USING A WEARABLE HEALTH TRACKER TO IMPROVE HEALTH AND WELLBEING UNDER STRESS

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EXECUTIVE SUMMARY

Stanford University, Spire, Inc., and LinkedIn Corp's Employee Wellness Team conducted a pilot study with a subset of LinkedIn's U.S. workforce where the Spire health monitor was given to 114 employees to compare with a 111-employee control group. Sets of gold-standard stress- and anxiety-related measures were administered before and after a one-month intervention period. Compared to the control group, the Spire group experienced a 10% decrease on the Perceived Stress Scale ($p<0.05$), a 12% decrease in stress symptoms on the Mood and Anxiety Symptom Questionnaire ($p=0.001$), and a 11% decrease in negative affect on the Positive and Negative Affect Schedule ($p=0.005$). Over a 30-day period, using Spire led to 2.5 (27%) fewer anxious days and 3.5 (35%) more energetic days compared to the control group. Although not statistically significant, physiological measures supported these results, showing the use of Spire led to 37% (median 28%) more calm- and 25% (median 8%) more focus-related breathing patterns. Spire also led to 15% (median 7%) more tension-related breathing patterns attributed to the learning curve associated with any new technology. These results are useful for practitioners aiming to improve stress reactivity by training employees to be more mindful of their breathing in order to become more skillful in down-regulating their nervous system, reducing symptoms of anxiety, and cultivating qualities of wellbeing and productivity. In summary, the results indicate there is promise in the use of wearable health trackers as a scalable means of improving stress response among knowledge workers for improved health, wellbeing, and productivity.

INTRODUCTION

The modern workplace is both exhilarating and exasperating – often in the same day. In this report, we focus on a crucial question: *How can we train knowledge workers to be productive and healthy in fast-paced and demanding environments – at scale?*

One crucial factor to understand productivity and wellbeing in the workplace is how employees respond to *stress*. Stress is sometimes considered a necessary evil of the modern workplace: it drives performance but can sometimes lead to negative outcomes such as absenteeism (being physically absent from the workplace without good reason), presenteeism (being physically present but unproductive or not working at full capacity), and greater physical and mental healthcare costs. For this reason, many employee health programs focus on reducing or managing stress.

Yet there are positive aspects of understanding and utilizing stress that are rarely recognized. Stress itself is not inherently negative. The question of whether stress has a negative or beneficial impact in the workplace is a function of how employees respond to that stress.

One technique researchers have used to demonstrate how employees can be trained to respond more effectively to stress is to help them cultivate a stress-as-enhancing mindset (Crum, Salovey & Achor, 2013). Another is to improve cognitive self-regulation skills using mindfulness training (Good, *et al.*, 2015). This report investigates an aspect common to those and nearly all stress management trainings – stress physiology – and investigates a scalable means of improving it.

The goal of the authors was not to identify a single technique for improving adaptive responses to stress; there is likely no 'silver bullet'. Rather, the goal was to investigate the extent to which a particular technique – continuous stress physiology tracking and feedback – is effective for improving health and wellbeing outcomes.

Wearable health monitoring

Wearable physiology monitoring is a rapidly evolving segment of clinical and non-clinical health interventions. The passive, continuous features differentiate it from point-to-point measurement techniques and biofeedback exercises that require the participant to disengage from work practices to engage their full attention.

There has been great promise and potential in the potential of passive monitoring but the vast majority has focused on the technical rather than clinical aspects. Further, such monitoring has focused solely on physical activity whereas in the workplace it is the *mental* wellbeing of employees that arguably presents an even larger opportunity because it drives both productivity and health costs. The study reported on here investigates an approach that focuses less on capturing data and more on real-time feedback to trigger real changes and outcomes.

Respiration: Key to stress regulation

The most direct, effective, and repeatable way to consciously experience, regulate, and harness the human stress response is through awareness and conscious manipulation of respiration. The reason for this is that respiration is the only stress-related autonomic indicator under direct conscious control (Sherwood, 2006). That is, respiration is unique because breathing patterns robustly reflect cognitive/emotional stress (Plarre, et al., 2011), calm (Sherwood, 2006), and concentration (Vlemincx, et al., 2011) while being amenable to being consciously manipulated to relax and down-regulate the nervous system (Sherwood, 2006).

Though physiological stress-reactivity training has been practiced in the workplace for some time (McCraty, et al., 2003), there is an opportunity for improvement in scale, ease-of-deployment, and reduced detraction of work time by *using passive measurement and real-time notification* of stressful episodes. Respiration has been shown to be optimal for this purpose because it can be manipulated successfully without requiring employee dis-engagement from cognitive work (Moraveji, 2012).

