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BreatheWell: Developing a Stress Management App on Wearables for TBI & PTSD

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Abstract

Hundreds of thousands of United States military service men and women have returned home from recent conflicts with post-traumatic stress disorder (PTSD) and/or traumatic brain injury (TBI) resulting in debilitating stress and anxiety. Slow, deep, diaphragmatic breathing is commonly prescribed by healthcare providers as an intervention strategy for emotion regulation and stress management. However, due to the cognitive ramifications of prolonged stress and TBI, people living with PTSD and TBI often find it challenging to learn the technique, remember to practice it and recognize when to use it. This article describes the development and initial user-testing of BreatheWell, an app designed for wearable technology aimed at assisting military service members with PTSD and TBI to manage stress, although the target user population could be expanded to other populations that would benefit from stress management and cognitive aids. BreatheWell was developed for Google Glass and for Android Wear smartwatches to remind users to initiate daily practice of relaxation breathing and provide support for pacing inhalation and exhalation. Development efforts were based on user-centered design principles. Information about service members' attitudes towards these emerging technologies was gained in the process. Future directions include development of a biosensor cueing system.

Keywords

Brain injury, stress, wearable technology, Google Glass, smartwatch, sensor technology

Introduction

BreatheWell is a breathing retraining app developed for Android Wear smartwatches and Google Glass to assist military service members with PTSD and TBI to manage stress. Both Android Wear smartwatches and Google Glass, aka "Glass", are wearable computers that use a smartphone-like format allowing users to download apps designed for brief interactions. Android Wear smartwatches are worn on the wrist and have varying features, depending on the manufacturer, but all are designed in the shape of a wristwatch. Google Glass is a head mounted wearable with an optical display designed in the shape of a pair of eyeglasses. Separate versions of BreatheWell were developed for Android Wear and Glass. Both versions of BreatheWell have features not found in smartphones versions including the ability to program reminders to practice deep breathing at user-specified intervals, the ability to customize picture (Glass version) and sound options with a user's own photos and music, and the ability to view the user's heart rate in real time (Android Wear version).

Posttraumatic Stress Disorder (PTSD) and traumatic brain injury (TBI) frequently co-occur in military service members returning from Iraq and Afghanistan, often impacting independent living and quality of life (Tschiffely et al. 2015). Common clinical features of PTSD include increased anxiety and perceived threat, avoidance of anxiety and the presence of hyper-arousal symptoms: anger, startle response, hyper-vigilance and difficulty concentrating (American Psychiatric Association 2013). Deficits in memory and executive functioning, common cognitive sequelae of TBI, can add to stress and anxiety and can complicate and even hinder recovery from PTSD. Further, the physiological and emotional impacts of intense and prolonged stress also appear to hinder recovery from TBI (Cooper et al. 2000).

When a person is exposed to a stressor, the sympathetic nervous system is activated, resulting in the "fight or flight" response (Jansen et al. 1995). This response produces a

physiological reaction causing heart rate and respiration to increase, the pupils to dilate and the digestive and reproductive systems to slow down. The American Institute of Stress (AIS) recommends deep, focused breathing to activate the body's parasympathetic nervous system, which facilitates homeostasis after the fight or flight response (Take a Deep Breath 2012). Deep breathing increases the supply of oxygen to the brain and initiates a "relaxation response" by decreasing metabolism, heart rate, and blood pressure, which together cause muscles to relax and tension to ease (Take a Deep Breath 2012). Slow diaphragmatic, breathing has been documented to improve mood stabilization and anxiety/anger management and is commonly used as a tool for emotion regulation and is (Brown et al. 2013). Breathing retraining, the practice of using slow, deep breathing to promote relaxation, is a widely used technique in stress reduction therapies. It can be used to manage acute stress as well as aid processing during cognitive behavioral therapy interventions (O'Donohue and Fisher 2009; Ursano, et al. 2004, VA/DoD 2012).

Executive dysfunction, a common sequela of TBI, makes patients more vulnerable to intrusive memories and emotional dysregulation, and it interferes with self-awareness, self-monitoring and initiation of emotion regulation strategies. Additionally, executive dysfunction and deficits in memory can reduce the effectiveness of breathing retraining by interfering with a person's ability to pace their breathing, remember and initiate daily practice and/or use deep breathing during periods of increased stress. Daily practice during periods of low stress is particularly important to support effective use during periods of high stress.

