experiences from memory. In behavioral economics, Kahneman and Snell (37) called this momentary record—as applied to hedonic mood states—*experienced utility*. With AA, it became possible for researchers to create their own aggregates of experienced utility over time and compare those to the subjective aggregates provided by respondents (38–41) (for laboratory-based AA studies, see Fredrickson and Kahneman (12) and Kahneman et al. (42)).

Early research revealed the extent to which memory-based self-reports deviated from more immediate “objective” accounts obtained through AA (for reviews of memory biases, see Schwarz (43,44)). For example, early ecological momentary assessment research on smoking cessation showed that people poorly recalled their quit dates and that they overestimated in memory their actual experience of distress when quitting smoking in comparison to what they actually reported in real time using an electronic diary (30). Women also overestimated in retrospective ratings their premenstrual symptoms relative to what they reported in the moment (45). This general pattern of overestimation in memory has since been replicated for a variety of emotions (46) as well as physical pain (47,48). Early pain research also showed that retrospective reports of pain were influenced by pain at the time of recall (Eich et al. (49), cf., Ross (50)) and by the most intense pain during the previous week (51). Importantly, this latter research by Stone et al. (51) extended laboratory evidence demonstrating that people often neglect the duration of their experiences and instead weight aggregate judgments by their most intense and most recent episodes (“peak-and-end” effects) (52). Taken together, these AA applications corroborated evidence of the fallibility of autobiographical memory (53) and highlighted the advantages of measuring experiences in real time to remedy bias.

Implicit in this perspective is that different kinds of self-report procedures could be arranged hierarchically from the most biased to the least biased (Table 1, *Core Difference*). In this hierarchy, ambulatory self-report procedures were considered the most valid and thus came to be seen as the “criterion standard” of self-report, whereas memory-based reports were considered the least valid (e.g., Kahneman (54) and Stone et al. (55)). Underlying this hierarchy is that momentary experience was the criterion to be captured, and it could be done with more or less validity depending on the method used. This went hand in hand with the assumption that self-reports at different levels of abstraction *should* map onto each other. That is, a retrospective report about how one felt during the past 2 weeks should correspond fairly closely to an arithmetic mean of what actually happened during the past 2 weeks. Likewise, a trait report of personality should closely correspond to the accumulated lifetime experiences. To the extent that beliefs or memories diverged from actual experience, this pattern of bias called into question the validity of traditional self-reports.

TABLE 1. Three Conceptual Themes in Self-reports (Core Differences, Brain and Bodily Systems, and Assumptions) and Recommendations From Each Theme

Conceptual Theme	Core Difference	Systems	Assumptions	Recommendation
<b>Bias</b>				
Traditional – trait	Most biased	Not specified	<ul style="list-style-type: none"> <li>• Self-reports should converge</li> <li>• Divergence indicates bias.</li> <li>• AA is better</li> </ul>	<ul style="list-style-type: none"> <li>• Use AA whenever possible</li> </ul>
Traditional – retrospective				
Ambulatory – end of day				
Ambulatory – momentary	Least biased			
<b>Knowledge</b>				
Traditional – trait	Semantic knowledge	Semantic memory	<ul style="list-style-type: none"> <li>• Self-reports may not converge</li> </ul>	<ul style="list-style-type: none"> <li>• Use AA to measure episodic or experiential knowledge</li> </ul>
Traditional – retrospective	Semantic/episodic blend	Semantic, episodic memory	<ul style="list-style-type: none"> <li>• Divergence is because they tap different subjective knowledge</li> </ul>	
Ambulatory – end of day	Episodic knowledge	Episodic memory	<ul style="list-style-type: none"> <li>• AA is different, not better</li> </ul>	
Ambulatory – momentary	Experiential knowledge	Working memory, STM		
<b>Differing Selves</b>				
Traditional – trait	Believing self	D/LTM	<ul style="list-style-type: none"> <li>• Self-reports may not converge</li> </ul>	<ul style="list-style-type: none"> <li>• Use AA to measure the experiencing self or when linking experience to homeostatic autonomic biological systems</li> </ul>
Traditional – retrospective	Remembering self <sup>a</sup>	D/LTM	<ul style="list-style-type: none"> <li>• Divergence is because they tap different networks and systems</li> </ul>	
Ambulatory – end of day	Remembering self <sup>b</sup>	D/LTM, CA/SAL, HPA, IM	<ul style="list-style-type: none"> <li>• AA is different, not better</li> </ul>	
Ambulatory – momentary	Experiencing self	CA/SAL, ANS, HPA, IM		

AA = ambulatory assessment; STM = short-term memory; D/LTM = default/long-term memory network; CA/SAL = core affect/salience network; HPA = hypothalamic-pituitary-adrenal axis; IM = immune system; ANS = autonomic nervous system including sympathetic and parasympathetic divisions.

