J Med Syst (2016) 40: 192
DOI 10.1007/s10916-016-0551-0

MOBILE SYSTEMS

Naturalistic Enactment to Elicit and Recognize Caregiver State Anxiety

Darien Miranda [1] · **Jesus Favela** [1] · **Catalina Ibarra** [1] · **Netzahualcoyotl Cruz** [1]

Received: 4 March 2016 / Accepted: 12 July 2016 / Published online: 21 July 2016

Abstract Caring for people with dementia imposes significant stress on family members and caregivers. Often, these informal caregivers have no coping strategy to deal with these behaviors. Anxiety and stress episodes are often triggered by problematic behaviors exhibited by the person who suffers from dementia. Detecting these behaviors could help them in dealing with them and reduce caregiver burden. However, work on anxiety detection using physiological signals has mostly been done under controlled conditions. In this paper we describe an experiment aimed at inducing anxiety among caregivers of people with dementia under naturalistic conditions. We report an experiment, using the naturalistic enactment technique, in which 10 subjects were asked to care for an older adult who acts as if she experiences dementia. We record physiological signals from the participants (GSR, HR, EEG) during the sessions that lasted for approximately 30 min. We explain how we obtained ground truth from self-report and observation data. We conducted two different tests using the Support Vector Machine technique. We obtained an average precision of 77.8 % and 38.1 % recall when classifying two different possible states: "Anxious" and "Not anxious". Analysis of the data provides evidence that the experiment elicits state anxiety and that it can be detected using wearable sensors. Furthermore, if episodes of problematic behaviors can also be detected, the recognition of anxiety in the caregiver can be improved, leading to the enactment of appropriate interventions to help caregivers cope with anxiety episodes.

Keywords Anxiety estimation · Naturalistic enactment · Dementia · Wearable sensing · Anxiety elicitation · Physiological signals

This article is part of the Topical Collection on *Mobile Systems*

✉ Jesus Favela
favela@cicese.mx

Darien Miranda
panzerfausten@gmail.com

Catalina Ibarra
caiben03@gmail.com

Netzahualcoyotl Cruz
netzahdzc@gmail.com

[1] Computer Science Department, CICESE, Ensenada, Mexico

Introduction

It has been estimated that between 5 to 7 % of those 60 and older suffer from dementia, with the total number of persons with dementia (PwD) expected to double every 20 years worldwide [1]. Dementia is characterized by changes in personality and behavioral functions that can be very challenging for caregivers. Informal caregivers, mostly family members and friends, can be affected from the loss of intellectual functions and the inability of the PwD to perform activities of daily living. PwD presents behavioral and psychological symptoms of dementia (BPSD) that impose additional burden on caregivers. These symptoms, which are estimated to be present in 90 % of PwDs [2], include aggression, agitation, wandering, verbal aggression or psychosis, and affect caregivers and eventually undermine their health and capacity to care for the PwD.

A recent study estimated that 60 % of caregivers develop anxiety or depressive disorders in the first 24 months of caring for a person with dementia [3]. Almost 25 % of them have a significant clinically anxiety level [4]. Moreover, dementia care is particularly stressful, demanding more hours and complications on informal caregivers, than the care of non-dementia patients [5]. Another study reported that caregivers suffering anxiety experience a death rate 63 % greater than non-caregivers of the same age [6].

Numerous strategies have been proposed to deal with caregiver anxiety. These can be classified as: Focused on emotions; Based on problem resolution; and dysfunctional strategies [4]. Caregiver burden increases when dysfunctional strategies are used more frequently while problem solving strategies decrease [7]. Monitoring coping strategies can help predict caregiver anxiety and burden [8].

Recent work has been done on stress and anxiety recognition within pervasive healthcare [9–11], however none of them have focused on caregivers. Clinical approaches to detect stress among caregivers are based on self-report [12–14]. In contrast, our interest is on detecting anxiety without the intervention of the subject.

This work focuses on State Anxiety, which is experienced when the subject is confronted with a specific situation [15]. While caregivers can experience continuous stress that could lead to long-term anxiety, detecting and dealing with anxiety episodes triggered by specific events, such as problematic behaviors by the person with dementia (for instance verbal abuse), can help in instrumenting adequate coping strategies aimed at improving the caregiver-PwD relation.