Mobile applications, or "apps", can be used to pace breathing during low and high stress periods. Several breathing retraining apps exist for iOS and Android smartphones. However, most have limitations including restricted customization options and a dependence on the user to remember to practice daily use of the breathing strategy. The innovation of wearable computer technology ("wearables") may offer some advantages for using some apps similar to those used

on smartphones. Wearables may allow the user to access an app more quickly (without pulling out a smartphone) and to use it more discretely while in public. They are also likely to support behavioral and health monitoring more broadly through the incorporation of biosensor technology. Further, users, particularly those with memory deficits, may be less likely to lose or forget to bring a wearable with them in the community as it is worn on the body.

Discussion

The development team began developing a breathing coach for wearables in 2014 on Google Glass. When Google stopped offering that platform to consumers in early 2015, the team decided to complete the Glass-based version in order to gather as much user feedback as possible. Results showed sufficient positive feedback for a breathing coach on a wearable platform. Consequently, a new development project for BreatheWell on Android Wear smart watch devices was undertaken.

Development of the BreatheWell app

BreatheWell was designed for a specific set of users with specific needs following a user-centered design philosophy. User-centered design is a participatory design process that engages the user in design decisions whenever feasible, placing input from user research as the focal point of the design decisions (Luna et al. 2010; International Organization for Standardization 2010). It is also a highly iterative process, involving multiple versions with ongoing tests and revisions and refinements based on user input. This participatory process focuses on understanding the specific needs of the user in context and attempts to take into account the environment and other people the user may interact with while using the technology (Luna et al. 2010; International 2010).

Target users for BreatheWell are military service members with PTSD and TBI as well as healthcare professionals that support them. This target user population could be expanded to

other populations that would benefit from stress management and cognitive aids. Nineteen military service members with PTSD and TBI and four healthcare providers (a speech-language pathologist, two clinical psychologists, and one clinical social worker all whom specialize in TBI and/or PTSD) contributed to the design process through initial design conceptualization, focus groups, interviews, questionnaires, feasibility testing and clinical testing.

Initial discovery of user needs was derived from input from the speech-language pathologist and one of the clinical psychologists, both of whom regularly supported service members with PTSD and TBI in using breathing for relaxation. Their input was used to inform the initial prototype of the app for Glass. The novelty of Glass made it necessary to build a working prototype of the app first in order to be able to demonstrate how a Glass-based breathing app would function. This prototype, along with several leading smartphone breathing apps, were demonstrated in a focus group with five service members living with PTSD and mild to moderate TBI for greater than twelve months. The focus group participants made recommendations that influenced the features, settings and display of the app. Specific suggestions regarding the use of calming background images and relaxing sounds were gathered. Participants also requested customizability of the voices providing guidance on inhalation and exhalation – choice of male and female voices, and option to mute voice guidance.

Focus group participants suggested the user be provided with several options for calming background images, such as tropical scenes, snow or mountains. Sixty-four photos matched to their suggestions were collected and shown to eight people, four of whom had a diagnosis of PTSD and TBI; the other four were healthcare providers and research scientists. Each used a five-point scale to rank how relaxing they felt the scene was. The top eight photos ranked most relaxing scenes were selected (see Figure 1). Focus group participants also suggested the user be given the option to select from a variety of preloaded songs and ambient noise tracks. Twenty-

five songs and ambient noise tracks matched to their suggestions were collected and played for six people, four of whom had a diagnosis of PTSD and TBI while the other two were healthcare providers. Each were asked to use a five-point scale to rank how relaxing the music and sounds were, resulting in a set of seven songs and ambient noise tracks including two meditation melodies, as well as sounds of rain, a stream, a fan, the ocean and a rainforest.

