Industrial and Organizational Psychology (2020), **13**, 103–116
doi:10.1017/iop.2020.18

CAMBRIDGE UNIVERSITY PRESS

PRACTICE FORUM

Is the future of leadership development wearable? Exploring self-tracking in leadership programs

Marian N. Ruderman* and Cathleen Clerkin

Center for Creative Leadership
*Corresponding author. Email: ruderman@ccl.org

(Received 17 October 2019; accepted 01 November 2019)

This practice forum explores how the "quantified self movement" can contribute to developing leaders by offering new approaches to assessment and feedback. Often associated with wearable technologies (digital technologies worn on the body), self-tracking sensors and feedback systems help individuals assess how they interface with the world, automatically capturing and monitoring data for learning, growth, and change. The authors make the case that such tools can create ongoing opportunities for learning intrapersonal qualities relevant to leadership. In particular, they offer insights about using self-tracking to manage responses to stress and fatigue and for the delivery of verbal presentations. The exploration also notes concerns about the use of technological devices for development purposes. The authors conclude by offering a summary of six factors to consider before using self-tracking tools for leadership development, and by identifying four aspects of self-tracking approaches that would benefit from more I-O psychologist involvement.

Keywords: leadership development; self-tracking; stress reactions; fatigue levels; vocal characteristics

A key component of leadership development is feedback through assessments (Church & Rotolo, 2013; Day, Fleenor, Atwater, Sturm, & McKee, 2014; Tornow & London, 1998). This includes 360-degree assessments (in which feedback is systematically garnered from multiple people), personality or learning assessments, or feedback from a coach or peer. Regardless of the source, rich assessment experiences help leaders understand what they are good at, as well as confront what they need to change, learn, or stop doing (McCauley, Van Velsor, & Ruderman, 2010). Thus, feedback via assessment acts as both catalyst and compass for developing goals for greater effectiveness. We propose that the emerging industry of self-tracking technologies holds the potential to create a new avenue for leadership development assessment and feedback; however, more research and development are needed before such technologies can reach this potential.

The quantified-self and leadership development

The practice of tracking one's own reactions is not new. Researchers and laymen alike have long used logs to record and reflect on experiences and notice changes over time. However, recent advances in biometrics and sensor technologies have revolutionized how, and what, individuals can self-track. In 2007, *Wired* writers Gary Wolf and Kevin Kelly coined the term "quantified self" to describe this new technology-based form of self-tracking, or "self-knowledge through numbers"

(https://qsinstitute.com/). Since then, both the term and the concept have taken off, and are now considered a worldwide movement (Swan, 2012).

Often associated with wearable technologies (digital technologies worn on the body), quantified-self tracking systems help individuals gauge how they interface with the world, automatically capturing data and monitoring responses for the purposes of learning, growth, and change. The widespread use of fitness trackers and smartphones have made sensor-enabled wearables of all types commonplace (examples include wristbands, clip-on devices, digital badges, jewelry, apparel, and headgear). These technologies are usually paired with digital applications, which offer simplified, real-time data dashboards providing feedback on the metrics being assessed. The use of sensors to monitor and change psychophysiological properties, or somatic data, is a rapidly growing industry (Lupton, 2012; Millings et al., 2015), with trend reports predicting large expansions in wearable technology in the next 5 years—both in terms of devices and usage (Page, 2015; Wurmser, 2019).

While the quantified-self movement initially focused largely on everyday health and fitness, there is a burgeoning interest in how this technology can be applied to the workplace (PricewaterhouseCoopers, 2016; Schatsky & Kumar, 2018). Organizational wellness initiatives are rapidly incorporating fitness trackers (Pettey, 2018). Hospitals and healthcare providers are exploring how self-tracking can be used to supplement healthcare systems (Kroll, Boyd, & Maslove, 2016). Self-tracking systems are being tested to improve workplace safety, such as tracking work hours and exhaustion to prevent factory accidents (Rausch, 2016) or medical incidents (Peixoto, Ribeiro, Pereira, Nunes, & Pereira, 2018).

Given the escalating interest and versatility in wearables and self-tracking devices, we believe it is a matter of time before such tools are applied to other aspects of organizational life—including leadership development. Indeed, consumer reports already indicate that individuals believe wearables can increase their efficiency at work, and they expect their organizations will provide them with self-tracking technology in the future to help with productivity (PricewaterhouseCoopers, 2016). To this end, organizations are beginning to partner with technology providers to determine how wearables can increase operational efficiency, augment employee abilities, and increase self-awareness (Schatsky & Kumar, 2018).

Self-tracking technologies are appealing because they have the benefits common to data-based interventions—they allow for exploration of the current state, provide images of a desired state, and provide the feedback necessary for practice and implementation. We believe that such technologies could be beneficial for leadership development in that it would shift assessment from the occasional event to an ongoing learning process embedded into everyday work life—a change that learning and development professionals have been advocating for years (Bersin, 2017; McCauley, DeRue, Yost, & Taylor, 2014). Furthermore, self-tracking measures have high ecological validity because they are collected in real-world settings; and quantified-self sensors and apps allow for a formative approach to learning, enabling individuals to identify discrepancies between current assessment scores and desired scores.

But despite the emerging trend of quantified-self feedback at large, the use of these tools for developing leaders is in its infancy. There has been little discussion in the field to date as to how industrial and organizational (I-O) psychology practitioners could leverage "the quantified leader" for development purposes. What are the best practices? Which measures are relevant to leader development? What are common pitfalls or limitations? Who would benefit? In this practice forum, we share our experiences exploring these technologies as leadership development practitioners. We conducted several field tests to learn more about the use of self-tracking technologies for development purposes. We share our preliminary results, and offer future directions—and precautions—as to how the field can better leverage the quantified-self movement for leader development purposes.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Can wearable technology address the needs of leaders?