A health monitor for respiration retraining

The Spire activity tracker and accompanying app was created to provide individuals with greater training in breath regulation without distracting them from workplace tasks. To do this, the Spire device unobtrusively senses breathing patterns and alerts of noteworthy changes. The app classifies periods of time into “calm”, “focused”, or “tense” breathing based on established studies (Plarre, et al., 2011; Vlemincx, et al., 2011). The app also includes guided auditory experiences that teaches mindfulness, meditation, and relaxation training.

Goal of this report

Wearable devices for stress-reduction have long been promised as a crucial tool in mitigating issues of information overload and fragmented attention in the modern workplace. However, this has not yet been validated nor have possible mechanisms for how such devices would impact stress been described.

The goal of the study in this report was to pilot the potential of using passive sensing, real-time notifications, and training in breathing training to improve stress reactivity amongst knowledge workers to simultaneously improve mental health and productivity. The study was conducted as part of a broader inquiry from Stanford University’s Department of Psychology on studying stress mindset training in a large organization. The results of that broader study are outside the scope of the current report but updates can be accessed from the Mind & Body Lab’s website at https://mbl.stanford.edu.

STUDY DESIGN

A study was designed to evaluate the impact of the Spire health monitor on knowledge workers. The goal was to investigate the impact of Spire on stress and productivity measures in a naturalistic environment. Though the goals were relatively straightforward, the complexity inherent in gaining permission, recruiting employees on company time, deploying devices, and conducting assessments in a corporate setting at a scale large enough to be statistically viable meant this pilot study used a number of different related measures and treated the study as a first step in understanding the effects.

The study was conducted in partnership with LinkedIn Corporation's Health and Wellness team among their U.S. employees and included 5 phases:

(1) Recruitment/Registration
(2) Pre-assessment
(3) Baseline
(4) Intervention
(5) Post-assessment

The structure and timeline of the study is illustrated in Figure 1:

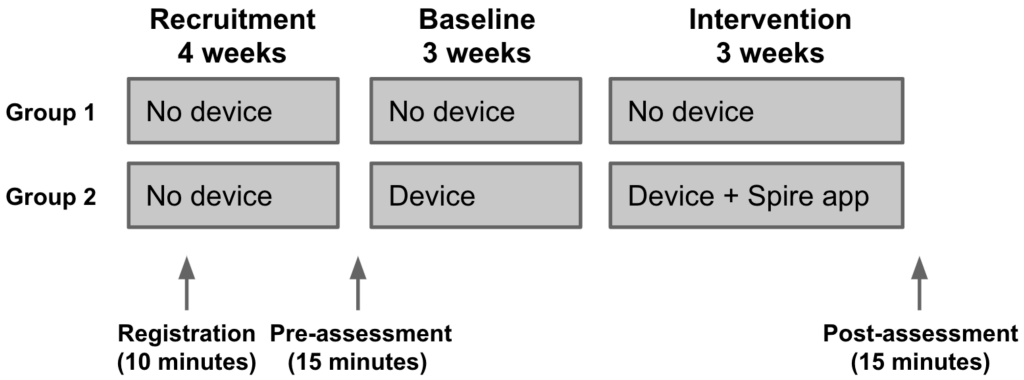

Figure 1: Study design and timeline.
Both groups ultimately received identical recruitment materials.

Recruitment and Registration
In the recruitment phase, employees heard about the opportunity to enroll in the study. Employees received emails about a program and "mini-course" from their company's employee wellness team. The opportunity was approved by an institutional review board at Stanford University and messaged as an opportunity to enroll in a stress management program and study conducted by Stanford University where employees would pay out-of-pocket to participate (a rarity for a company-subsidized activity) but would receive a Spire activity tracker at a discount ($50 as opposed to $149.95). As an incentive, registering and completing the program also granted employees a $50 credit for use only at the company store for wellness-related products.

To register, employees were pointed to a webpage hosted on commercial website but customized for LinkedIn. The website also had participants sign a consent form and give their shipping address in order to receive their Spire. If any participants requested a refund at any time, they were given one and removed from the study. Participation was restricted to U.S.-based employees to reduce cost and complexity.

Employees had approximately 1 month to consider registering for the program, after which registration was closed and after a further month the program began. Participants knew this was a LinkedIn-only event and that all participants required a @linkedin.com email address and due to technical limitations, the program was only offered to employees who had Apple iPhone devices 5 and 6. No Android devices were supported.