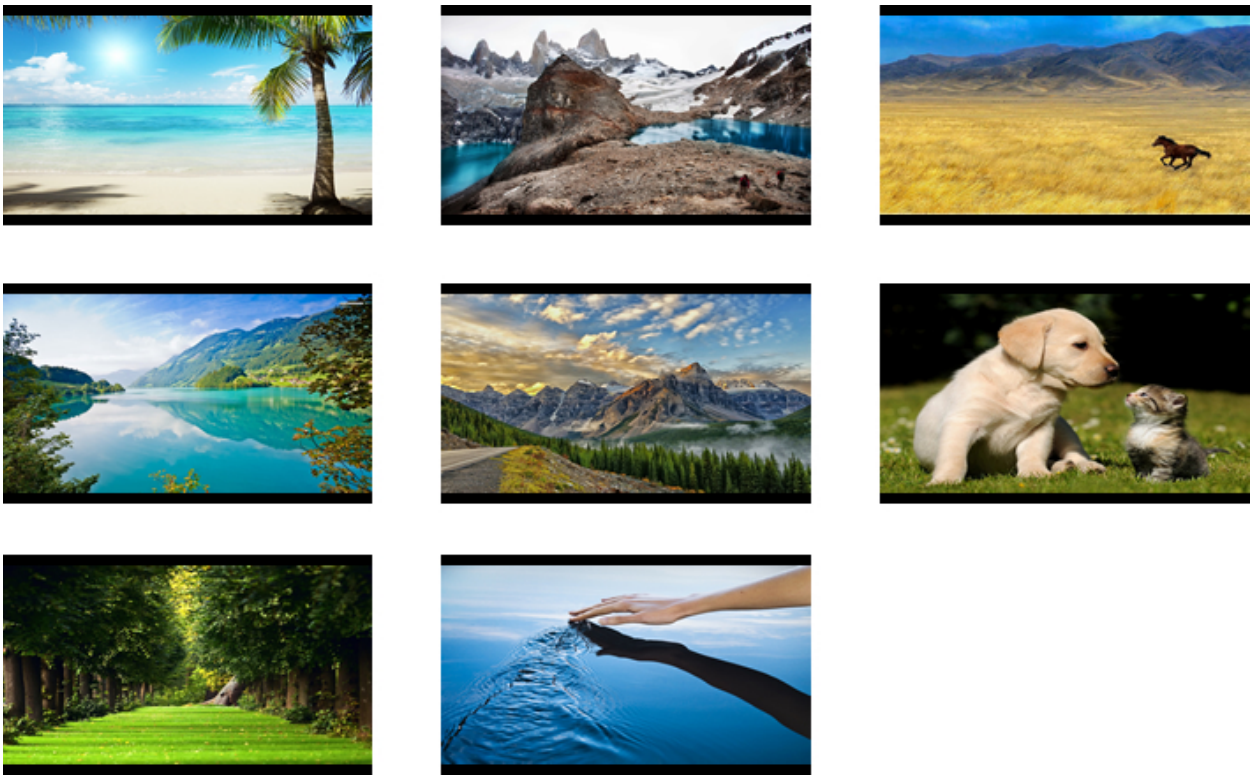

Fig. 1. BreatheWell Screenshots of User Selected Background Images (Glass Version).

Fully functioning prototypes of BreatheWell were then developed for Glass and Android Wear based on target user input. Both versions provided the user with the ability to toggle on/off a stress rating at the start and completion of the breathing exercise, user programmable reminders to practice, in-use adjustment of the rate of inhalation and exhalation, voice guidance options to guide the user to perform the breathing technique (including the choice of a male or female voice and the ability to toggle the feature on or off), and a selection of seven relaxing songs and sounds as well as the ability to add custom music selections from the user's personal library and the

option to use the app without playing music at all. Both versions have an instructional video of a person with PTSD and TBI demonstrating the breathing technique, although the video plays directly on Glass in the Glass version but is played through the companion app residing on the smart phone or tablet paired with the Android Wear smartwatch for the Android Wear version. Both also have a graphical element to show the pace of inhalation/exhalation. The breathing pace bar on the Glass version is light green and transparent so that the photo behind it can be viewed, and it is at the bottom of Glass' rectangular screen (see Figure 2). The breathing pace bar on the Android Wear version is blue and runs along the perimeter of the watch face (see Figure 3). The Android Wear device also vibrates at the end of each inhalation and exhalation to provide a tactile cue to the user.