Leaders are challenged to improve performance—their own and others'. At the heart of this challenge is often the need to build self-management skills, or intrapersonal competence (Silzer & Church, 2009). Often difficult to measure, intrapersonal skills help people to maximize performance in a variety of situations, including those that are pressured or risky. Leadership development experts have identified three aspects of intrapersonal competence: self-awareness, self-regulation, and self-motivation (Day, 2000; McCauley, 2000). These competencies help leaders guide themselves in the face of changing or uncertain circumstances by enhancing self-direction. Using a data-based approach, technology-fueled self-tracking tools hold the potential to integrate goals related to intrapersonal competencies into a leadership development curriculum.

Traditional 360-degree assessments offer leaders self-awareness on general competencies (e.g., that they are seen as lacking composure under pressure); but rarely include the nuanced and operationalized information needed regarding *how* to adjust behaviors and perform more effectively. In contrast, self-tracking devices offer not only awareness of data (e.g., an initial sign of lack of composure, such as elevated heart rate), but the data are broken into quantifiable, physical, microcomponents (e.g., the number of beats per minute), enabling the setting of highly specific goals. In addition, digital dashboards assist with self-regulation by providing frameworks for planning change, guidance about what changes to make, and monitoring of progress. As leaders attempt to change, the devices offer real-time information regarding the effectiveness of their behaviors, helping leaders understand and achieve self-regulation. Moreover, continuous evaluative feedback also acts as a powerful self-motivator (Burgers, Eden, van Engelenburg, & Buningh, 2015) because frequent feedback can reinforce intentional efforts to change. In short, self-tracking helps to shed light on microcomponents of behaviors, thus creating the possibility of improved mastery of these behaviors.

Self-tracking technologies are also promising because they measure the psychophysical aspects of leadership that can be difficult to observe or articulate by human raters—for example stress level, alertness, reaction time, vocal tone, and emotional valence. There is often a temptation to ignore these sorts of intangibles in leadership development because they are hard to measure and develop. However, these intangibles affect the quality of performance and can impact perceptions of ability, and subsequently, leadership attainment. While these systems offer metrics on a wide variety of psychophysical aspects, for the purposes of our exploration we focused on three topics that we believe are central to both performance and being seen as a leader: management of reactions to stress, fatigue management, and vocal mannerisms. Next, we explain our rationale for selecting these topics, along with how and why leaders can use self-monitoring devices to address self-management in these areas.

Stress reactions

Stress is one of the most persistent challenges of leaders in particular (Harms, Crede, Tynan, Leon, & Jeung, 2017) and the workforce at large (American Psychological Association, 2017). Leaders are often asked to act during stressful situations, and it can be challenging to respond in a healthy way. The experience of stress corresponds with two clear physiological signals: heart rate variability and ectodermal skin response. Heart rate variability (HRV) measures the beat-to-beat changes in heart rate[1] and is considered an accurate measure of autonomic nervous system activation. Generally, low HRV (or less variability in heartbeats) indicates that the body is under stress. A higher HRV indicates better emotion regulation abilities (Appelhans & Luecken, 2006).

[1]Note that *heart rate* refers to the average heartbeats per minute, while *heart rate variability* (HRV) measures the specific changes in timing (or variability) between successive heartbeats.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

HRV patterns can be measured through a variety of heart rate monitors and are typically presented on a data dashboard associated with a sensor.

The ectodermal skin response refers to the amount of sweat produced by the body. When the sympathetic nervous system (SNS; i.e., "fight or flight" system) is aroused, sweat glands are activated, which increases skin conductance. This can be measured through an ectodermal activity (EDA)[2] sensor. EDA rises in response to environmental threats such as fear or unfairness (Dunn, Evans, Makarova, White, & Clark, 2012). EDA sensors have a long history of being used in psychological research and biofeedback devices (Hentschely, Smith, & Draguns, 2004). Modern devices often require pressing a fingertip against a sensor, as the extremities are a good place to measure skin conductance.

Although they work differently, both HRV and EDA sensors assess physiological signals associated with stress. Monitoring these physiological aspects of stress allows leaders to increase awareness of what triggers bodily stress reactions, explore their feelings, and experiment with ways to regulate and modify reactions to respond more effectively. This is especially important in the workplace, where the body's default responses may not be effective for leadership purposes (e.g., "fight or flight" are rarely good options during a stressful business meeting). Because skin conductance and heart rate variability are not controlled consciously, they offer insights into subconscious physiological responses and emotional experiences. The sensors are associated with feedback apps that provide guidance on how to regulate responses. With repeated practice, the devices can be used to teach self-regulation strategies such as lowering SNS activation or changing cognitive interpretations of the situation. Use of the monitors allows people to understand the efficacy of their attempts to respond to internal bodily reactions. Moreover, both HRV and EDA readings can be associated with meditative states, making it possible to use these tools to teach contemplative practices to leaders, which, in turn, may lead to more effective reactions to stress.

Understanding the physiological signals associated with stress is not only helpful as distressing situations occur but also post-situation when rumination gets in the way of thinking clearly (Roger & Petrie, 2017). Being able to read these signals can be helpful in learning to adeptly express emotions. Furthermore, learning to regulate responses to stress is at the center of resilience training and can influence how people speak and act when experiencing stress.

Fatigue

Fatigue impacts performance and increases the risk of errors and accidents (Sonnentag, Binnewies, & Mojza, 2008). Although there are many ways to assess fatigue, we focused on fatigue associated with lack of sleep. In today's "always on" work culture of travel and 24/7 accessibility, sleep is perhaps leaders' most important personal resource. Lack of sleep has been linked to lower performance, including problems with emotion regulation, memory, attention, and problem solving (Nowack, 2017). But despite the solid scientific evidence, many leaders do not get enough sleep. A Center for Creative Leadership survey found that 42% of leaders get fewer than 6 hours of sleep a night—a far cry from the recommended level of 8 hours (Clerkin, Ruderman, & Svetieva, 2017). In the US, 23% of employees report being too sleepy to function (Kessler et al. 2011). Yet, unlike other safety issues, such as washing hands or wearing safety goggles, it is very difficult for organizations to mandate the sleep required to prevent fatigue.