Ambient-assisted interventions for caregivers

An Ambient-assisted Intervention System (AaIS) focuses on proposing, or directly enacting, strategies aimed at addressing problematic behaviors exhibited by a PwD [16]. An AaIS uses ambient intelligence to improve PwDs quality of life by identifying the presence of BPSDs, deciding on an appropriate intervention, and either modifying the environment or persuading either the PwD, or the caregiver, to act on the system's advice. Both, inappropriate environments and upsetting personal interactions combine with unmet needs to trigger problematic behaviors. For instance, a PwD might exhibit apathy after being scolded by her caregiver or might undergo wandering triggered initially by her need to move after a long period of rest [17]. When detecting these behaviors the AaIS could, for instance, recommend the caregiver to encourage the PwD to help with simple house chores or take a walk around the block with him. With feedback from the caregiver as to the efficacy of the strategies proposed, the AaIS can be trained to offer effective recommendations.

By detecting problematic behaviors and inferring probable causes, behavior-aware applications can provide tailored and opportune interventions, such as notifying caregivers, offering assurance to the patient, or directly modifying the physical environment. For example, as daylight decreases at nightfall, a person with dementia might experience confusion and anxiety for not being able to recognize his or her surroundings. This could lead to a desire to wander, a phenomena known as sundowning syndrome. An approach to deal with this behavior is to increase the lighting conditions.

We propose to extend the AaIS framework to analyze the behavior of caregivers and enact coping strategies that would assist them in dealing with situations that cause them stress or anxiety. Thus, rather than enacting strategies to deal with problematic behaviors, in this case the strategies are aimed at reducing the negative effects of these behaviors on the caregiver by enacting or suggesting adequate coping strategies, as illustrated in Fig. 1.

An important aspect of the extended AaIS framework is the detection of negative behaviors in the caregiver, such as anxiety or stress. These behaviors might also trigger problematic behaviors in the PwD, since emotional contagion has been found to grow stronger in PwDs. That is, the PwD might sense anxiety on the caregiver, and unconsciously mimic that behavior [18].

In this paper we describe an experiment aimed at eliciting anxiety on informal caregivers and collecting physiological data from them under stressful conditions from which this negative behavior can be inferred. The next section describes the experiment conducted.

An experiment to elicit anxiety on informal caregivers

We designed an intervention to induce anxiety on informal caregivers under controlled and naturalistic conditions. To achieve this we applied a technique known as Naturalistic Enactment (NE) [19]. NE was originally proposed to evaluate pervasive healthcare technologies, where having high

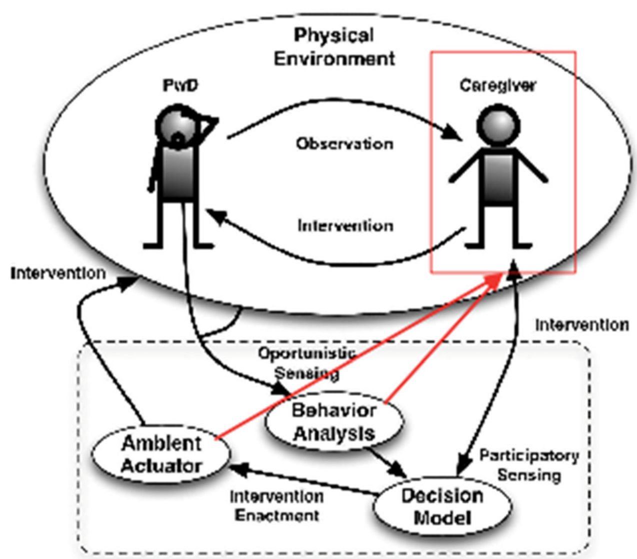

Fig. 1 Extended AaIS framework that includes assisting the caregiver in dealing with stress and anxiety

ecological validity and direct user involvement is important, yet using actual patients can put them at risk. NE consists of a naturalistic enactment of tasks (i.e. the exposure to situations and tasks in natural conditions) to simulate the experience of the user under normal conditions, and thus unearth issues and behaviors that would otherwise have been difficult to capture.