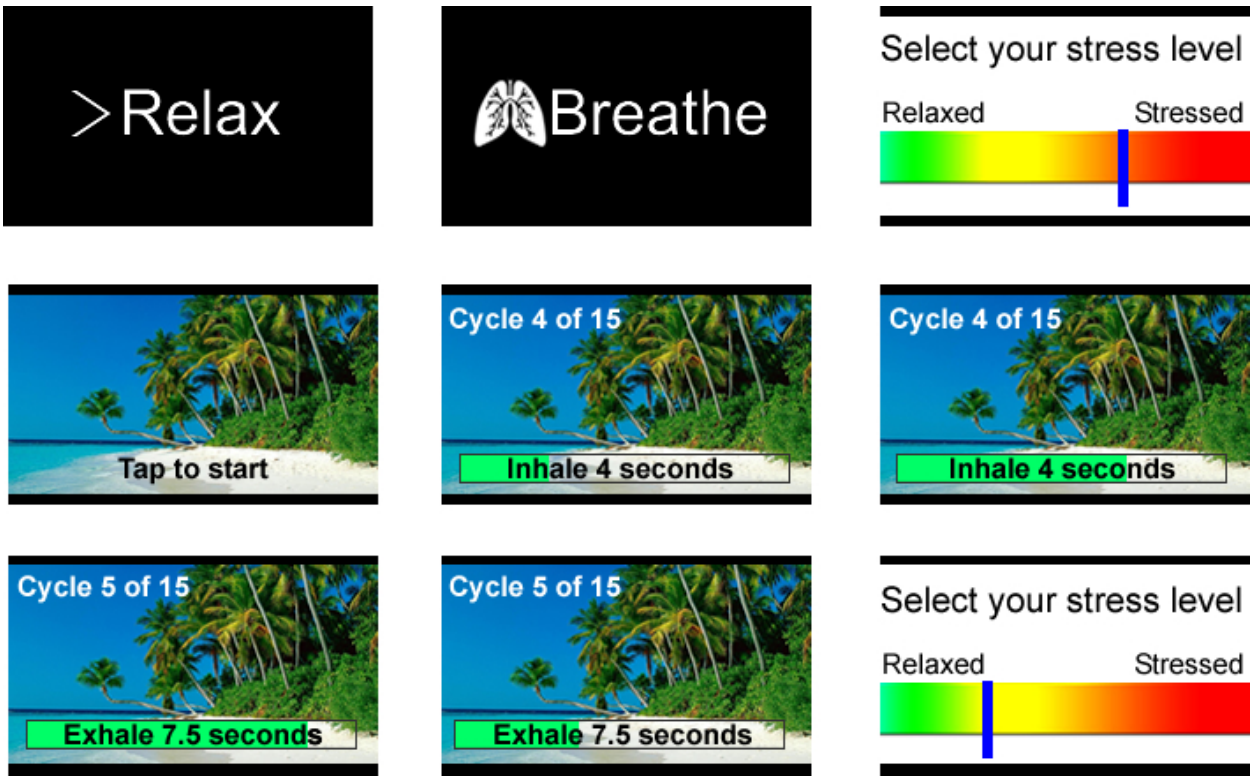

Fig. 2. BreatheWell Screen Flow (Glass version).

Fig. 3. BreatheWell on Wear Screen Flow (Displayed on LG Urbane).

Both versions allow the user to adjust the number of breathing cycles; only the Android Wear version allows that to happen while in use. Additionally, the Android Wear version allow the user to program a pause in breathing after inhalation and/or after exhalation, an optional element of breathing retraining incorporated by some but not all users. This feature was added after additional research and feedback from user testing.

Several design decisions were made in response to the opportunities and limitations of the two platforms. Background images are displayed only on the Glass version. Additionally, users can also choose to add calming photos, such as pictures of their children or pets, from their own library. The Android Wear version does not display calming images because the smartwatch platform would require too much visual attentiveness relative to Glass. Instead, the Android Wear version displays the user's heart rate (not available on Glass, but built into many smart watches) providing real time biofeedback (Figure 3). (Demo of the Android version)

Usability and Clinical Testing

Enhancements to the initial prototypes during in-house testing and usability testing with stakeholders resulted in eight "builds" of the app on Glass and six on Android Wear. Fourteen military service members living with PTSD and TBI participated in the usability testing of BreatheWell, seven provided user input into the Glass version and seven provided user input into the Android Wear version. Participants were recruited from the SHARE Military Initiative at Shepherd Center in Atlanta, Georgia, where they each were receiving treatment for PTSD and TBI. The participants were primarily male (13 of 14) with ages ranging from 26 to 42. Time since injury ranged from 1.5 years to 12 years. All reported experiencing significant stress, anxiety and/or emotion dysregulation and described symptoms of memory impairment and/or executive dysfunction.