Sleep and fatigue monitoring have become a focus in medicine, athletics, and the military, and several sleep tracking tools are now available. At present, actimetry sensors are the most promising: generally worn on the wrist like a watch, they measure gross motor activity and

[2]Over the years, the terminology used to describe ectodermal activity has changed moving from a variety of specific terms such as galvanic skin response (GSR) to the more general EDA.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

can be used to calculate variables such as total sleep time, sleep efficacy, sleep onset latency, and wakefulness after sleep onset. There currently are many types of actimetry sensors, and they differ in their sophistication. Like the tools for monitoring responses to stress, actimetry sensors can help leaders become more aware of their habits, analyze them, and work on self-improvement. The data help people to explore their sleep habits, understand measures associated with sleep deprivation, and associated apps can provide relevant advice to improve sleep performance and lower fatigue. For instance, leaders can use data about their circadian rhythms the way that military and athletes do: to strategize when to do challenging tasks and when to avoid dangerous or high-risk situations.

Vocal characteristics

Leaders need to be skilled speakers—persuading high-level stakeholders or rallying underperforming troops. Yet anxiety around public speaking is common, affecting 15–30% of adults and even interfering with work responsibilities (Glassman et al., 2014). In fact, the anticipation of public speaking is used in experiments to induce social anxiety (Durlik, Brown, & Tsakiris, 2014). In the leadership literature, strong vocal delivery has been linked to positive leadership characteristics, including charisma (Awamleh & Gardner, 1999; Den Hartog & Verburg, 1997) and credibility (Holladay & Coombs, 1993, 1994). Research by DeGroot and Motowidlo (1999) suggests that vocal cues can be valid indicators of perceived promotability in organizations. Moreover, research suggests that training can help speakers gain conscious control over their voices (Sulter, Schutte, & Miller, 1995).

Traditionally, leaders have gotten feedback on their communication in an impressionistic way. While this is invaluable, it is also subjective. In recent years, technologies have led to an increased understanding of vocal mannerisms (Niebuhr, Voße, & Brem, 2016). Quantified-self assessments of communication (known as voice analytics) offer objective acoustic measurements—using voice analysis algorithms to identify the different features of voice. Vocal characteristics typically analyzed include pitch, pitch variability, pausing, pace, disfluencies, and volume variability. These features are then converted to outcome data, which can be used to understand vocal capabilities. Training with such tools can help speakers gain insights, confidence, and vocal control. As with other data-based development tools, the feedback reports are accompanied with automated and personalized performance coaching; the easy, repeated use of such tools allows for practice and implementation of improved techniques. The technology allows for the setting of very specific goals and repeated practice to reach those goals.

Testing the tools

There were a wide variety of self-tracking sensors claiming to provide assistance with stress management, sleep/fatigue management, and vocal characteristics. We restricted our testing to tools that appeared to be appropriate for augmenting leadership talents. Influenced by an inquiry approach (Argyris & Schon, 1978), our testing was intended to understand and appreciate the experiences of users (i.e., both leaders and leadership development practitioners). All of the tools we chose are intended to help individuals better understand their interior state and hard-to-control responses, allowing for repertoires to be broadened and more constructive responses identified. Since the technology is changing rapidly, we do not offer detailed descriptions of specific tools, but rather discuss the general themes and concerns that emerged. We used a multi-stage process to examine the instruments. Each phase had a series of checkpoints that had to be reviewed to get to the next phase (see Table 1). This examination is just the beginning because the experimental evidence on the efficacy of these tools for leadership development is currently lacking.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Table 1. Multistage process used for device examination

Method	Participants	Timeline	Data collected	Criteria
Review of websites, scientific articles, user reviews, conversations with experts	N/A	Ongoing	Literature review	Appropriateness Scientific soundness Price
Self-tests	The authors	1–2 weeks	Quantified-self data	Practicality Face validity
Beta-tests	About 20 colleagues of different ages, body types, and genders. All were engaged in the field of leadership development.	2–4 weeks	Quantified-self data, user feedback debrief interviews, and focus groups.	Face validity User experience
Quasi-experimental tests	About 120 leaders who were participating in leadership development training.	1–5 days	Quantified-self data, survey data of related psychological measures, user feedback on devices.	Face validity User impact Construct validity Criterion validity

First, we located and reviewed the available tools. Because of the infancy of the field, formal databases such as EBSCO Psychology and EBSCO Business did not yield any peer-reviewed articles on the use of self-monitoring devices for leadership development purposes, so we identified available tools based on searches of Google, user reviewers, and conversations with colleagues. We looked for tools that (1) appeared to be appropriate for use with leaders in formal development or learning settings; (2) included sufficient information about the scientific basis for metrics; (3) were within a modest price range; (4) were based on a theory recognized as supported by evidence; and (5) recommended activities to improve scores. Of the approximately 20 tools found, a total of 8 devices were selected, including a combination of wristbands, optical monitors, chest straps, and sensors.

Next, both authors tested the tools on themselves, focusing on practicality and face-validity for use in leadership development programs. We examined aspects such as comfort, simplicity, wireless capability, battery life, cleaning, and safety risks. We used each tool for at least a week. Two main issues resulted in eliminating devices at this stage: (1) discomfort or impracticality; (2) meaningless data (due to vague or inaccurate data summaries or devices that did not detect meaningful amounts of variation). If we could not get them to work consistently in a way that made sense to us, we did not ask others to use them. Five devices were identified as suitable for further testing.