47% of registered participants were female. Mean age was 34 (SD=8). Employees registered from all job roles and departments in the company as well as 10 different U.S. locations including home offices. 7% of employees used an Apple Watch with their device (see Figure 2).

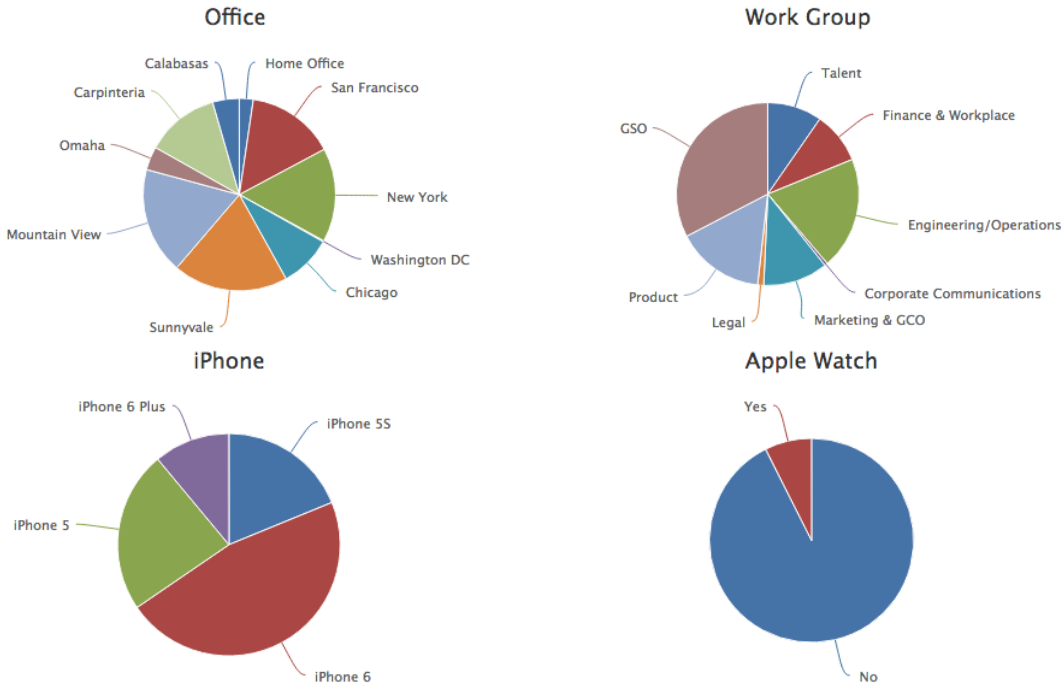

Figure 2: A visual breakdown of characteristics and tech medium usage of employees who registered for the study. A randomly-selected subset of these users were in Groups 1 and 2.

Once the recruitment phase was complete, employees were randomly assigned into different groups: intervention (114 employees) and control (111 employees). There were two other groups pertaining to the Stanford collaboration, but not pertinent to the current report. Factors such as employee vacation, non-compliance, technical problems, and more led to some amount of attrition. In all, 102 participants remained of the control and 67 in the intervention groups. Fewer in the intervention group successfully complied with the study procedures, as only participants that downloaded the Spire app were kept, and this

was not a required component of the control group.

It's important to reiterate that there was little precedent at this company for an employer-sponsored or subsidized-event in which employees were expected to pay out of pocket. For this reason, the employer participation rate far exceeded expectations.

Pre- and Post-Assessments
The psychometric assessments conducted before and after the intervention were identical. They were conducted online and took approximately 15 minutes to complete.

Baseline
The goal of this phase was to assess median respiratory characteristics for the intervention group before they received daily Spire feedback via their device and phone. In order to get their respiratory data without influencing it, a "baseline" version of the Spire app was created that recorded data but which did not provide notifications or feedback. The screen was blank and the only feature the user could access was settings. It did notify the user if their Spire monitor needed to be repositioned or was low on battery.

Intervention
The intervention phase was marked by an email to the intervention group to overwrite the "baseline" app and begin using the "real" Spire app. This app included guided audio training to explain foundational concepts of breathing retraining. During this time, the control group (who hadn't yet received any device) was sent emails reminding them that they could begin using their device in one month's time.

Each participant was instructed to complete each of the following five in-app guided auditory exercises called "boosts" which trained them in how their breathing reflects their state of mind and how to undertake particular breathing practices and use the Spire app (each was 6-9 minutes in duration):

Exercise 1: "The Slow Breath"
Learn to take a truly deep breath by not straining but rather physiologically dis-engaging so the breath becomes effortless.

Exercise 2: "Streaks and Box Breathing"
Learn about streaks in the app and how to breathe evenly, namely to use a 4-sec inhale followed by a 4-sec exhale.