<sup>a</sup> Likely a blend of remembering and believing.

<sup>b</sup> Likely a blend of remembering and experiencing.

### Ambulatory Self-Reports Reflect Different Types of Knowledge

In time, there has been a shift in understanding the relationship between traditional and ambulatory self-reports. This shift was rooted in research from cognitive psychology, which, at the time, distinguished between semantic and episodic declarative memory as distinct mental processes (56). Although semantic and episodic memory are now considered types of memory processing tasks rather than distinctive knowledge systems (57,58), research from cognitive psychology helped researchers to understand that the distinctions between traditional and momentary self-reports were more than a simple matter of bias—they were reflecting different sources of knowledge that people use when reporting their subjective experiences in these different ways.

Robinson and Clore (59) outlined this perspective best in their accessibility model of emotional self-report, which linked trait, retrospective, and momentary self-reports of emotion to different types of subjective knowledge. As shown in Table 1, trait self-reports were characterized as measuring semantic knowledge—that is, conceptual knowledge extracted from momentary experience (among other sources) that is no longer associated with time and place. By contrast, AA procedures were characterized as measuring episodic knowledge—that is, event-specific knowledge about subjective *experiences situated in a particular time and context* (60). When momentary self-reports are used, respondents can directly introspect on *experiential knowledge* as it is being generated (e.g., current pain levels, emotions, feelings of stress). When short-term recall reports are used such as with daily diaries (61) or the Day Reconstruction Method (62), people were thought to use episodic memory to recreate the episodic details of events, which can introduce episodic memory biases (e.g., peak-and-end effects). When longer-term retrospective reports are used (e.g., 1- to 4-week recall), respondents seem to stop trying to recall and summarize memories for specific experiences and instead start accessing relevant semantic knowledge to help guide their verbal reports (63). Thus, retrospective reports are often more consistent with episodic beliefs than actual experience (38,64–70)—they incorporate a greater degree of gender and cultural norms (64–67) and intensify personality differences (38,68).

This shift from simply documenting bias to trying to understand the knowledge contained within the content of verbal reports led to new underlying assumptions about self-report procedures. As shown in Table 1 (*Assumptions*), from this perspective, AA procedures were no longer seen as inherently better than traditional self-reports; *they were different*. They provided different yet complementary information about psychological functioning (71–74).

### Different Self-Reports Tap Different Functional Selves

A recent research theme builds on the previous perspective by suggesting that self-reports measure *different types of conscious “selves”* (2–4,75), namely, the experiencing (momentary), remembering (retrospective), and believing (trait) self. These conscious selves become activated in different circumstances by

different task demands, have different inputs with the brain and body, and serve different functions in behavior and decision making.

The concept itself of differing selves with different relative inputs and qualities of consciousness itself is not new (e.g., Singer and Salovey (3) and Tulving (60)). For example, Markus and Wurf (2) discussed the concept of multiple selves that are context dependent. In 1993, Singer and Salovey wrote about *The Remembered Self* (3). In 1985, Tulving (60) wrote about different qualities of consciousness—*auto-noetic* and *noetic* conscious—when people use semantic and episodic memory, respectively. However, recent publications, including those by Wilson and by Kahneman, have explicitly mapped different selves onto different types of self-report procedures. For example, Kahneman (1,75) recently expanded on his concept of experienced utility to distinguish between the “experiencing” and “remembering” self that are captured by momentary and traditional self-reports, respectively. Likewise, research in affective forecasting has distinguished between past, present, and future (predicted) selves, which are tapped by retrospective, online, and prospective self-reports, respectively (4). Thus, from this perspective, different self-report procedures cultivate different “selves” that guide how a person responds on that instrument.