Our next step was to test the user experience with a larger group of colleagues (between 10 and 20 people, depending on the device). We sought out people of different ages, body types, and genders who worked in the field of leadership development. We thought of them as "beta-testers" rather than subjects. Afterward, we conducted informal debriefings, asking them to share their candid reactions regarding usability, face-validity, helpfulness, and the impact of using the tools. We learned that not all devices work well for all people. In several tests, people had technological issues syncing the monitor with the analytic software, resulting in diminished value of the data visualizations. In most cases, we found that people required more in-depth direction and coaching around the use and output of the tools. Only two devices were identified as suitable for use with clients in the leadership classroom. These devices were user-friendly, scientifically sound, and encouraged deep meaning-making with the data. They provided skills training and feedback about progress with relationship to metrics, and the relevance to the "how" of leading was clear.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Quasi-experimental tests in leadership development settings

In this phase of testing we were interested in user impact, face validity, construct validity, and criterion validity. From a client standpoint, the tools had to feel relevant and useful to the leaders who were investing time and money in development; and from a research–practitioner standpoint, we wanted to know if the tools explained leadership outcomes and how similar they are to other assessments (e.g., 360s, personality tests, expert observations). We were also extremely interested in feedback on the user experience.

HRV monitor device

We tested an HRV monitor device for face validity and impact in several classrooms and got generally positive feedback. People found it easy to use and were interested in becoming more aware of the connections between physiology, behavior, and feelings of stress. However, we also experienced some difficulties: there was substantial variation in how easily participants in a classroom setting adjusted to using the devices.

Following these pilots, we conducted a quasi-experimental study to see if the use of the monitor in conjunction with an associated meditative breathing app was effective at building resilience to stress, among other measures (Ruderman & Clerkin, 2015). The app provided both instructions as to how to breathe in a way believed to lower stress, as well as real-time feedback from the sensor regarding heart rate variability. We asked clients to volunteer to use the monitors and the breathing technique for at least 5 minutes a day for 5 days while participating in a standard leadership development classroom. Seventy of 73 participants volunteered, and 65 participants used the monitors at least 4 out of 5 days.

Overall, we did not find statistically significant self-reported differences between this experimental group and those in the standard program.[3] However, we did find a positive relationship between HRV-related scores on the app and self-ratings of resilience; specifically, participants who on average "scored higher" on the breathing app (i.e., were evaluated as having calmer breathing patterns) also showed more gains in a self-report measure of resilience between day one and day five.[4]

Voice analytics

The second device that made it to client testing was a voice analytic tool. The tool allowed individuals to record their voice using an app, and then upload the recording to a personalized data dashboard that provided numeric scores on a variety of vocal qualities as well as a coaching section that offered feedback for improvement. As with the HRV monitor, we first piloted the device in several classrooms, asking leaders for their feedback about the user experience. Again the responses were positive, with most people finding the app intuitive and the dashboard accurate. Users liked seeing what they were doing well and the provision of specific suggestions for improvement in areas needing development. We experienced fewer technical issues with this device (largely because it was not a wearable, but a voice recording app connected to software). A field study examining the predictive validity of this tool is currently underway. Preliminary results suggest a positive correlation between higher vocal scores as rated by the software and leader emergence within classroom settings. Thus, we have some evidence that this particular self-tracking tool is relevant for leadership development.

[3]We believe that the low dosage between group intervention (i.e. 5 minutes for 5 days) may have been overwhelmed by the similarities of being in an intensive 5-day leadership development program.

[4]Linear regression analysis was used to test if positive breathing scores significantly predicted participants' change scores in self-ratings of resilience. The results of the regression indicated that the breathing scores predicted 8% of the variance in resilience change scores ($R2$ =.08, $F(2,53)$=4.68; β = .29, p=.04).

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Lessons learned: Essential factors for using self-tracking tools in leadership development

Our pilots indicated that there is both acceptance and demand among clients for using self-tracking tools; however, few tools were both rigorous and accessible enough to be a good resource for leadership learning and development. The tools that had the most promise provided very specific feedback and helped users to intuitively connect behaviors and outcomes. Based on our experiences, we identified six factors that practitioners should consider when exploring these tools for leadership development. These factors, along with details about our experiences and advice, can be found in Table 2.

Finding the right device is not the only requirement for successful implementation of self-tracking tools. Once an appropriate tool is identified, human motivation and support also need to be taken into consideration. Just as with the success of any other tool for development, there must be a commitment to using the tool and processing the feedback. For example, in our HRV/breathing intervention, we noticed that one or two participants used the practice time to check emails, ignoring the biofeedback on the screen. In such cases, the quality of data matters little if leaders lack intrinsic motivation. As with most efforts to change personal habits, intention to change matters (Prochaska & DiClemente, 2005). Self-tracking tools raise consciousness and can reinforce new behaviors, but they cannot force someone who is resistant or skeptical of different habits to try something new. Just as with other learning interventions, readiness to change is critical (Rafferty, Jimmieson, & Armenakis, 2012). The tools require both setting specific goals and putting in the practice time to reach them.

Additionally, the impact of self-tracking data will be limited if there is no support for development or change. As with other forms of assessment, the data itself is a starting point. Leaders need to know how to leverage the data to develop a personalized and operationalized strategy for self-development. The organizational culture also needs to support change efforts. Practitioners could offer supplemental materials and/or coaching to help leaders make the connections they need. Educators may be able to offer insights as to how to use these tools from a lifelong learning perspective. They could also help combine them with other tools in pedagogically meaningful ways and provide input as to the importance of practice. Some devices can connect to social networks that could be used to help leaders with goals and accountability. As with most development processes, ongoing practice and social support are essential.

What is the future of quantified-self methods in leadership development?

Based on our experiences with self-tracking tools, we believe they can become a meaningful component of leadership development—if more research is done, and if the technology becomes more accurate. These tools offer the promise of real-time feedback to help leaders optimize their performance. However, to realize this promise, the technologies need insights and contributions from I-O psychologists. There is an opportunity for I-O researchers and leadership development practitioners to collaborate with experts in emotional regulation, sensor technology, and psychophysiology to not only leverage self-tracking devices, but to help shape the future design and implementation of these tools. In particular, there are four areas that we think would benefit from more I-O psychologist involvement in order to make these technologies useful to our field: validity standards, data relevance, ethical issues, and universal usability.