Exercise 3: "Notifications and the Calming Breath"
Learn about notifications and alerts, and then about how to lengthen exhalation to down-regulate the nervous system.

Exercise 4: "Goals and the Natural Breath"

Learn about goals for hitting a certain number of minutes of calm, tense, and focus minutes in your day.

Exercise 5: "Progress and the Mirror Technique"
See your progress in the app to see changes over time – and learn the mirror breathing technique.

Bonus Content: At the end of the program, employees were given a 50% discount code to purchase a Spire device for friends or family. They were also given access to an online audio course on mindfulness and meditation.

KEY FINDINGS

The primary analyses of interest were (1) assessing the impact of Spire in the intervention group using gold-standard psychometric scales, (2) comparing the change to the control group (who hadn't received their devices yet), and (3) investigating any physiological changes that occurred as a result of wearing the tracker over time. To reiterate, both groups enrolled (and paid) to be part of the same stress management program and received access to the same content.

As discussed earlier, the pre- and post-assessments contained a set of different measures. The scales used were peer-reviewed and shown to be valid and reliable assessments of each criterion measured. Reported here are a particularly relevant subset of the statistically significant results at $p<0.05$ and $p<0.10$ significance levels using repeated measures *t*-tests. The reason for focusing only on tests where the results are significant is because this was a pilot study to identify psychometric areas to study more robustly.

In all the figures below, black vertical bars are shown to help visually compare distance between groups in both timestamps. Each measure is presented on a single page to enhance readability. We noted that the control group also improved in many of these measures, ostensibly due to the fact that they were engaged in a training program (that hadn't completely began yet).

Measure #1: Perceived Stress Scale (PSS)

This 5-point Likert scale is one of the most broadly used psychometric scales and identifies the extent to which one views their current life circumstances as stressful (Cohen, Kamarck, Mermelstein, 1983). The PSS has been shown to predict biological markers of chronic stress and increased risk of disease and mental health disorders such as depression (van Eck, Nicolson, 1994).

The intervention group experienced a significant decrease on the PSS (B=-0.18, p=0.009) while decrease in the control group was marginal (B=-0.07, p<0.10). Figure 3 illustrates how the reduction in the intervention group was significantly greater than the control's.

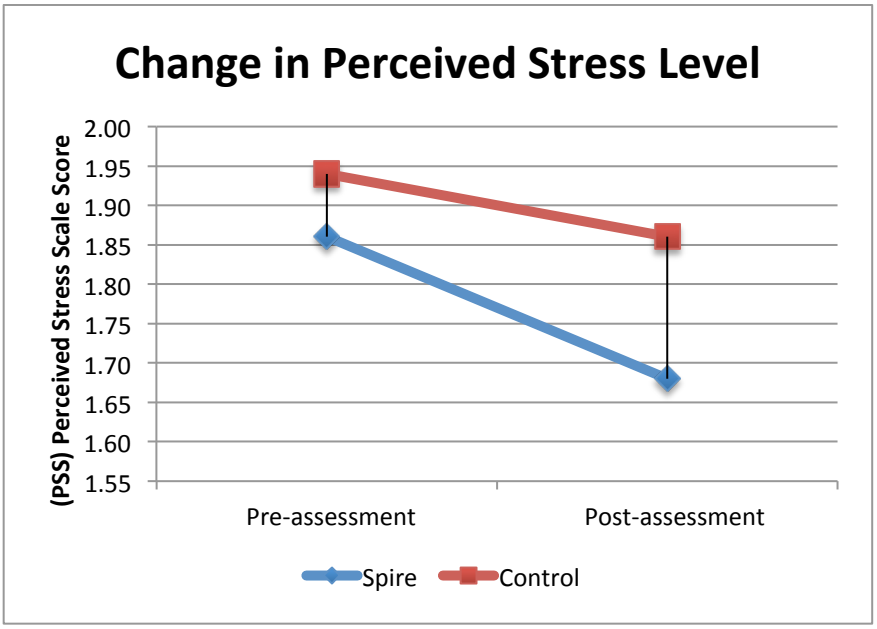

Figure 3: The reduction in perceived stress was significantly greater in the intervention (10%) than the control (4%) group (B=-0.24, p<0.05). (Cohen, Kamarck, Mermelstein, 1983)

Measure #2: Mood and Anxiety Symptoms Questionnaire (MASQ)
We administered an abbreviated version of MASQ scale (Wardenaar et al, 2010) originally developed by Clark & Watson (1991). Our version of the scale assessed anhedonic depression, anxious symptoms, and general distress symptoms

In both groups, there was no effect on anhedonic (B=-0.05, p=0.71) and anxious symptoms (B=-0.12, p=0.30). However, results were significant for general distress symptoms. Looking at the intervention group alone, use of the Spire device resulted in a significant reduction in distress symptoms (B=-0.25, p=0.001) while effect on the control group was marginal. Figure 4 compares the effect in the intervention group with the control group.

