Proceedings of the 10th World Congress on Electrical Engineering and Computer Systems and Sciences (EECSS'24)
Barcelona, Spain – August 19 - 21, 2024
Paper No. ICBES 120
DOI: 10.11159/icbes24.120

Smartwatch Behavior Monitoring and Proximity Detection to Predict Biopsychosocial Interaction Experiences of Dyads

Aiden Walker, Raven Weaver, Maureen Schmitter-Edgecombe, and Diane J Cook
Washington State University
{aiden.walker, raven.weaver, schmitter-e, djcook}@wsu.edu
Pullman, WA, USA

Abstract – Family members typically provide most in-home care for older adults with dementia. This support can take an emotional and physical toll on the caregiver. There is a need to support caregivers, particularly in-the-moment during interactions. In this work, we lay a foundation for providing such real-time support. Using smartwatches and machine learning, we detect interactions within older adult dyads. We then predict responses to EMA questions about their well-being that are posed throughout the day and after interactions. We validate our method for a sample of n=10 participants (5 dyads) based on continuous data collected over 14 days.

Keywords**:** smartwatch, ecological momentary assessment, response prediction, dementia, caregiving

1. Introduction

The prevalence of dementia is increasing globally, with the U.S. projected to reach nearly 13 million persons living with Alzheimer’s Disease and Related Dementias (ADRDs) by 2050 [1]. ADRDs are among the most expensive diseases for individuals, families, and society, socially and financially [2], [3]. Dementia also complicates the management of other chronic illness [4] due to behavioural change and a diminished capacity to engage in decision-making. Technology to support persons living with dementia (PLwD, [5]) have demonstrated positive impacts on mobility [6] and sense of empowerment [7], but have not adequately addressed the needs that are faced by caregivers.

Family members, typically spouses and adult children, provide most of the in-home primary care for older adults with ADRDs and assume most of the long-term care expenses [1]. Despite interventions to support ADRD caregivers, many continue to report immense challenges that affect their own health and the health of PLwD [8]. Caregivers for PLwD are twice as likely to experience significant emotional, financial, and physical difficulties compared to caregivers of persons without dementia, including heavier care burdens and poorer quality of life [9] . In fact, caregiver distress and burden are associated with poor health outcomes for the PLwD, including worsening behavioural and psychological symptoms and increased risk of institutionalization [11]. For caregivers, assistive technology interventions emphasizing psychoeducation, psychosocial-supportive, therapeutic strategies, and cognitive/physical training benefited their mental health, skills learning, and social connectedness [12], [13]. Work to unobtrusively assess ADRD caregiver burden is early but promising. Technology-based interventions that are effective, scalable, and do not increase caregiver burden are of particular interest [14], [15]. Because individuals want to stay in their own homes as long as possible, the health and well-being of informal caregivers is a crucial goal. Support for caregivers directly impacts the ability of PLwD to live at home [16].

In this paper, we design and apply technologies to better understand how interactions between healthy dyads influence both members of the dyad, individually and mutually. We introduce novel methods to detect dyadic interactions using continuous smartwatch behaviour monitoring and proximity detection. We also collect continuous smartwatch data and extract digital markers that reflect behaviour context. Based on these components, we use machine learning methods to predict participant response to Ecological Momentary Assessment (EMA) well-being questions. We hypothesize that we can predict within-person changes in responses to the EMA questions. These technologies will allow us to anticipate caregiving stressors and design just-in-time interventions to support persons living with dementia and their caregivers.

2. Methods

We recruited n=10 healthy older adults (5 dyads) to wear Apple Watch smartwatches continuously for 14 days while data were collected. All participants were 60+, White, non-Hispanic, and most (n=9) had at least one year of college. Watches collected accelerometer and rotation readings at 10Hz. Heart rate was sampled once every 5 seconds and location was collected every 5 minutes or when accelerometer-based movement was greater than a minimum threshold. Additionally, participants used the smartwatch app to provide an audio description of their activities at the end of each day.

The Apple Watches were programmed to detect interactions. Using Bluetooth capability on the watch, we defined dyad physical “closeness” as the watches being within 2 meters of each other. After the dyad had been close for at least five minutes, both participants were prompted to questions, using the watch interface, one minute after the interaction concluded. Such ecological momentary assessments (EMA) are considered a reliable measurement technique for recording events, subjective symptoms, and physiological/behavioural data in natural settings [17], [18]. Each person’s day is divided into five windows (within a 12-hour period). If no interaction was detected for a given window, the EMA prompt was delivered near the end of the window. The questions asked participants to respond to each prompt with a Likert scale rating reflecting the past 30 minutes (Questions 1-2, 4-7) or currently (Question 3), with higher ratings indicating greater agreement:

1) I felt confident about my ability to handle personal problems (1-5)
2) I felt things are going my way (1-5)
3) How anxious do you feel (1-5)
4) How much interaction have you had with your partner (1-3)
5) I felt emotionally drained because of my partner (1-5)
6) I felt angry about interactions with my partner (1-5)
7) How well have you coped with everyday life (1-5)

Our goal is to predict a person’s EMA response based on their current behaviour context. Behaviour markers were extracted for 30 minutes prior to the EMA response. Behaviour markers are defined by applying statistics to each 30-second window of accelerometer, rotation, and location readings. Statistics include the value mean, median, minimum, maximum, standard deviation, zero crossings, interquartile range, skewness, kurtosis, and signal energy. A feature vector containing these values is fed to a random forest classifierto predict the EMA response.

3. Results

Fig. 1 shows the distribution of responses to the seven EMA questions. As the figure indicates, there is a large variation in response mean and deviation among the sample. Participants wore the watches 70% of the data collection time, on average. Participants received 740 EMA prompts and responded to 676, yielding a response rate of 91%. In each case, participants wore the watches a full 30 minutes before an EMA question was delivered.

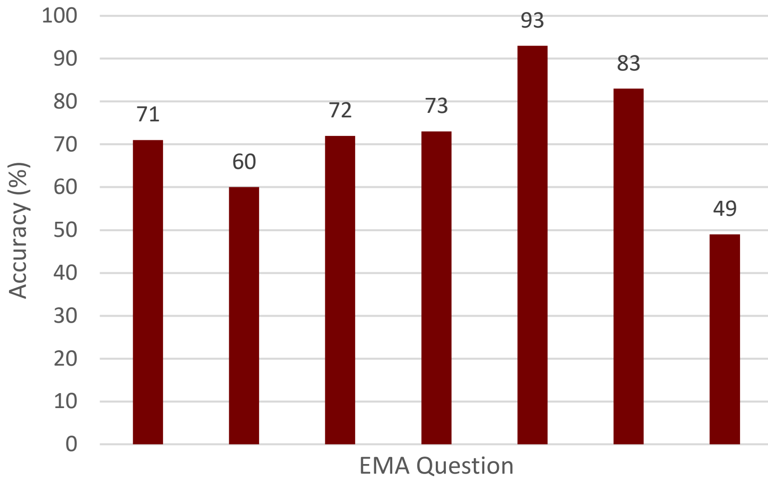

Fig. 2: Classification accuracy for each EMA response using a random forest.
deviation for each EMA question across the 10 participants.

The classification accuracy overall was 70% based on 10-fold cross validation. As Fig. 2 shows, accuracy ranged from 49-93%. The results are better than a random-guess accuracy of 20% (33% for question 4). However, there is a large amount of variation in predictive performance. Questions that were answered with more consistent Likert ratings (e.g., questions 5 and 6) were easier to predict than those with a large variance (e.g., questions 1, 2, and 7, see Fig. 1). Figure 3 plots the predictive accuracy for each dyad, together with the percentage time the dyad spent wearing the watch. As the figure indicates, there is not a strong relationship between watch time and response predictability.

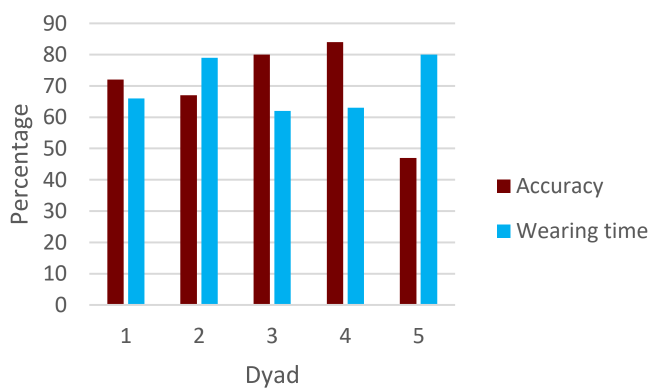

Fig. 3: Classification accuracy and percentage time wearing watch for each dyad.

4. Discussion and Conclusions

Findings from this study indicate that smartwatch and machine learning technology can be used to predict in-person changes and future stress levels. By analysing behaviour context that accompanies EMA response, we may gain a more in-depth understanding of the mechanisms that contribute to biopsychosocial reactions after dyadic interaction and determine whether potential stressors can be identified in real time. This study is limited by a small sample size and the inclusion of healthy dyads. Future work can address these limitations and evaluate the feasibility of designing timely interventions based on smartwatch-detected behaviour and interactions to promote caregiver health and wellbeing as well as support mood and healthy behaviour for persons living with dementia.

Acknowledgements

This research is supported in part by NIH/NIA grants R35AG071451 and R25AG046114. The authors would like to thank Bryan Minor for his help with the design and maintenance of the smartwatch apps.