Naturalistic Enactment represents an alternative to either the use of a controlled experiment in which a single stimuli, known to generate the expected emotion, is provided to the subject, or to follow the subject in their everyday activity with the hope of recording instances of the behavior of interest. An example of the former is the Trier Social Stress Test, in which individuals are asked to make a 5-min presentation, for instance a job interview, in front of a group of people wearing white coats [20]. There is ample evidence that this situation generates anxiety in most participants, however, the stimuli is very different from the one experienced when caring for a PwD. On the other, several techniques have been proposed for data collection from people performing their every day activities. Using Participant Observation, a researcher observes the subject and records behaviors and conditions. A limitation of this method, particularly for observing behaviors such as anxiety, is that the researcher might influence the participant's mood or his desire to disclose his mood. An alternative approach for naturalistic data collection is the Experience Sampling Method [21], in which subjects are asked to record their feelings and experiences in real-time, this can be done either periodically or opportunistically. However, this technique is not precise enough to synchronize the physiological data being gathered with the anxiety experienced by the subject. This would require the individual to recognize that he is experiencing anxiety and at that moment record the experience, which in itself might change his mood.

By using Naturalistic Enactment we put the subject in a condition that is controlled to elicit anxiety, and thus can be reproduced with other subjects, and yet it is perceived by the individual as a typical caregiving situation, which will make him act and react naturally.

In order to expose our subjects to a realistic and stressful caregiving situation under controlled conditions, we conceived an exercise that consisted of a naturalistic enactment of a therapy session with a person acting as being a PwD. An elder of 75 years old acted as if she suffered from mild dementia. She was trained with typical behaviors such as: mumbling, screaming, wandering, repetitive questioning, among others. She was already familiar with these behaviors from acquaintances that suffer from dementia. The participants were told that they would be working with a person who actually suffers from dementia.

Written consent was obtained from all participants before the first session and a non disclosure agreement was also signed to avoid the participants to talk to each other about the experiment, the behaviors of the elder or any techniques on how to handle the elder's behavior, for as long as the experiment lasted.

Subjects

The subjects were recruited by sending an email to the University's graduate students. A compensation of two movie theater tickets was offered, although many of them expressed interest in participating in spite of the prize. Participants consisted of 10 graduate students (5 male, 5 female) with an average age of 24.7 (St. dev. = 1.0593).

Therapy tasks

For five minutes, and once instrumented, the subjects relaxed by concentrating on their own breathing with eyes closed to obtain baseline physiological data. Participants were asked to guide the older adult through a therapy session, which involved two of the 8 tasks that were explained during the training session. These included activities such as Lace tying, image classification and object separation.

The whole intervention was conducted over 3 weeks, during weekdays, for a total of 15 days. Each participant conducted a therapy with the older adult lasting approximately 30 min. Each day two participants assisted to the site.

Setup

We settled a room to make it look as if a person with dementia lived there. This included: old furniture, low illumination, old pictures and paper hint tags over the hand washer. A laptop, a video camera, and a smartphone were used to monitor the experiment.

Two researchers stood at the wooden table to operate the equipment and take notes. We sat both the participant and the elder face to face in a circular table.

Data gathering

Before beginning the task, we provided participants with an electrical pulse reader (Zephyr Hxm) on the chest to monitor heart rate/Inter-beat Interval, an Empatica E3 wristband to get Galvanic Skin Response data and a Muse band EEG monitor. All sessions were videotaped for further analysis.

For the first device, we developed the "Care Me Too" application for Android, which connects via Bluetooth Low Energy. Figure 2 shows the "Care Me Too" application running on an Android device.

For the Zephyr HxM program, we used the anxiLogger command line program (https://github.com/panzerfausten/anxiLogger) developed for an earlier study [22].