We would also like to point out that differing selves (experiencing, remembering, and believing selves) likely reflect different relative inputs of immediate sensory experience (from the world and/or the body) versus experience that is derived from long-term memory (LTM) (3,60). The experiencing self is, relatively speaking, more tied to the corporeal information from the body and sensory information from the world. As such, the experiencing self should be closely linked to brain activity within those networks that collectively help to represent and regulate a person’s current autonomic state and changes in homeostasis (“core affect network” (CA) (76) or “salience network” (SAL) (77)). The experiencing self should also be tied to portions of this network that are involved in the conscious representation of somatovisceral cues such as the dorsal anterior cingulate cortex (77) and anterior insula (78) (for an excellent neuroscience review in psychosomatic medicine, see Lane et al. (79)). By contrast, the remembering and believing selves require greater activation of the default/long-term memory (D/LTM) network, relatively speaking.<sup>1</sup> There may be less of a link to the current sensory state of the body, particularly for the believing self. Although sensations from the body are never really “off” or irrelevant to any mental state, representation of the body in awareness is likely minimized phenomenologically during beliefs as opposed to the immediate present.

Each self, in turn, plays important roles in mental life and behavior. The experiencing self serves to integrate information across different systems—in present time awareness—to

<sup>1</sup> The “default network” (80,81) or the “long-term memory network,” seems to be active whenever people engage in inwardly focused mental activity, such as spontaneous, highly associative mental activity (e.g., daydreaming or mind wandering) (13), constructing an imagining of the future or a memory of the past (82), or constructing object perceptions (83).

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respond flexibly and in a coordinated way to both novel and known environments (84,85). The experiencing self is, essentially, the “front-line” self that functions to help individuals maintain homeostasis and navigate physical and social environments in situ. By contrast, the remembering self filters and consolidates our experiences so that we can learn, communicate, and make decisions about the future based on our past. The characteristics of the remembering self reflect the three main functions of autobiographical memory—self (e.g., maintaining continuity of the self), social (e.g., facilitating communication), and directive (e.g., guiding planning and decision making) (86,87). Lastly, the believing self is also a “storyteller” but at a higher level of abstraction that reflects the collection of identities and self concepts that help individuals maintain identity through time (2). The believing self also serves as mental scaffolding for interpreting incoming information, and for anticipating and forecasting the future, among other roles (2,45).

### PRACTICAL IMPLICATIONS OF DIFFERING SELVES FOR PSYCHOSOMATIC MEDICINE

In the previous section, we reviewed three perspectives on the differences between momentary (ambulatory), remembered, and trait self-reports. Of these three perspectives, the theme of differing functional “selves” with different connections to the bodily and sensory input may have several practical implications in psychosomatic medicine. Understanding the distinctions among experiences, memories, and beliefs can help researchers choose which “self” they want to cultivate for a given hypothesis, and which corresponding self-report measure to use. In this section, we review several practical implications of this perspective using examples within psychosomatic medicine research. The following sections highlight the role of the experiencing self in psychosomatic medicine; the last section highlights briefly the role of the remembering and believing selves as they affect health related decisions.

#### The Experiencing Self May Show Stronger Connections to Bodily Processes Than the Remembering or Believing Selves

Research suggests a strong link between the psychology of the experiencing self and stress related bodily reactions such as cardiovascular reactivity, hypothalamic-pituitary-adrenal (HPA) axis reactivity, and immune system function. It is the experiencing self whose blood pressure rises in response to stressful situations (88), whose cortisol responds to a stressor (29), and whose immune system reacts to elevated feelings of hostility during spousal fights (89). Although humans can evoke the stress response through memories and anticipated thinking (90), acute autonomic, hormonal, and immune responses are most commonly activated as people act and react to life’s momentary stressors through the eyes of the experiencing self. As evidence of this linkage, psychological states measured intensively through AA often show stronger associations with various cardiovascular, HPA, and immune biomarkers compared with traditional self-reported traits. For example, in their cardiovascular research, Kamarck and colleagues (88) proposed that everyday experience—in particular, how people