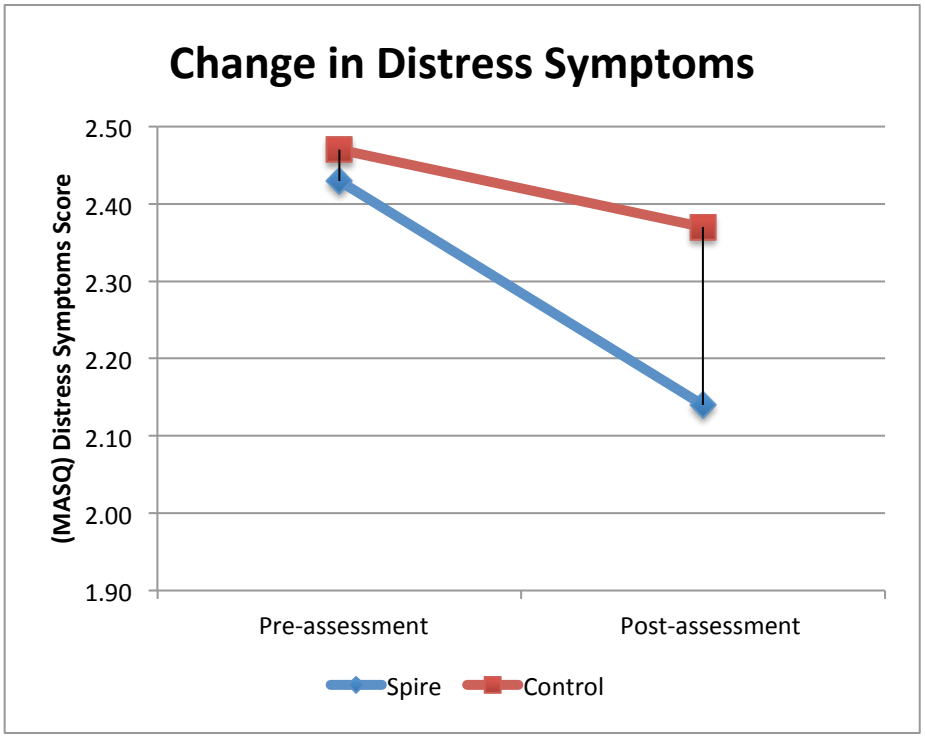

Figure 4: The reduction in negative affect was significantly greater for the intervention (12%) than the control (4%) group (B=-0.23, p<0.05). (Wardenaar et al., 2010)

Measure #3: Positive and Negative Affect Schedule (PANAS)
Widely regarded as a highly reliable measure for non-clinical populations, this scale measures general affect (Clark, Watson, & Tellegen, 1988). Participants report how much they feel different emotions and for this study participants were again asked about their emotions over the previous three weeks. This 10-item scale of 5-point Likert scales allows researchers to group and evaluate positive and negative affect separately.

There was no effect of the intervention on positive affect (*B*=0.09, p=0.449). However, the intervention group experienced a significant main effect in the negative affect component of the measure (*B*=-0.20, *p*=0.005) while the main effect in the control group was marginal. Figure 5 compares the effect on the intervention group with that in the control group.