Validity standards

We found that some of the sensors were not as accurate or sensitive as they should be for use in leadership development. Both the EDA and HRV monitors got confounded by extraneous movements. The voice analytic tool was limited by extraneous sounds. Even the sleep monitor

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Table 2. Six factors to consider before using self-tracking tools for leadership development

Factor	Issue	Details and examples	Advice
Price	Currently, there is a steep quality–cost tradeoff when it comes to self-tracking devices. Medical-grade devices tend to be cost-prohibitive, while affordable ones tend to lack the sensitivity and sophistication necessary to offer accurate feedback.	At present, the gap between medical-grade devices and commercial trackers spans a couple of thousand dollars. For our explorations, we focused on devices that cost under $300. We did not charge our learners to use the devices.	We predict that soon, this price gap will close, and higher-quality devices will be available at a lower cost. In the meantime, practitioners should be wary of low-cost devices, and know that adding quantified-self aspects to development can be costly.
Face validity	An important consideration for client use is face validity—whether the device appears to accurately measure outcomes that are useful for leaders.	Leaders have competing priorities and need a compelling reason to make the effort that self-tracking tools require. The "cool factor" is not enough. Assessments must have an obvious connection to their daily tasks. A weak connection may lead to rejecting the feedback or losing commitment to monitoring performance.	Practitioners should be able to explain to leaders why and how devices can improve leadership. Ideally, this case should be made before self-tracking methods are introduced. If the case cannot be made, it might not be the right device.
Understandable assessment feedback	A concern related to face validity is understandable feedback—leaders need to be able to understand and interpret the feedback they are given by the tools.	All of the devices we tested had some type of format for data presentation built in. However, they differed with regard to how much help they provided sifting through the data. Some assessments were so vague or high level that they did not offer any insightful information (e.g., "you've been awake for 8 hours"). Others offered only numbers, without a clear explanation of what the numbers meant.	Practitioners should examine the output associated with the tools. Look for dashboards that offer easy-to-understand displays balanced with information about fine-grained measures. Ideally, feedback should also use language that makes the nuances indicated by the measures both discussable and actionable. Personalization of data display options is a plus.
Ease and adaptability of use	Self-monitoring for leadership development requires that devices and associated software be straightforward and easy to use. They also have to be adaptable to different modes of leadership development (e.g., coaching, classroom-based, experience-driven) and be capable of being used as a personal development technique by an individual.	We found that many self-monitoring tools can be hard to put on, turn on, or sync. These difficulties are compounded greatly in classroom settings with dozens of leaders sharing the same struggles. For instance, although HRV chest straps are highly reliable, some participants found them too awkward to put on and wear. HRV optical scanners also caused some people trouble—falling off if people moved quickly or turning off when there were Wi-Fi problems. The EDA devices were simple, but some leaders found them hard to use for an extended length of time, as they required keeping a finger on a sensor.	Unlike athletes or military, who need to test their physical capabilities, leaders are not motivated to endure uncomfortable monitors and complicated straps. We found that leaders had very little patience for being "hooked up" to awkward devices. Thus, we recommend prioritizing comfortable and simple tools to encourage leaders to use devices regularly.

(*Continued*)

Table 2. (*Continued*)

Scientific soundness	There are a lot of self-tracking tools on the market today, and many of them lack scientific soundness, producing data that lack reliability or construct validity. Moreover, even those with strong scientific backing have likely been validated by a different population (e.g., athletes, military, clinical), and findings may or may not generalize to leaders.	All the tools we selected claimed to have sound psychometric properties. However, none of the tools were validated in the leadership population. We found that accuracy for the leadership population varied. For instance, one device created for athletes did not accurately measure the movements of the more sedentary. Another device, created for a clinical population misattributed everyday movements (such as teeth brushing) to signs of a seizure.	While face-validity might be most important to clients, reliability and construct validity should be the most important to practitioners. It is not enough to check whether the tools claim to be validated, as different companies have different levels of scientific rigor, and findings may not generalize. We recommend that practitioners conduct pilot tests before using these tools with clients.
Accessible raw data	Many tools do not allow access to the raw data they collect. This can be an issue for those trying to conduct research and/or examine validity, reliability, and explanatory utility in the leader development space.	For each tool, we checked whether we could get access to raw data. In almost all cases, it was not readily available. Because of this, we contacted the companies to see whether we could gain access. A few agreed to share the raw data, while others stated that it was proprietary.	Raw data are extremely important for conducting and replicating research. It should not be assumed that raw data are provided by these devices. We recommend contacting the companies to find out whether collecting raw data is possible.
Fit with curriculum and pedagogy	The tools probably should not be used just by themselves for leadership development. They should be combined with other modalities of development and carefully integrated into the learning objectives.	Sports performance coaches have success combining wearables with face-to-face coaching. Athletes are used to making small changes in order to enhance performance or alleviate stress. They emphasize the goal-setting aspects of the devices.	Borrowing from sports psychologists and consultants to the performing arts, coaching works well with wearables. Wearables allow for a high level of personalization in consultation with an expert. If used with a large group, practitioners should be prepared to handle resistance to technology.

occasionally confused watching TV with sleeping. Other reviews of quantified-self options have come to similar conclusions (Donker et al., 2013). Performance monitoring is only as good as the measures. We have metric standards for looking at the reliability and validity of 360-degree feedback scales; analogous guidelines are necessary for monitors for self-development. In addition, despite the strong fascination with the use of self-tracking tools, proven evidence of efficacy for behavior change is lagging. I-O psychologists should take an active role in establishing the field standards regarding the threshold of accuracy that should be met for purposes of leader development.