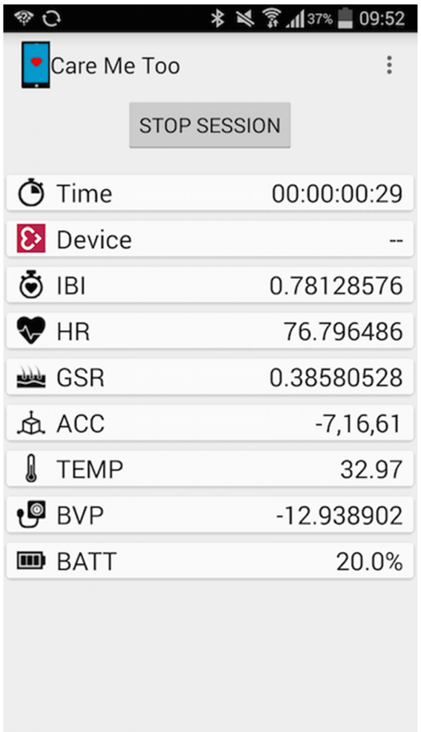

Fig. 2 The "Care Me Too" Android application displaying values from different sensors

Establishing ground truth

Establishing ground truth was a challenging and time-consuming task. Each session took us around 10 h of work to complete. All videos from the sessions were analyzed to segment the events of interest, namely, when the older adult enacted a behavior that could induce anxiety on the subject. For instance, in one case the older adult, while engaged in the therapy asks the subject: "*Where is my mother?*" These segments where classified as one of four possible levels according to the criteria described in Table 1. Behaviors in level 0 are not likely to elicit anxiety, while those in level 3 are very likely to surprise the participant and produce state anxiety, as the subject experiences a loss of control over the situation.

In order to obtain ground truth, two researchers coded the sessions live, by taking notes of time, level of perceived anxiety, and a description of the event. This description was noted by either what the participant and/or the elder said or did at the moment. The participants were asked to record in a paper form their anxiety level whenever they felt it changed. Figure 3 shows the format filled by one of the participants.

Finally, we partitioned each session in 30 s segments and labeled them as "No anxiety" and "Anxiety". A third label "ambiguous" was used when the data was not sufficient to discriminate the presence of anxiety. To determinate the label we used the observation data, auto-report and the analysis recorded video. For the video we used a heuristic of the subject movements, voice tone and eye gaze.

Data processing

EEG has been correlated with affective states [23], thus we estimated the correlation between eye blinking, obtained from the EEG signal, and the state of anxiety as estimated from the approach described above. Correlation varied from 0.78 to 0.91, which is relatively high, but insufficient to be used as a substitute for ground truth. Besides, there are episodes where the EEG signal is poor because the subjects move during the session, producing noise. However, it is worth pursuing this approach since it could help reduce the labor-consuming task of video segmentation and annotation.

We developed a python library to process all the physiological data, including export, feature extraction, timestamp synchronization, and plotting anxiety data from all the devices. We started by down-sampling the GSR data from 4.0 Hz to 1.0 Hz. Then we detected signal peaks and filtered those greater than a threshold ($t >= 0.04$ for not normalized data). We also calculated the "Half Recovery Time" of the signal.

Since the heart rate sensor only reports data when the heartbeat happens, we grouped the data in windows of one second to compare it with the rest of the signals.

Table 1 Event codification criteria

Level	Criteria	Event example
0	PwD is passive, PwD is willing to participate, Participant and PwD are engaged with the task.	The PwD performs the activity as requested
1	Reluctant behaviors, Unwilling to participate, Complaining about the task.	"I don t like this game", "This is too hard" , "Do it yourself"
2	Mumbling, Talking nonsense, Unpredictable behavior.	"Where is my mother?", "Who are you?"
3	Shouting, Threatening the participant, Paranoia, Urge to leave.	"MOTHER, WHERE ARE YOU!!??" , "I WANT TO LEAVE NOW!", "WHO ARE YOU? LET ME GO!"