Sit-by interviews were completed with each participant during which either the Glass or Android Wear version of BreatheWell was demonstrated, and all participants spent time wearing the device and testing the app. Comments on user experiences and structured interview responses were recorded for qualitative analysis. Participants provided input on the display of information, ease of use, usefulness and other design preferences. Additionally, information about service members' experience with and attitudes towards these emerging technologies was gained in the process (see Tables 1-5). Some initial responses to experiencing BreatheWell included, "It's pretty cool", "I really like it", and "I'm very impressed with it." All fourteen participants reported they felt the BreatheWell app could help them. Favorite features identified included the wearable format (users stated they would be most likely to use a breathing app in wearable form because it is more accessible, meaning they would not have to fetch their phone from a pocket or another location in their home when needed); user customization options including turning features on or off and adding personal photos (Glass version only) and music; the ability to set

reminders to practice; and the biofeedback provided by the heart rate display (Android Wear version only). Concerns reported included worries about eye strain and limitations for users with vision problems (Glass version only), as well as the potential difficulty operating the small screen on the Android Wear version, particularly for those with fine motor deficits.

Table 1. Participant Experience with and Use of Technology (n = 14).

Do you use any of the following on a regular basis? (Device)	**Percentage**
Laptop of desktop computer	79%
Tablet	71%
Regular cellphone	0%
Smartphone	100%
Mp3 player (separate from another device)	29%
Fitness or tracker	21%
Smartwatch	7%
Google Glass	0%

Table 2. Participant Use of Breathing Apps – Device type (n = 14).

Do you use a relaxation breathing app on any of your devices?	**Percentage**
Smartphone	88%
Tablet	25%
Fitness Tracker	0%
Smartwatch	0%

Table 3. Participant Use of Breathing Apps – Frequency (n = 14).

How often do you use apps to assist with breathing for relaxation?	**Percentage**
Every time I breathe for relaxation	14%
About half of the times I breathe for relaxation	7%
Very few of the times I breathe for relaxation	36%
I never use an app when I breathe for relaxation	43%

Table 4. Participant Experience While Using Google Glass (n = 7).

Ease of use and comfort using Google Glass	**Percentage**
It would be easy or very easy for me to use Google Glass	57%
It would be easy or very easy for me to use BreatheWell on Glass	100%
I would feel very comfortable wearing Google Glass out in the community	86%

Table 5. Participant experience while using Android Wear (n = 7).

Ease of use and comfort using Android Wear devices	**Percentage**
It would be easy or very easy for me to use Android Wear	86%
It would be easy or very easy for me to use BreatheWell Wear	71%
I would feel very comfortable wearing Android Wear in the community	100%

Participants also provided information about their experience using breathing retraining. Fifty-seven percent of the participants reported it was hard or very hard to remember to practice breathing for relaxation daily and 57% also reported practicing one or more times daily. This indicates that nearly half of the participants may have the potential to benefit from reminders to practice. Participants were also asked about whether they felt it would be helpful if the app or wearable could detect when the user is becoming stressed and suggest they try some deep breathing to relax. All 14 participants responded “yes”. Several participants stated they sometimes either do not remember to use the breathing strategy when stressed or do not recognize their stress and anxiety is increasing until it is escalated so high that the breathing strategy is less effective. One participant remarked he felt such an innovation could have had a positive impact in his life, stating, “I think other situations could have gone differently if I had one. Like maybe I’d still be able to see my wife and kids.”

Feedback gathered through this process was incorporated into the beta version, the ninth build of the app on Glass and seventh on Android Wear. End-user testing of the finalized beta versions was performed with three healthcare practitioners with specialization in PTSD and TBI,

contributing to additional enhancements. Each version is now undergoing clinical testing which will likely contribute to additional refinements. Thus far each version has been tested outside of the clinic and "in the wild" by one target user, each of whom had different clinical experiences. Preliminary information is favorable and supports continued testing.