Data relevance

Every tool we examined promised to provide insights through data, but the data provided were often not useful for our needs. For instance, several devices simply offered basic metadata such as location, date, or amount of time used. While these types of data are valuable for user or marketing research, they are of little use to I-O psychologists or leaders. This is critical, given that a recent qualitative study on fitness trackers found that individuals were more likely to use trackers when the data were useful, accurate, and aligned with a previously formed goal (Canhoto & Arp, 2017). There is a marked opportunity for I-O psychologists to help create tools that provide data that are relevant to leadership and/or the workplace. Based on our review, we believe that much of the technology required to introduce quantified self-assessment into leadership development already exists. What is lacking is empirical testing, calibration of instruments for the leadership population, and the knowledge about how to best combine these tools with pedagogy, learning objectives, and other tools for optimal development.

Ethical and privacy issues

At the time of writing, there are significant issues about data privacy and security with these tools. For instance, 2015 study of 79 smartphone health applications found that two-thirds of apps certified as safe and trustworthy by the UK NHS Health Apps Library still sent identifying information over the internet without encryption, and 20% did not have a privacy policy (Huckvale, Prieto, Tilney, Benghozi, & Car, 2015). A related issue is ownership of data. Is quantified-self data strictly the property of the individual? Does the company selling the device own it? If an organization or coach pays for the tools, do they have rights to see the data? Can they use it for surveillance purposes? The General Data Protection Regulation law implemented by the European Union in 2018, along with other similar regulations worldwide, are an important first step to address some of these issues, but many questions remain. As is common with new technologies, applications have outpaced legal guidance. Until these issues are settled, there is the risk of adverse employee impact and misguided use of data. I-O psychologists should be attuned to these current debates and consulted for policy developments. For data to be developmental, there must be confidentiality and ethical standards in place and recognition of the intrusion these devices can cause. Without appropriate ethical guidelines, self-tracking tools run the risk of becoming disempowering.

Universal usability

Our test subjects were fairly homogeneous. All were interested in leadership development, were highly educated, and were working in American organizations. Additional research needs to be conducted to see if these tools hold promise in different sociocultural settings and the growing diversity of people engaged in developing their leadership abilities. Future research should also explore who would benefit most from this type of approach and why. For instance, a recent study found that people were more likely to try an augmented reality wearable when they expected functional benefits and social conformity; however, these results were moderated by personality

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

differences (Rauschnabel, Brem, & Ivens, 2015). Similarly, trend reports suggest that currently people under 40 are more interested in wearable devices (Page, 2015; PricewaterhouseCoopers, 2016). However, this trend may change as such tools become more commonplace, and generations grow older. We suspect that wearables are most useful with people who are highly goal-driven, as the devices indicate small increments of change. Future research should look at the motivational impact of small increments of improvement.

Conclusion

Quantified-self methods hold both promise and challenges for leadership development. The promise is that they offer specific feedback for intrapersonal qualities and internal sensations that can make or break performance in a pressured situation. In addition, they enable people to take an iterative approach to learning, connecting ongoing monitoring to development—offering feedback that is specific and operational. They align nicely with the trend to promote continuous learning and development in organizations, making work and the experience of learning about what one does, versus what one *thinks* one does, seamless and available on demand. However, despite general enthusiasm for quantified-self methods, some challenges keep them from being ready for easy adoption. First and foremost, the technology is not always easy to use. Second, the measures do not always have face validity for leadership roles because most of the devices were created for other audiences. Third, privacy and ethical issues are not easy to address. Fourth, more research is needed to determine what development scenarios they work best in (e.g., it may be that they enhance coaching initiatives and action learning but are not helpful in classroom or digital learning settings).

The tools discussed here are just the tip of the iceberg. There are many more on the horizon that could also facilitate leadership development by increasing intrapersonal competences (i.e., self-awareness, self-regulation, and self-motivation). For example, many sensor technologies are currently experimenting with ways to assess mood. Such tools could be used within leadership development to improve empathy and emotional intelligence. Similarly, there are electroencephalogram wearables being developed that promise to track attention during conversations, which could be used to provide leaders with unique feedback about their communication skills. "Smart shoes" could be used to provide leaders with feedback regarding whether they are spending a disproportionate amount of time in certain offices or departments while ignoring others. Contact lenses could provide data on stress levels based on tear composition. Quantified-self clothing could offer feedback about nonverbal behavior (e.g., slouching, crossing arms). Virtual and augmented reality could offer new ways to teach emotional regulation and create a positive feedback loop for behavior change. In short, there is a myriad of possible tools and applications and little certainty about what will become mainstream in the future.

At the same time that self-tracking tools are becoming more popular, the environment is growing more demanding of leaders. Leaders and HR professionals are increasingly looking for just-in-time leadership development solutions and new models of capability building. I-O psychologists are in a prime position to steer the adaption and adoption of self-monitoring approaches to behavior change for purposes of leadership development. Moreover, it is critical that I-O researchers offer expertise in creating ethical and methodological guidelines for the future of the self-tracking movement in the workplace.