interpret and respond to daily stressors—incorporates (and therefore reflects) sympathetic nervous system activity. Alterations in sympathetic nervous system activity, in turn, lead to increased risk of cardiovascular conditions like atherosclerosis. Through the Pittsburgh Healthy Heart Project, Kamarck and colleagues (88) used AA to collect momentary self-reports of psychosocial stress along five dimensions (e.g., social conflict, task demand, decisional control, negative affect, and arousal) concurrent with ambulatory blood pressure and heart rate readings in daily life. Analyses showed strong associations between momentary self-reports of psychosocial stress and ambulatory blood pressure and heart rate. Moreover, aggregated momentary reports of daily stress predicted atherosclerosis risk measured by mean carotid artery wall thickness, whereas *comparable trait measures of stress did not*. Similarly, recent research on patients with coronary heart disease showed that momentary affective experience during a 24-hour monitoring period was a stronger predictor of ambulatory heart rate variability than were scores on the Beck Depression Inventory (91). Taken together, this research suggests that momentary measures of psychosocial stress and emotions taken in situ outperformed global or retrospective measures in predicting disease risk. In other words, the psychology of the experiencing self mattered more to cardiovascular risk than the psychology of the remembered or believed self. This asymmetry makes sense given that the experiencing self has greater links to components of the salience network and networks involved in the regulation of autonomic activation. Therefore, the experiencing self—and its links to hemodynamic reactivity—may be an important risk factor in the development of disease (88).

The experiencing self is also strongly tied to hormones such as cortisol, a stress-related byproduct of the HPA system. For example, Nicolson (92) showed that ambulatory self-reports of emotional states, daily hassles, and stressors—not just the experience of major life events—can increase salivary cortisol in daily life. Research has also shown links between fluctuating mood states and ambulatory cortisol in a sample of white collar workers (93) and higher salivary cortisol levels among people currently experiencing or anticipating a stressor (29). Importantly, there seem to be stronger associations between cortisol and affect that is measured using AA than when using questionnaires like the trait version of the Positive and Negative Affect Schedule (25). For example, Steptoe and colleagues (25) found that higher momentary positive affect was strongly related to lower waking and total cortisol levels, whereas trait affect was only weakly related to waking cortisol levels, despite momentary and trait affect in this study being moderately correlated,  $r = 0.46$ . These findings are consistent with the cardiovascular findings reviewed above (88,91), which, together, show that repeated momentary measures of affect outperform the corresponding trait measure in predicting these particular biologic responses.

The experiencing self also has links to immune system function. For example, laboratory work by Kiecolt-Glaser and colleagues (89) shows that the immune system is especially sensitive to the experience of hostility. Hostile interactions among couples slowed wound healing by 60% compared with

couples without such hostility. Similarly, research suggests strong associations between the experience of momentary affect and immune responses (94–97). For example, in a laboratory study of upper respiratory viral infection, a measure of baseline state negative affect taken before virus administration significantly predicted a biologic marker of immune function (mucus secretion), whereas a trait negative affect measure taken on the same day did not (95). In another study by the same team, lower levels of positive affect aggregated from daily measures were associated with a 2.9 increase (odds ratio) in the likelihood of getting a cold, whereas lower levels of positive affect measured using a traditional trait measure were only associated with a 1.6 increase (odds ratio) in the likelihood of getting a cold (96). Although both odds ratios were statistically significant, effect sizes were stronger for the averaged daily measure than for the trait measure. Thus, the averaged daily measure of positive affect provided a more sensitive account of participants' emotional states in the time leading up to virus administration. In light of this evidence, variations in state affect—through connections to the autonomic nervous system (ANS) and HPA-activity—are thought to be an important mechanism affecting immune system function (95,98,99).

#### **The Experiencing Self May Show Stronger Connections to Reward and Threat Circuitry Than the Remembering or Believing Selves**

The experiencing self also may have stronger links to the CA network that modulates reactions to reward and threat. For example, recent evidence shows that functional magnetic resonance imaging–measured patterns of striatal activation to reward stimuli were strongly associated to reports of positive emotion measured using AA (100,101). Associations with trait positive emotion were not tested; however, we suspect that patterns with trait reports would have been much weaker because trait reports measure the believing self, which is more temporally distant from the experiences that should be affected by striatal differences in reward processing. By measuring feelings of pleasure in real time in response to real-world rewards, the researchers were able to capture the feelings that were most functionally linked to the underlying neurobiological processes.