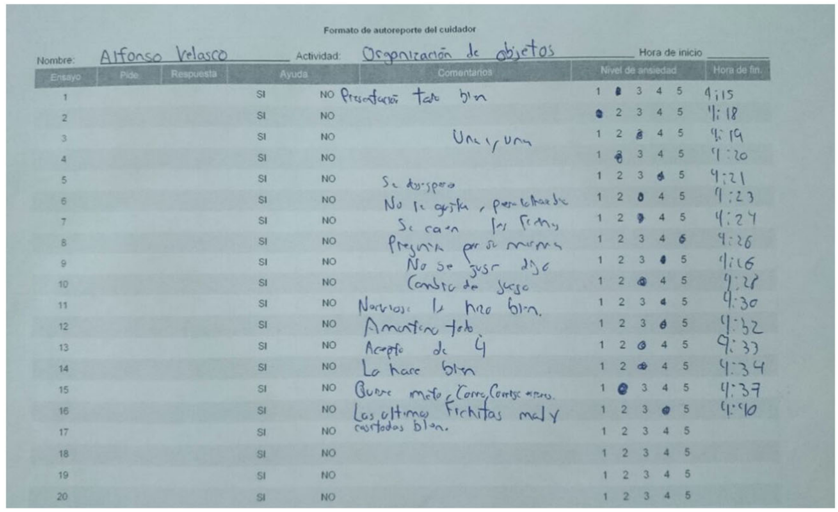

Fig. 3 Format used by the participants to report their anxiety level

Results

The physiological data collected was used to create models to infer anxiety using the Support Vector Machine algorithm. We present the results from 5 individuals, those with more self-report data, from which we had more reliable ground truth. As ground truth we used the "anxiety" and "not anxiety" segments obtained as described in section 4.2. All the segments were 30 s long. In all the tests we used 9 features from the GSR and IBI signals. For GSR we used Peaks amplitude, Maximum peak amplitude, Minimum peak amplitude, Peak variance, and Average half-time recovery. The features used for IBI are: Minimum, Maximum, Average and Standard Deviation. A total of 212 "anxiety" segments and 310 "not anxiety" were obtained.

Figure 4 shows the anxiety spans obtained for session number 1 of participant 7. The IBI signal is displayed on top. Red segments correspond to anxiety spans, green to not anxious spans and gray ones were classified as ambiguous.

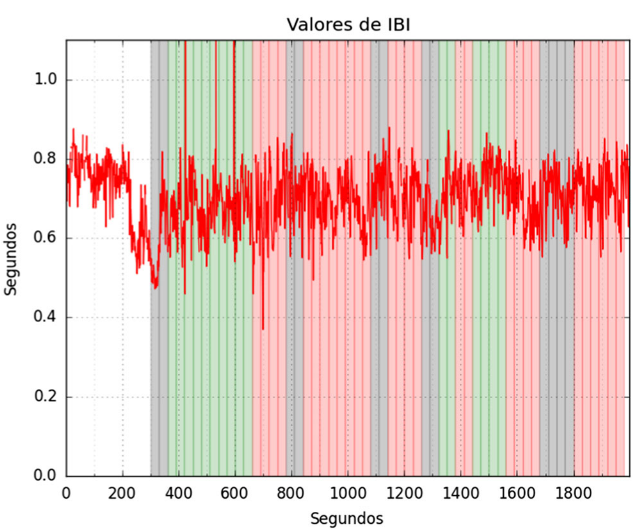

Fig. 4 Classification results for Participant 7, session 1 with the IBI signal shown on top

We conducted a "Leave-one-out" cross-validation test. For each participant, we took the data from the rest of the participants to train the model and the participant data to test it. A SVM model with a radial basis function kernel was used. We also conducted a separate test for GSR, IBI and GSR + IBI signals. Table 2 shows the results obtained.

The average precision was 77.79 %, with the best results obtained using only the IBI (80.37). This is in part explained by the different patterns in GSR observed in the sessions. Indeed, IBI has been reported to correlate well with stress [24]. Recall, or specificity, was much lower, 38.12 % on average, and 46.75 % using only IBI. Since Type II errors (false negatives) are preferable to type I errors (false positives) higher precision is more desirable than high recall. False negatives correspond to the status quo, where the anxiety is not automatically detected and a coping strategy is not triggered, while a false positive implies bothering the user by proposing a coping strategy that he doesn't need. Furthermore, long periods of anxiety are more relevant than shorter periods, thus missing to detect an isolated period of anxiety within a 60-s window is not critical, while a longer episode of anxiety has higher probability of being detected.

We performed an additional test using data from all subjects for training (80 % of all segments were used for training

Table 2 Classification results per signal

Signal	Precision (RBF)	Recall (RBF)
GSR + IBI	76.21	36.14
GSR	76.78	31.49
IBI	80.37	46.75
AVERAGE	77.79	38.12

and 20 % for testing). This produced a small improvement in precision (81.48 %) but a more significant increase in recall (51.16 %). This provides evidence of differences in the physiological response of individuals to these stimuli, this was particularly true for the GSR signal.