References

American Psychological Association. (2017). *Stress in America: Coping with change.* Stress in America™ Survey. Retrieved from http://www.apa.org/news/press/releases/stress/2017/state-nation.pdf

Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of General Psychology*, **10**(3), 229–240. doi: 10.1037/1089-2680.10.3.229.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

Argyris, C., & Schon, D. 1978. *Organizational learning: A theory of action perspective*. Reading, MA: Addison-Wesley.
Awamleh, R., & Gardner, W. L. (1999). Perceptions of leader charisma and effectiveness: The effects of vision content, delivery, and organizational performance. *The Leadership Quarterly*, **10**(3), 345–373. doi: 10.1016/S1048-9843(99)00022-3
Bersin, J. (2017). *HR technology disruptions for 2017: Nine trends reinventing the HR software market*. Oakland, CA: Deloitte Development LLC. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/us/Documents/human-capital/us-hc-disruptions.pdf
Burgers, C., Eden, A., van Engelenburg, M. D., & Buningh, S. (2015). How feedback boosts motivation and play in a brain-training game. *Computers in Human Behavior*, **48**, 94–103. doi: 10.1016/j.chb.2015.01.038
Canhoto, A. I., & Arp, S. (2017). Exploring the factors that support adoption and sustained use of health and fitness wearables. *Journal of Marketing Management*, **33**(1–2), 32–60. doi: 10.1080/0267257X.2016.1234505
Church, A. H., & Rotolo, C. T. (2013). How are top companies assessing their high-potentials and senior executives? A talent management benchmark study. *Consulting Psychology Journal: Practice and Research*, **65**(3), 199–223. doi: 10.1037/a0034381
Clerkin, C., Ruderman, M. N. & Svetieva, E. (2017). *Tired at work: A roadblock to effective leadership*. Greensboro, NC: Center for Creative Leadership. Retrieved from https://www.ccl.org/wp-content/uploads/2017/11/Tired-at-Work-Roadblock-to-effective-leadership-white-paper.pdf
Day, D. V. (2000). Leadership development: A review in context. *The Leadership Quarterly*, **11**(4), 581–613. doi: 10.1016/S1048-9843(00)00061-8
Day, D. V., Fleenor, J. W., Atwater, L. E., Sturm, R. E., & McKee, R. A. (2014). Advances in leader and leadership development: A review of 25 years of research and theory. *The Leadership Quarterly*, **25**(1), 63–82. doi: 10.1016/j.leaqua.2013.11.004
DeGroot, T., & Motowidlo, S. J. (1999). Why visual and vocal interview cues can affect interviewers' judgments and predict job performance. *Journal of Applied Psychology*, **84**(6), 986–993.
Den Hartog, D. N., & Verburg, R. M. (1997). Charisma and rhetoric: Communicative techniques of international business leaders. *The Leadership Quarterly*, **8**(4), 354–390. doi: 10.1016/S1048-9843(97)90020-5
Donker, T., Petrie, K., Proudfoot, J., Clarke, J., Birch, M. R., & Christensen, H. (2013). Smartphones for smarter delivery of mental health programs: A systematic review. *Journal of Medical Internet Research*, **15**(11). doi: 10.2196/jmir.2791.
Dunn, B. D., Evans, D., Makarova, D., White, J., & Clark, L. (2012). Gut feelings and the reaction to perceived inequity: The interplay between bodily responses, regulation, and perception shapes the rejection of unfair offers on the ultimatum game. *Cognitive, Affective & Behavioral Neuroscience*, **12**(3), 419–429. doi: 10.3758/s13415-012-0092-z
Durlik, C., Brown, G., & Tsakiris, M. (2014). Enhanced interoceptive awareness during anticipation of public speaking is associated with fear of negative evaluation. *Cognition and Emotion*, **28**(3), 530–40. doi: 10.1080/02699931.2013.832654
Festekjian, A., Tram, S., Murray, C. B., Sy, T., & Huynh, H. P. (2014). I see me the way you see me: The influence of race on interpersonal and intrapersonal leadership perceptions. *Journal of Leadership & Organizational Studies*, **21**(1), 102–119.
Glassman, L. H., Herbert, J. D., Forman, E. M., Bradley, L. E., Izzetoglu, M., Ruocco, A. C., & Goldstein, S. P. (2014). Near-infrared spectroscopic assessment of in vivo prefrontal activation in public speaking anxiety: A preliminary study. *Psychology of Consciousness: Theory, Research, and Practice*, **1**(3), 271–283. doi: 10.1037/cns0000009
Harms, P. D., Crede, M., Tynan, M., Leon, M., & Jeung, W. (2017). Leadership and stress: A meta-analytic review. *The Leadership Quarterly*, **28**(1), 178–194. doi: 10.1016/j.leaqua.2016.10.006
Hentschely, U., Smith, G., & Draguns, J. G. (2004). Defense mechanisms and their psychophysiological correlates. In U. Hentschely, G. Smith, J. D. Draguns, & W. Ehlers (Eds.), *Advances in psychology defense mechanisms: Theoretical, research and clinical perspectives*, vol. **136** (pp. 611–636). Stuttgart, Germany: Elsevier.
Holladay, S. J., & Coombs, W. T. (1993). Communicating visions: An exploration of the role of delivery in the creation of leader charisma. *Management Communication Quarterly*, **6**(4), 405–427. doi: 10.1177/0893318993006004003
Holladay, S. J., & Coombs, W. T. (1994). Speaking of visions and visions being spoken: An exploration of the effects of content and delivery on perceptions of leader charisma. *Management Communication Quarterly*, **8**(2), 165–189. doi: 10.1177/0893318994008002002
Huckvale, K., Prieto, J. T., Tilney, M., Benghozi, P. J., & Car, J. (2015). Unaddressed privacy risks in accredited health and wellness apps: A cross-sectional systematic assessment. *BMC Medicine*, **13**(1), 214. doi: 10.1186/s12916-015-0444-y
Kessler, R. C., Berglund, P. A., Coulouverat, C., Hajak, G., Roth, T., Shahly, V., . . . **Wash, J. K.** (2011). Insomnia and the performance of US workers: Results from the America insomnia survey. *Sleep*, **34**(9), 1161–1171.
Kroll, R. R., Boyd, J. G., & Maslove, D. M. (2016). Accuracy of a wrist-worn wearable device for monitoring heart rates in hospital inpatients: A prospective observational study. *Journal of Medical Internet Research*, **18**(9), e253. doi: 10.2196/jmir.6025
Lupton, D. (2012). M-health and health promotion: The digital cyborg and surveillance society. *Social Theory & Health*, **10**(3), 229–244.
McCauley, C. D. (2000, April). *A systemic approach to leadership development*. Paper presented at the 15th Annual Conference of the Society for Industrial and Organizational Psychology, New Orleans, LA.
McCauley, C. D., DeRue, D. S., Yost, P. R. & Taylor, S. (Eds.). (2014). *Experience-driven leader development*. San Francisco, CA: Wiley.

https://doi.org/10.1017/iop.2020.18 Published online by Cambridge University Press

McCauley, C. D., Van Velsor, E., & Ruderman, M. N. (2010). Introduction: Our view of leadership development. In E. Van Velsor, C. D. McCauley, & M. N. Ruderman (Eds.), *The Center for Creative Leadership handbook of leadership development* (3rd ed., pp. 1–26). San Francisco, CA: Wiley.