Future directions

Future directions include full clinical testing of BreatheWell as well as further development of the app to allow integration with a wireless sensor to detect physiological indicators of stress through ecological momentary assessment. Integrating with a biosensor will allow provision of cues to support the user in use of breathing for relaxation at optimum times. A consumer market product review revealed most currently available stress detection products are not wearable and few work with mobile apps. Those that do work with mobile apps seem to have limited user defined settings and are not well validated. Further, a review of the literature revealed many existing methods of stress detection either are not well studied or have a high rate of error, primarily due to false positive readings.

Continued exploration into the efficacy of using multiple modes of stress detection, such as galvanic skin response and heart rate variability, in a wearable format is needed to identify which combination of stress detection methods will work best for this purpose. Several prefabricated sensors under development by technology companies are expected to become commercially available in early 2017 and may help foster this development. Once a stress detection sensor is effectively integrated with BreatheWell, the next steps will be to identify whether machine learning and/or context awareness can further increase accuracy and functionality as well as to determine user preference for cueing methods.

Conclusion

BreatheWell for Glass and Android Wear may meet the needs of some users with PTSD and TBI. Further clinical testing is still needed. It will be important that user needs and preferences are well matched to the features of both the BreatheWell app and the device on which it resides in order for the user to gain the most benefit. Military service members with PTSD and TBI who prefer wearables, have functional use of their right eye and right hand may prefer to use Glass because of its hands-free interface. However, Glass is not currently available (at the time of this publication) for consumer purchase. Until a new Glass-like product is released, Android Wear devices and similar wrist-worn devices are the most viable platforms for wearable breathing support apps. Some users may prefer the Android Wear version due to their comfort with wearing Android Wear in the community and the biofeedback feature (heartrate display). Continued advancements in sensor technology should eventually offer the ability to connect BreatheWell to a biosensor that detects physiological signs of increased stress. This will enhance the functionality of the app by alerting users to onset of stress episodes.

Wearables may offer some advantages over smartphones for some users, depending on needs and preferences. Preliminary user experience data indicate that wearables appear to be well accepted by military service members living with PTSD and TBI. Consequently they should continue to be explored as assistive technology (AT) for this population, especially as new forms with increased functionality enter the consumer marketplace.

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Works Cited

American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorder*. 5th ed. American Psychiatric Publishing, 2013, pp. 271–280.

Brown, Richard P., et al. "Breathing Practices For Treatment of Psychiatric and Stress-Related Medical Conditions." *Psychiatric Clinics of North America*, vol. 36, no. 1, 2013, pp. 121-140.

Cooper, D.B., et al. "Association between Combat Stress and Post-Concussive Symptom Reporting in OEF/OIF Service Members with Mild Traumatic Brain Injuries." *Brain Injury*, vol. 25, no. 1, 2011, pp. 1-7.

International Organization for Standardization. ISO FDIS 9241-210, Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems. ISO, 2010.

Jansen, A. S., et al. "Central Command Neurons of the Sympathetic Nervous System: Basis of the Fight-or-Flight Response." *Science*, vol. 270, no. 5236, 1995, pp. 644-646.

Luna, D., et al. "User-Centered Design to Develop Clinical Applications. Literature Review." *Studies in Health Technology and Informatics*, vol. 216, 2015, p. 967.

O'Donohue, W. T. and Fisher, J.E. *General Principles and Empirically Supported Techniques of Cognitive Behavior Therapy*. John Wiley & Sons, 2009.

"Take a Deep Breath." *The American Institute of Stress*, 12 Aug. 2012, www.stress.org/take-a-deep-breath/. Accessed 11 Nov. 2016.

Tschiffely, A.E., et al. "Examining the Relationship between Blast-Induced Mild Traumatic Brain Injury and Posttraumatic Stress-Related Traits." *Journal of Neuroscience Research*, vol. 93, no. 12, 2015, pp. 1769-1777.

Ursano, Robert J., et al. "Practice Guideline for the Treatment of Patients with Acute Stress Disorder and Post-Traumatic Stress Disorder." *The American Journal of Psychiatry,* vol. 161, no.11, 2004, pp.3-31.

VA/DoD. "VA/DoD Clinical Practice Guideline for Management of Post-Traumatic Stress." *Department of Veterans Affairs, Department of Defense*. (2010). www.healthquality.va.gov/PTSD-Full-2010c.pdf. Accessed 22 Nov. 2016.

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