Other empirical evidence suggests that the experiencing self has strong ties to amygdala activation as it related to the core affective network. In a prospective imaging experiment, individuals who reported greater experiences of negative affect across 28 days of experience sampling demonstrated significantly greater amygdala activation during the first block of briefly presented, masked fearful faces 1 year later, when compared with those who reported lower levels of momentary negative affective experience (102). Although other studies have found a link between amygdala response and trait measures of neuroticism that are taken close to the time of scanning (103), trait ratings of neuroticism taken by Barrett et al. at the beginning of the experience sampling study did not predict amygdala response 1 year later.

Experiences also may show earlier responses to pharmacological interventions, particularly those interventions targeted at

the salience network. In a trial of antidepressant medication by Lenderking and colleagues (104), changes in depressive symptoms were detected earlier among patients randomly assigned to track their symptoms using daily diary questionnaires compared with patients who reported their symptoms using standard 1-week recall measures. Interestingly, weekly clinician assessments using the Hamilton Rating Scale for Depression (HAM-D) and the Montgomery-Asberg Depression Rating Scale showed similar changes in depression between the two reporting groups. Cautiously, the authors suggested further research on this finding but mentioned that “findings are also consistent with the hypothesis that [daily symptom reports may be] a more sensitive measure of response to depression treatment than the HAM-D or MADRS” (p875). Other researchers have noted similar concerns about the sensitivity of summary scales as primary end points in pharmacological research (105). For example, Pasqua and colleagues (105) noted that, “Summary scales [like the HAM-D] are not sufficiently sensitive to differences in pharmacological properties and possibly too crude a measure to translate efforts ... into clinically meaningful differences” (p150). Although Pasqua and colleagues suggest improving sensitivity by developing better depression subscales, the work by Lenderking and colleagues suggests improving sensitivity by tracking real-time symptoms in daily life.

#### **Using Trait Measures as Proxies for the Experiencing Self Can Lead to Null or Inconsistent Patterns in the Literature**

Researchers need to understand that, as a rule, trait or global measures tap knowledge that is more deliberate, reflective, and stable in nature (15,59). As a result, using trait measures as shortcuts to the experiencing self can result in reduced sensitivity of measurement, weaker effect sizes, or even null results. Yet in many areas of research, trait reports are still used as the primary way of linking psychological concepts like emotional style to biology (8). As Kagan wrote:

*“A serious problem with the reliance on [trait] questionnaire indexes of personality is that the scientists interested in [their] biological correlates ... typically relate a profile of blood flow or a genetic polymorphism ... with a questionnaire measure that can be obtained in less than an hour and lacks an equally sound theoretical background. Because the questionnaire data are too crude an index of the psychological correlates of a genetic feature, biochemical profile, or brain state, this strategy is unlikely to reveal strong relations between the biological and psychological measures” (8, p369).*

We agree with this observation; however, offer a middle way rather than abandoning self-reports in favor of objective measures (8,106,107). We suggest that intensive AA of experiences in real time can lead to more sensitive measurement of phenomenological end points, leading to improved detection when linking subjective factors to biologic factors. The reason is that AA provides a window onto subjective experiences that are more

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temporally and functionally connected to the bodily processes that modulate situated and contextualized behavior. In short, by using more sensitive self-report methods, researchers will maximize their ability to detect linkages between the psychological and biologic. As noted by Lane and colleagues (108), this linkage is often the critical “starting point” for both establishing a phenomenon and then investigating the mechanisms that connect these levels.