Millings, A., Morris, J., Rowe, A., Easton, S., Martin, J. K., Majoe, D., & Mohr, C. (2015). Can the effectiveness of an online stress management program be augmented by wearable sensor technology? *Internet Interventions*, **2**(3), 330–339. doi: 10.1016/j.invent.2015.04.005

Moretti, L., Dragone, D., & Di Pellegrino, G. (2009). Reward and social valuation deficits following ventromedial prefrontal damage. *Journal of Cognitive Neuroscience*, **21**(1), 128–140. doi: 10.1162/jocn.2009.21011

Niebuhr, O., Voße, J., & Brem, A. (2016). What makes a charismatic speaker? A computer-based acoustic-prosodic analysis of Steve Jobs tone of voice. *Computers in Human Behavior*, **64**, 366–382.

Nowack, K. (2017). Sleep, emotional intelligence, and interpersonal effectiveness: Natural bedfellows. *Consulting Psychology Journal: Practice and Research*, **69**(2), 66–79.

Page, T. (2015). A forecast of the adoption of wearable technology. *International Journal of Technology Diffusion*, **6**(2), 12–29.

Peixoto, R., Ribeiro, J., Pereira, E., Nunes, F., & Pereira, A. (2018). Designing the smart badge: A wearable device for hospital workers. In *Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth'18)*, (pp. 20–24). New York, NY: EAI. doi: 10.4108/eai

Pettey, C. (2018). Wearables hold the key to connected health monitoring. Retrieved from https://www.gartner.com/smarterwithgartner/wearables-hold-the-key-to-connected-health-monitoring/

PricewaterhouseCoopers. (2016). *The Wearable Life 2.0: Connected living in a wearable world.* [Consumer Intelligence Series Report]. Retrieved from https://www.pwc.com/us/en/services/consulting/library/consumer-intelligence-series/wearables.html

Prochaska, J. O., & DiClemente, C. C. (2005). The transtheoretical approach. In J. C. Norcross & M. R. Goldfried (eds.), *Handbook of psychotherapy integration* (2nd ed., pp. 147–171). Oxford, UK: Oxford University Press.

Quantified Self Institute. (2016). Quantified Self Institute. Retrieved from https://qsinstitute.com/.

Rafferty, A. E., Jimmieson, N. L., & Armenakis, A. A. (2012). Change readiness: A multilevel review. *Journal of Management*, **39**(1), 110–135.

Rausch, T. (2016, August 9). *Can wearables improve factory conditions? Understanding the round-the-clock needs of factory workers* [blog]. Retrieved from https://medium.com/laborlink-insight/can-wearables-improve-factory-conditions-df7e1836e188

Rauschnabel, P. A., Brem, A., & Ivens, B. S. (2015). Who will buy smart glasses? Empirical results of two pre-market-entry studies on the role of personality in individual awareness and intended adoption of Google Glass wearables. *Computers in Human Behavior*, **49**, 635–647.

Roger, D., & Petrie, N. (2017). *Work without stress: Building a resilient mindset for lasting success.* New York: McGraw-Hill Education.

Ruderman, M. N., & Clerkin, C. (2015). *Developing leadership by building psychological capital.* Greensboro, NC: Center for Creative Leadership. Retrieved from https://www.ccl.org/wp-content/uploads/2015/08/Developing-Leadership-By-Building-Psychological-Capital.pdf

Schatsky, D., & Kumar, N. (2018). *Workforce superpowers: Wearables are augmenting employee's abilities.* Retrieved from https://www2.deloitte.com/us/en/insights/focus/signals-for-strategists/wearable-devices-in-the-workplace.html

Silzer, R., & Church, A. H. (2009). The pearls and perils of identifying potential. *Industrial and Organizational Psychology*, **2**(4), 377–412. doi: 10.1111/j.1754-9434.2009.01163.x

Sonnentag, S., Binnewies, C., & Mojza, E. J. (2008). "Did you have a nice evening?" A day-level study on recovery experiences, sleep, and affect. *Journal of Applied Psychology*, **93**, 674–684. doi: 10.1037/0021-9010.93.3.674

Sulter, A. M., Schutte, H. K., & Miller, D. G. (1995). Differences in phonetogram features between male and female subjects with and without vocal training. *Journal of Voice*, **9**(4), 363–377. doi: 10.1016/S0892-1997(05)80198-5

Swan, M. (2012). Health 2050: The realization of personalized medicine through crowdsourcing, the quantified self, and the participatory biocitizen. *Journal of Personalized Medicine*, **2**(3), 93–118. doi: 10.3390/jpm2030093

Tornow, W., & London, M. (1998). *Maximizing the value of 360-degree feedback: A process for successful individual and organizational development*. San Francisco, CA: Jossey-Bass.

Wurmser, Y. (2019). *Wearables 2019: Advanced wearables pick up pace as fitness trackers slow* [report]. Retrieved from https://www.emarketer.com/content/wearables-2019

Cite this article: Ruderman, M.N., and Clerkin, C. (2020). Is the future of leadership development wearable? Exploring self-tracking in leadership programs. *Industrial and Organizational Psychology*, **13**, 103–116. https://doi.org/10.1017/iop.2020.18