Limitations

Although we gathered data from different devices, we only used two physiological signals to conduct tests and visual interpretation. Anxiety detection is a hard problem, and becomes harder under naturalistic conditions. Ground truth gathering is a time consuming task when working with cognitive states. It took us approximately 10 h of work to annotate the videos and process each 30 min of data to establish ground truth. An alternative that should be explored is the use of digital means to facilitate the report of anxiety episodes by the participant, rather than using pen and paper the participant could for instance hold a device and grasp with different strengths to signal anxiety.

The relationship between caregiver and person with dementia is also complex. In this paper we conducted an experiment with persons with no emotional attachment or long history to the person with dementia. Although the real situations might differ from the results exposed, we showed a feasible approach to gather data from caregivers.

Further anxiety detection methods are also needed, in particular to develop general models that do not require training using data from the user.

Conclusions

We conducted a naturalistic enactment experiment to induce and detect anxiety states making use of wearable technology. As confirmed by self-report and observation, the intervention was successful in eliciting anxiety among participants while caring for a PwD. We proposed a method for obtaining ground truth in a NE environment through self-report, observation and video codification. Our results indicate that our approach can be used to detect anxiety on the caregiver in naturalistic conditions. We obtained a precision of 80 % using only the IBI signal; this is consistent with previous results in anxiety recognition in either controlled environments, such as riding a roller coaster [25], or conducted in everyday office work [26], and using a variety of sensors. However, our main contribution relies on the use of Naturalistic Enactment to elicit anxiety among caregivers. Gathering anxiety data under naturalistic conditions is an important step in the direction of developing applications that can assist caregivers to cope with this condition. Once these anxiety episodes are detected, the caregiver can be made aware of them and appropriate actions can be recommended to deal with this, such as deep breathing or making the caregiver aware of the condition of the PwD. In [27] for instance, the authors propose the use of micro-interventions to cope with stress that can be implemented on smartphones and provide evidence of their effectiveness.

While our aim was to gather anxiety data under naturalistic conditions, we have limited our approach to participants conducting one specific task, conducting a therapy with the PwD. A remaining challenge is to obtain reliable data while the participant conducts everyday activities. An additional open problem is to determine how and when to propose a coping intervention with the participant, and how to deal with false positives without disrupting the user.

References

1. Prince M, Bryce R, Albanese E, Wimo A, Ribeiro W, Ferri CP. The global prevalence of dementia: a systematic review and meta analysis. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association*. 9(1):63–75.e2, 2015.
2. Sadowsky, C.H., and Galvin, J.E., Guidelines for the management of cognitive and behavioral problems in dementia. *J. Am. Board Fam. Med.* 25(3):350–366, 2012.
3. Joling, K.J., van Marwijk, H.W., Veldhuijzen, A.E., van der Horst, H.E., Scheltens, P., Smit, F., et al., The Two-Year Incidence of Depression and Anxiety Disorders in Spousal Caregivers of Persons with Dementia: Who is at the Greatest Risk? *Am. J. Geriatr. Psychiatry.* 23(3):293–303, 2015.
4. Cooper, C., Katona, C., Orrell, M., and Livingston, G., Coping strategies and anxiety in caregivers of people with Alzheimer's disease: the LASER-AD study. *J. Affect. Disord.* 90(1):15–20 , 2006.Available from: http://www.sciencedirect.com/science/article/pii/S0165032705003034
5. Ory, M.G., Hoffman, R.R., Yee, J.L., Tennstedt, S., and Schulz, R., Prevalence and impact of caregiving: a detailed comparison between dementia and non dementia caregivers. *Gerontol.* 39(2): 177–186, 1999.
6. Schulz, R., and Beach, S.R., Caregiving as a risk factor for mortality: the caregiver health effects study. *Jama.* 282(23):2215–2219, 1999.
7. Miyamoto, Y., Ito, H., Otsuka, T., and Kurita, H., Caregiver burden in mobile and non-mobile demented patients: a comparative study. *Int. J. Geriatr. Psychiatry.* 17(8):765–773, 2002.
8. Tutar H, Cankurtaran E, Tekin P, Caykoylu A. The relationship between coping strategies and caregiver burden in caregivers of people with Alzheimer's dementia. Alzheimer's and Dementia. 2013;9(4, Supplement):P484 –. Alzheimer's Association International Conference 2013 Alzheimer's Association International Conference 2013.
9. Cruz, L., Rubin, J., Abreu, R., Ahern, S., Eldardiry, H., & Bobrow, D. G. A wearable and mobile intervention delivery system for individuals with panic disorder. In Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia (pp. 175–182). ACM 2015.
10. Williams, M. A., Roseway, A., O'Dowd, C., Czerwinski, M., & Morris, M. R. Swarm: an actuated wearable for mediating affect. In Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction (pp. 293–300). ACM 2015.