Consider the genetic underpinnings of emotion. Despite molecular evidence that the serotonin transporter gene (5-HTTLPR) regulates serotonin uptake (109) and that serotonin transporter gene differences are related to functional magnetic resonance imaging measured amygdala sensitivity (110), research linking this gene to subjective emotional phenotypes among nonclinical samples has been mixed (111). Yet, the bulk of this research has relied on trait reports of emotion such as neuroticism questionnaires as the principal measure of subjectively experienced emotion. However, the serotonin transporter gene is probably more effective at modulating the emotions of the *experiencing self* rather than the believing self. Using a 30-day daily diary technique, research by the first author and colleagues found that young adults with the risky 5-HTTLPR short allele reported elevated feelings of anxiety in daily life, especially on days with greater stressors (112). Importantly, although differences were found in the daily reports of anxiety reactivity, there were *no genotype differences in trait reports of anxiety* using a standard neuroticism questionnaire (Neuroticism, Extraversion, Openness – Five-Factor Inventory) despite the state and trait anxiety measures being correlated. Thus, we observed reliable genetic differences at the state level, but failed to show genetic differences at the trait level. A similar pattern was shown for a gene variant (rs13212041) that affects regulation of the serotonin 1B receptor, which is involved in aggression (113). Among young men, we found strong associations between this gene variant and aggregated reports of state anger and hostility from daily diaries (Cohen effect size  $d = 0.57$ ). We found weaker, although still significant, associations with a measure of trait anger and aggression ( $d = 0.43$ ) (unpublished observations) (113). Genetic associations have also been found for the catechol-*O*-methyl transferase Val/Met polymorphism and ambulatory reports of reward experiences in daily life (114). Taken together, this research suggests that AA may be more sensitive for measuring the real-time emotional correlates of genes that modulate neural structures involved in automatic emotion processing. To the extent that other genes are involved in regulating the CA/SAL network or other circuits that regulate subjective phenomenology (e.g., pain), AA will likely provide the most sensitive self-report measure.

Ambulatory assessment may also help clarify inconsistencies in other areas of research linking subjective outcomes to brain processes, such as the emotional effects of mindfulness meditation interventions. Research has found brain changes as a result of mindfulness training such as greater left-sided hemispheric activation (115,116); however, these changes often do not correspond with changes in self-reported emotion. This is not entirely surprising given the complex relationships between brain activity, bodily processes, and subjective measures at any given

point (117,118). Yet, often with laboratory studies, emotions are usually measured in the standard ways—either with trait measures of affective style (115) or with momentary reports made in the laboratory before and after training (116). These approaches may not be sensitive enough to detect affective changes as a function of meditation training. In a Goldilocks sense, trait measures of emotional style may be “too cold”—too slow and sluggish to change because they capture enduring beliefs about a person—but momentary measures administered only once or twice may be “too hot”—too volatile and overly sensitive to extraneous variables unless they are aggregated over many repeated observations.

For these reasons, AA methods might provide greater resolution to affective changes that unfold over longer periods with mindfulness practice. For example, in research by Fredrickson and colleagues (119), training in loving kindness meditation among a community sample resulted in improvements to their daily mood states during the 9-week period compared with those in a waitlist control condition. Moreover, self-reported positive emotions in daily life were “the mechanism of change” (p1045) that led to improvements in other traditional end points such as global purpose in life, improved social support, and improved health symptoms. Indeed, other AA research has revealed affective differences between individuals with high and low levels of mindfulness and between new and advanced mindfulness meditators in daily life (120–122). Taken together, research suggests that AA of affective experiences in naturalistic settings may be a useful tool for linking mindfulness practice to emotional changes.

### Remembering and Believing Selves Show Stronger Connections to Health Decisions

Health decisions like choosing a physician and returning for routine health checkups can have strong implications for mental and physical health. For these processes, the psychology of the remembering or believing selves may play more important roles than the experiencing self. Indeed, there is growing awareness that people’s recollections, however distorted, play an important role in prospective decision making (1,42,86,87,123). For example, how people remember painful procedures, more than their actual experience during the procedure, affects important decisions such as whether to undergo the procedure again. In one of the earliest demonstrations of this phenomenon, Kahneman and colleagues (42) showed that people’s memories for aversive events (e.g., submersing a hand in cold water) were highly influenced by how the procedure ends, and people were more likely to choose to undergo aversive experiences again if they had experienced “a better ending.” Later, this work was extended to a clinical sample of 682 colonoscopy patients, some of whom underwent a modified procedure that added several minutes of not-painful time to the end of their colonoscopies (124). Those who remembered the procedure as less painful were more likely to undergo follow-up colonoscopies 5 years later. These findings suggest that memories—and the use of retrospective self-reports—may serve important functions in the context of prospective health decisions and behavior. Thus, physicians (and researchers) should carefully

consider the way that their patients remember health information and health-related experiences including visits to the physician.