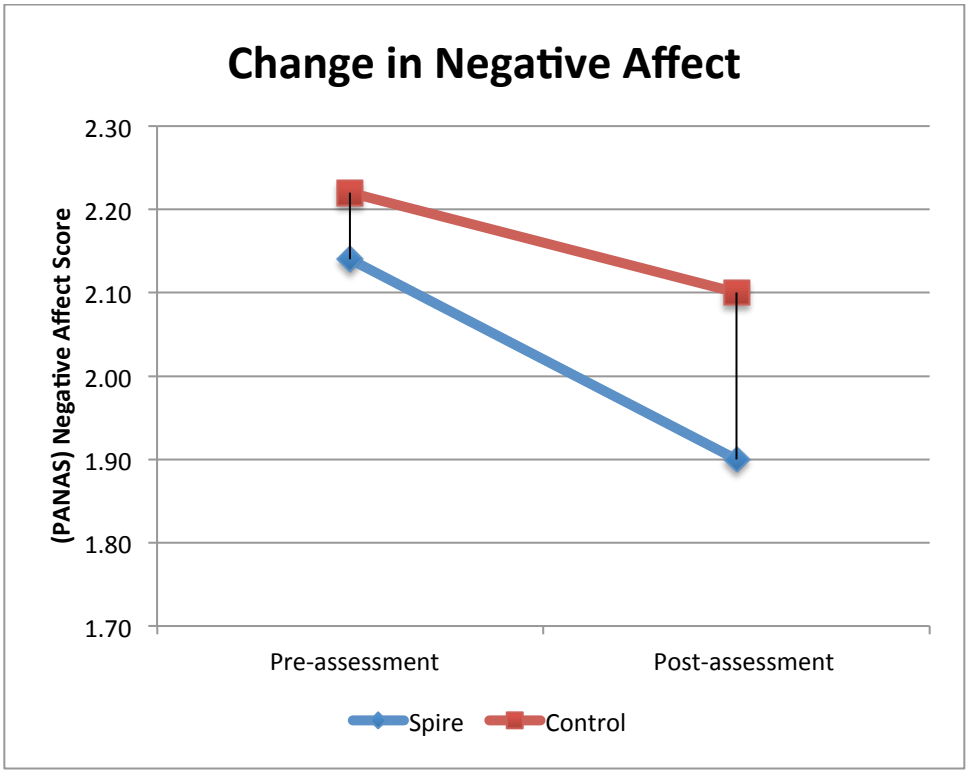

Figure 5: The reduction in negative affect was marginally greater for the intervention (11%) than the control (5%) group (*B*=-0.21, *p*<0.10). (Clark, Watson, 1988)

Measure #4: Quality of Life – Anxious Days (CDC HRQOL-14)
The CDC publishes this measure as part of health-related quality of life assessments (CDC, 2016). This item is part of a 14-item set of Healthy Days core questions and asks the participant to estimate the number of "worried, tense, or anxious" days they had in the past 30 days.

The reduction in self-reported healthy days was significantly lower for the intervention group (*B*=-2.89, *p*=0.003) while not different for the control group. Figure 6 compares the effect on the intervention group to the control group.

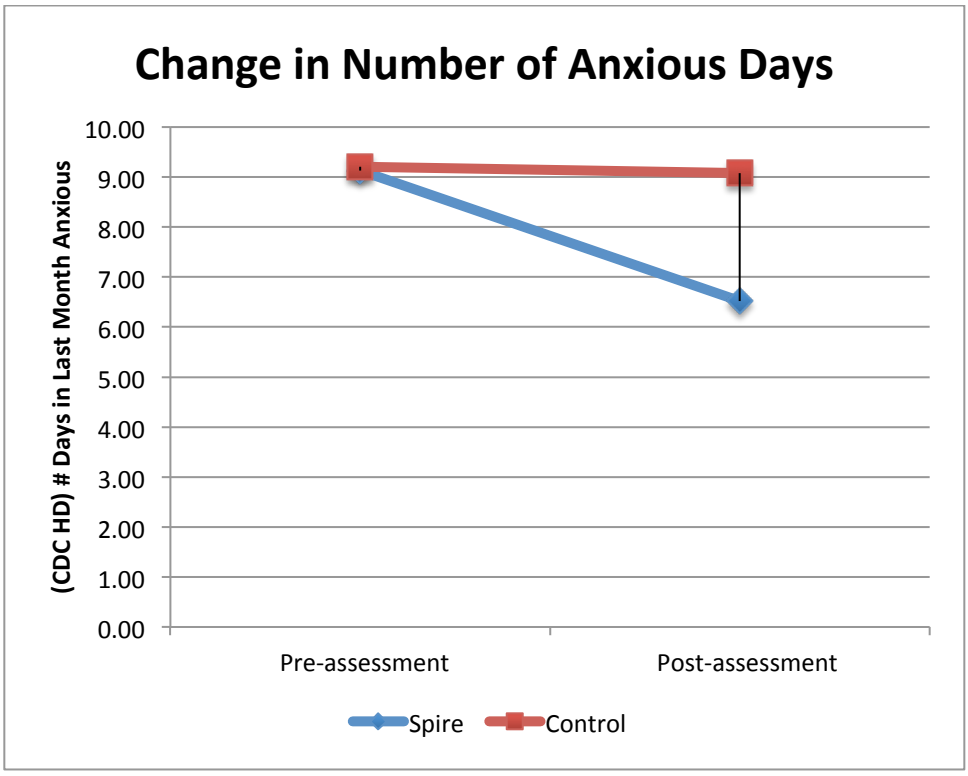

Figure 6: The reduction in number of self-reported number of anxious days in the last 30 days was higher for the intervention (29%) compared to control (1%) group (*B*=-0.3, *p*<0.05). (CDC, 2016)

Measure #5: Quality of Life – Energized Days (CDC HRQOL-14)

Another part of the CDC HRQOL-14, this subset measures how many days the user recalls being full of energy in the past 30 days. The reduction in self-reported healthy days was significantly lower for the intervention group (*B*=-2.83, *p*=0.007) while it was insignificant for the control group. Figure 6 compares the effect on the intervention to the control group.