References

[1] Alzheimer's Association, "Alzheimer's disease facts and figures," *Alzheimer's and Dementia*, 2023.

[2] D. Cantarero-Prieto, P. L. Leon, C. Blazquez-Fernandez, P. S. Juan, and C. S. Cobo, "The economic cost of dementia: A systematic review," *Dementia*, vol. 19, no. 8, pp. 2637–2657, 2020.

[3] S. E. Patterson, A. M. Tate, Y. L. Hu, J. J. Wang, R. F. Schoeni, and H. Choi, "The social cost of providing care to older adults with and without dementia," *Journals Gerontol. Ser. B Psychol. Sci. Soc. Sci.*, vol. 78, pp. S71–S80, 2023.

[4] J. E. Gaugler, "Unpaid dementia caregiving: A policy and public health imperative," *Public Policy Aging Rep.*, vol. 32, no. 2, pp. 51–57, 2022.

[5] J. Liddle, P. Worthy, D. Frost, E. Taylor, D. Taylor, R. Beleno, D. Angus, J. Wiles, and A. Angwin, "Personal and complex: The needs and experiences related to technology use for people living with dementia," *Dementia*, vol. 21, no. 5, pp. 1511–1531, 2022.

[6] G. E. Lancioni, L. Desideri, N. Singh, M. O'Reilly, J. Sigafoos, M. De Caro, and P. Taurisano, "Use of technology to sustain mobility in older people with cognitive impairment and dementia: A scoping review," *Disabil. Rehabiliation Assist. Technol.*, vol. 18, no. 5, pp. 635–649, 2021.

[7] C. Lobe and H. Abojabel, "Empowering people with dementia via using intelligent assistive technology: A scoping review," *Arch. Gerontol. Geriatr.*, vol. 101, p. 104699, 2022.

[8] M. Butler, J. Gaugler, and K. Talley, "Care interventions for people living with dementia and their caregivers," 2020.

[9] R. N. Collins and N. Kishita, "Prevalence of depression and burden among informal caregivers of people with dementia: A meta-analysis," *Ageing Soc.*, vol. 40, no. 11, pp. 2355–2392, 2020.

[10] N. Farina, T. Page, S. Daley, A. Brown, A. Bowling, T. Basset, G. Livingston, M. Knapp, J. Murray and S. Banerjee, "Factors associated with the quality of life of family carers of people with dementia: A systematic review," *Alzheimer's Dement.*, vol. 13, no. 5, pp. 572–581, 2017.

[11] J. Schein, C. Houle, A. Urganus, E. Jones, J. Pike, J. Husbands, and C. Willey, "The impact of agitation in dementia on caregivers: A real-world survey," *J. Alzheimer's Dis.*, vol. 88, no. 2, pp. 663–677, 2022.

[12] F. Deeken, A. Rezao, M. Hinz, R. Discher, and M. A. Rapp, "Evaluation of technology-based interventions for informal caregivers of patients with dementia—A meta-analysis of randomized controlled trials," *Am. J. Geriatr. Psychiatry*, vol. 27, no. 4, pp. 426–445, 2019.

[13] A. Pappada, R. Chattat, I. Chirico, M. Valente, and G. Ottoboni, "Assistive technologies in dementia care: An updated analysis of the literature," *Front. Psychol.*, vol. 12, p. 644587, 2021.

[14] A. Astell, M. Ellis, L. Bernardi, N. Alm, R. Dye, G. Gowans, and J. Campbell, "Developing technology to support the relationship between people with dementia and caregivers," in *International Conference of Alzheimer's Disease*, 2007, pp. 30–33.

[15] R. W. Levenson, K. Chen, D. Levan, E. Chen, S. Newton, D. Paul, C. Yee, C. Brown, J. Merrilees, D. Moss, and G. Wang, "Evaluating in-home assistive technology for dementia caregivers," *Cl. Ger.*, vol. 47, no. 1, pp. 78–89, 2024.

[16] N. M. Stall, S. Kim, K. Hardacre, P. Shah. S. Straus, S. Bronskill, L. Lix, C. Bell, and C. Rochon, "Association of informal caregiver distress with health outcomes of communitydwelling dementia care recipients: A systematic review," *J. Am. Geriatr. Soc.*, vol. 67, no. 3, pp. 609–617, 2019.

[17] J. Smyth and A. A. Stone, "Ecological momentary assessment research in behavioral medicine," *J. Happiness Stud.*, vol. 4, pp. 35–52, 2003.
[18] S. Shiffman, A. A. Stone, and M. R. Hufford, "Ecological momentary assessment," *Annu. Rev. Clin. Psychol.*, vol. 4, pp. 1–32, 2008.