Research in social psychology also highlights the important function of retrospective memories in behavior and decision making (44). For example, a 2-week computerized experience sampling study tracked the anticipated, experienced, and remembered emotions of university students' as they went on a spring break vacation (125). Students' anticipated and remembered feelings were much more positive than what they actually reported during their trip. Importantly, when asked whether they would repeat the trip again, their decisions were driven by their recollections. Thus, biased estimates of the past can be good predictors of future choice (1,44,126).

Taken together, research demonstrates a growing awareness of the special utility of the remembering self particularly for health-related decisions. The implication of this framework is that retrospective and trait self-reports will be maximally useful in research in which people activate their D/LTM networks to use their remembered or summary judgments to guide expectancies, decisions, and behaviors. In these contexts, memory-based self-reports may be the more sensitive measure than momentary self-reports for capturing decisional factors.

## SUMMARY AND RECOMMENDATIONS

We believe that the science of self-reports has evolved through three themes of understanding. Although different self-report procedures were originally ranked and directly compared with each other, later it was assumed that different self-report procedures captured different types of knowledge for experience. Today, there is a growing awareness of different conscious selves (experiencing, remembering, and believing selves), their functions, and relative links to bodily and brain processes. These linkages, in turn, should help inform researchers' decisions about how to use self-report procedures effectively in science. On the basis of this evidence, we can formulate several specific recommendations:

1. *Use ambulatory self-reports to maximize sensitivity when connecting psychological with stress-related biologic processes.* In general, biologic pathways (ANS, HPA, immune system, threat/reward circuits) involved in managing stress and maintaining homeostasis seem more strongly connected to the experiencing self than to the remembering or believing selves. Thus, when linking psychological phenomena to these systems, AA may provide a more sensitive psychological measure than traditional memory-based reports.
2. *As a rule, avoid using retrospective or trait reports as proxies for actual experience.* Using trait measures as proxies for experience may result in weaker or inconsistent results particularly when tested in connection to biologic pathways. The evidence reviewed in this article showed many examples of when patterns were not found in trait reports but were found in real-time reports using AA (25,88,91,95,102,112). Although experience, memories, and traits may all correlate (sometimes highly), they will not necessarily show the same associations with a predictor or criterion of interest.
3. *Think about which "self" is appropriate for a given research question.* If interventions are being used, consider the hypothesized mechanisms through which an intervention operates. If an

intervention is designed to improve the experience of mood, reduce pain, or reduce stress sensitivity, then ambulatory self-reports should provide greater resolution of treatment processes compared with memory-based reports. In that situation, use of highly stable trait measures may underestimate the effects of interventions designed to change experience. However, if an intervention acts to address beliefs and secondary appraisals of experiences after they occur, then treatment effects may be more apparent in retrospective measures.

4. *If you need to measure experience, there are affordable ways to do it.* Although it can be expensive to do computerized AA using smartphones or PDAs (see Kubiak and Krog (24) for current technology options), there are other low-cost ways to obtain close to real-time self-reports intensively over time. Lower-cost alternatives include Internet daily diaries that can be programmed at a fractional cost of traditional computerized experience sampling (61), the Day Reconstruction Method (62), text messaging or interactive voice recording with participants' own mobile phones (127,128), and Web-enabled surveys with hyperlinks sent to participants' own smartphones (129). Each of these approaches offers a more affordable and accessible way of tracking individuals in their daily lives. (For a beginning guide on getting started with these methods, see Conner and Lehman (127).)
5. *Do not abandon self-reports, but instead use them wisely.* Self-reports provide insight into the subjective lives of people, which have important implications for their health. Yet standard questionnaire approaches have come under criticism (rightly so) for being the primary way of linking biology to psychological concepts like emotional style (8,107). We agree that exclusive reliance on traditional self-reports is scientifically limiting. Instead of abandoning subjectivity in favor of objective measures, we propose using intensive momentary self-reporting techniques as a more sensitive way of linking psychological to biologic processes. More broadly, we encourage a more considered approach that recognizes the core differences among self-report techniques and the potential power of ambulatory self-report techniques in psychosomatic medicine.

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