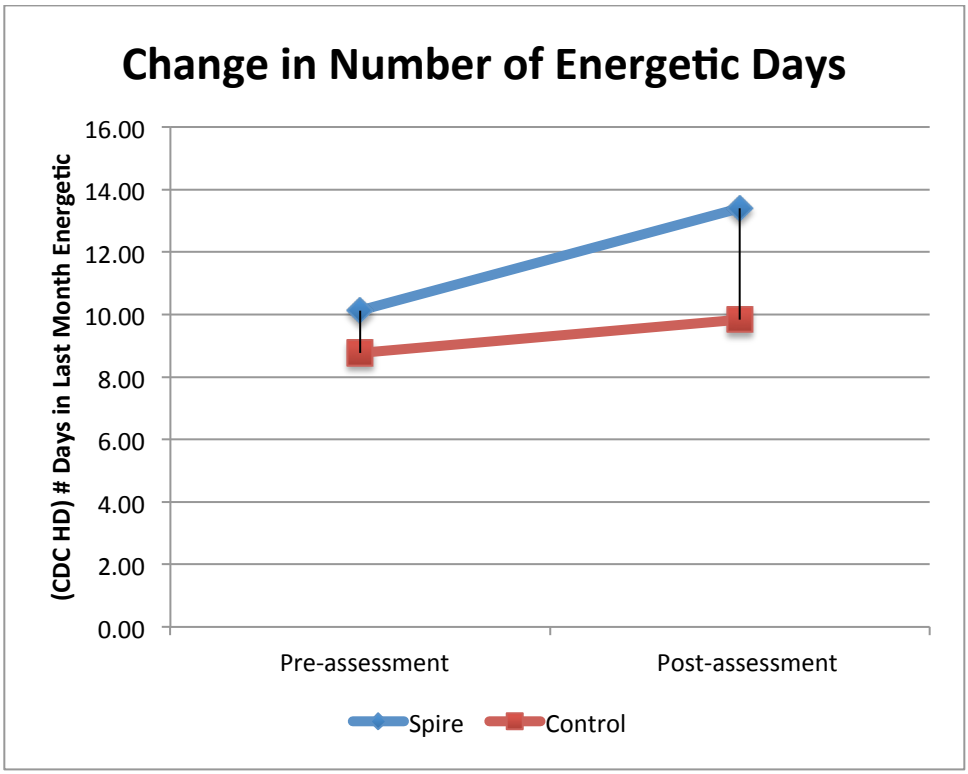

Figure 7: The increase in number of self-reported energized days in the past 30 days was higher for the intervention (32%) than the control (12%) group (*B*=0.29, *p*<0.05). (CDC, 2016)

Physiological measures
An analysis was done within the intervention group comparing respiratory characteristics during the baseline with intervention periods. This analysis looked at the average number of minutes spent per day in different Spire types of breathing called 'streaks'. Minute-by-minute, the Spire app senses the user's respiratory characteristics and compares it to their average in three different categories: "Calm", "Tense", and "Focus". The minimum duration of a streak is two consecutive minutes. Calm denotes breathing significantly slower than the user normally does. Tense denotes breathing more rapidly and erratically than they normally do. And Focused breathing is breathing at or around the user's normal frequency but with significantly higher consistency.

A significant number of users did not wear the Spire regularly enough so we restricted analysis to users who registered at least 2000 breaths for at least 2 workdays days during baseline and intervention periods, respectively. The amount of variability between participants was very high and hence, the statistical tests were insignificant and only trending.

Calm
The mean amount of Calm minutes experienced on a daily basis tended to increase 37% from baseline to intervention period (from 5.1% of the day pre-intervention to 7.0%). The median number of minutes per day increased 28%.

Tense
The mean amount of Tense minutes experienced on a daily basis tended to increase 15% from baseline to intervention period (from 6.2% of the day to 7.1%). The median number of minutes per day increased 7%.