11. Simm, W., Ferrario, M. A., Southern, J., & Whittle, J. Clasp: digital tactile ASD anxiety management 2013.
12. Hamilton, M., The assessment of anxiety states by rating. *Br. J. Med. Psychol.* 32(1):50–55, 1959.
13. Zung, W.W., A rating instrument for anxiety disorders. *Psychosomatics*. 12(6):371–379, 1971.
14. Julian, L. J. Measures of anxiety: State-trait anxiety inventory (stai), beck anxiety inventory (bai), and hospital anxiety and depression scale-anxiety (hads-a). Arthritis care & research, 63(S11): S467–S472 2011.
15. Julian, L.J., Measures of Anxiety. *Arthritis Care Res.* 63(11(0 11)), 2011. doi:10.1002/acr.20561.
16. Navarro RF, Rodriguez MD, Favela J. Intervention Tailoring in Augmented Cognition Systems for Elders With Dementia. Biomedical and Health Informatics, IEEE Journal of. 2014 Jan. 18(1):361–367.
17. Algase, D. Wandering in d0ementia, Annual Review of Nursing Re search, vol. 17, pp. 189–218, 1999.
18. Sturm VE, Yokoyama JS, Seeley WW, Kramer JH, Miller BL, Rankin KP. Heightened emotional contagion in mild cognitive impairment and Alzheimer's disease is associated with temporal lobe degeneration. Proceedings of the National Academy of Sciences.; 110(24):9944–9949, 2013.
19. Castro LA, Favela J, García-Peña C. Naturalistic Enactment to Stimulate User Experience for the Evaluation of a Mobile Elderly Care Application. In: Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services. Mobile HCI '11. New York: ACM; p. 371–380, 2011.
20. Kirschbaum, C., Pirke, K.M., and Hellhammer, D.H., The 'trier social stress test'—a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*. 28(1–2):76–81, 1993.
21. Larson, R., & Csikszentmihalyi, M. The experience sampling method. New Directions for Methodology of Social and Behavioral Science, 15, 41–56 1983.
22. Miranda D, Calderón M, Favela J. Anxiety Detection Using Wearable Monitoring. In: Proceedings of the 5th Mexican Conference on Human-Computer Interaction. MexIHC '14. New York: ACM; 2014. p. 34:34–34:41. Available from: doi:10.1145/2676690.2676694.
23. Bos, D. O. EEG-based emotion recognition. The Influence of Visual and Auditory Stimuli, 1–17 2006.
24. Fuller, B.F., The effects of stress-anxiety and coping styles on heart rate variability. *Int. J. Psychophysiol.* 12(1):81–86, 1992.
25. Chang KH, Fisher D, Canny J, Hartmann B. How's my mood and stress?: an efficient speech analysis library for unobtrusive monitoring on mobile phones. In Proceedings of the 6th International Conference on Body Area Networks 2011 Nov 7 (pp. 71–77). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).
26. Garica-Ceja E., Osmani V., Mayora O., Automatic Stress Detection in Working Environments from Smartphones' Accelerometer Data: A First Step IEEE Journal of Biomedical and Health Informatics, DOI:10.1109/JBHI.2015.2446195, 2015
27. Paredes P, Gilad-Bachrach R, Czerwinski M, Roseway A, Rowan K, Hernandez J. PopTherapy: Coping with stress through pop-culture. InProceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare 2014 May 20 (pp. 109–117). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).