Focus
The mean amount of Focus minutes experienced on a daily basis tended to increase 25% from baseline to intervention period (from 62.9% of the day to 78.6%). The median number of minutes per day increased 8%.

DISCUSSION

The results from this pilot study are encouraging. They show evidence that providing employees with data and respiration-based feedback about their stress physiology leads to some amount of skill development in stress management. The results fell into three categories: (1) intervention feasibility, (2) negative affect and symptoms, and (3) productivity-related measures. We describe each below, respectively.

First, the pilot was very popular at the company, illustrating the demand for such tools to improve how employees manage and harness stress in the workplace. However, attrition in the intervention group was significant (41%). We attribute this primarily to technical challenges, misunderstandings about program constraints (e.g., iPhone-only), and forgetting to wear the device regularly.

Second, negative affect generally decreased alongside improvements in the self-determination about how to regulate and harness stress. This is evidenced by a combination of multiple gold-standard measures that uncover negative affect and the qualitative feedback received. We attribute the decrease in negative symptoms to training employees in the well understood but infrequently applied practice of breath regulation: slowing down breathing in 'acute' instances to down-regulate the nervous system. This was supported by physiological measures, albeit marginally, as an increase in the number of minutes of calm breathing from baseline to the intervention period. Crucially, this was not a 'blanket' response to any stressful stimulus; employees were found to *manage* their stressful energy better: activating their stress response to be productive, leading to greater amounts of Focus in their day.

Finally, Spire significantly improved the number of energetic days employees experienced after the intervention. This was also seen, although marginally, as an increase in the number of minutes of physiological focus or concentration going from baseline to intervention period.

The control group did experience some gains, albeit marginal. The authors attribute this to multiple factors: company-wide fluctuations inherent to the market and simply being "in a program" to improve stress management. That the Spire condition magnified that effect was encouraging. Also of interest is the fact that the intervention group tended to experience a greater amount of tense breathing. We attribute this to becoming accustomed and perhaps perplexed by the new product and the feedback it provides. Another reason for this may be that the tense breathing occurred in a more-or-less positive "lean in" manner where they felt more "in control" (see program endorsements below) of their ability to manage stress so they let themselves get activated more often (Crum, et al, 2003).

Limitations

As described above, this was a pilot study. This was evidenced in multiple places including technical limitations of the product (not working on Android, Bluetooth connection issues, naïve algorithms, device malfunctions) and the guided content not being professionally recorded. Though we explicitly asked employees not to discuss their results with one another, this was certainly feasible and this could have contaminated the results if employees spoke to each other within their group or between.

ENDORSEMENTS

In the closing survey participants were asked about their experience with the program using the Spire device. This is a summary of their responses along with selected excerpts.

"In general the big win for me is the self-awareness that I now have when I am stressed. The Spire device is very spot-on in terms of the feedback it gives me. Before using it I just thought my state of stress was 'the way it was' and now I realize I have control over it. Love the boosts too. I told people in my family about this and they want in as well!"

***61%** of employees said that using Spire taught them to alter the level of stress they experience.*

"I learned that when I took calls at my desk or when I held scheduled webinars I was reminded to breathe due to being "tense". This helped me in that it trained my brain to take a deep breath before answering the phone or even to take a few deep breaths before a webinar that ultimately relaxed me as well as boosted my confidence."

***75%** of employees said that they have acquired new knowledge and skills as a result of the program.*

"I really enjoyed using Spire! I enjoyed seeing when I was more focused - or calm. It made me think about the balances I need in my life and what days I was happiest and how they were generally pretty balanced days."

"Simply being able to monitor my breathing changed the way I think about myself and my surroundings. The tips were VERY helpful. I think I developed a more acute sense of presence and perception of the surroundings."

***58%** of employees said that they implemented the knowledge & skills.*

CONCLUSION

A pilot study was conducted exploring the impact of a wearable health monitor in a knowledge worker population. Results show that the intervention significantly reduced negative stress and anxiety symptoms as well as providing an encouraging impact on productivity-related measures. Both these findings were corroborated by physiological measures. This motivates further study into the use of wearables for managing the symptoms of chronic stress and anxiety. This kind of delivery mechanism would seem to do well to complement workshops, retreats, and other traditional employee training methods. Ultimately, the potential of wearable devices for improving mental health and mental wellbeing is promising.

RESEARCHER ROLES

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Eric Smith, M.A. is a psychology graduate student at Stanford University and led statistical analysis of the quantitative study results.

Alyson Kane, B.A. is a statistics graduate student at Stanford University and focused on analysis of the respiratory characteristics in the study.

Michael Susi, B.A. is the Global Wellness Manager of LinkedIn Corporation.

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