iCareLoop: Closed-Loop Sensing and Intervention for Gerontological Social Isolation and Loneliness

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ABSTRACT

Social isolation refers to a lack of social contact and interaction, while loneliness is the subjective feeling of being alone. These two mental health concerns are highly correlated and can significantly increase the risk of premature death in the elderly. In fact, this risk may even rival that of smoking, obesity, and physical inactivity. To address this issue, we propose *iCareLoop*, a closed-loop decision support system with clinician-in-the-loop actuation to mitigate gerontological social isolation and loneliness. By implementing targeted interventions, this system can help maintain the mental well-being of elderly individuals, which is particularly crucial given the social disruptions caused by the COVID-19 pandemic.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in ubiquitous and mobile computing**.

1 INTRODUCTION

Social isolation and loneliness are serious mental health concerns for the elderly. Social isolation, the lack of social contact and support, increases dementia risk by 50% [8]. Loneliness, the subjective feeling of being alone, is associated with a 41% increase in chronic disease risk and fourfold increase in premature death risk [8]. These concerns have been exacerbated by COVID-19 preventative measures, which restrict social participation and exacerbate mental and physical health issues for the elderly [11].

In this work, we aim to address the problem of alleviating social isolation and loneliness in the elderly community. While there are many studies that use sensing systems to detect social isolation and loneliness, few have tackled the problem of coordinating effective interventions and monitoring whether the situation has improved. Therefore, we propose a closed-loop decision support system with clinician-in-the-loop actuation to fill this gap.

ICCPS '23, May 9–12, 2023, San Antonio, TX, USA

ACM ISBN 979-8-4007-0036-1/23/05…$15.00
https://doi.org/10.1145/3576841.3589632

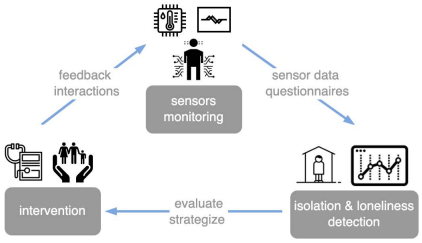

Figure 1: Closed-loop sensing and intervention system.

In order to accomplish our goal, we are faced with the challenge of providing clinicians with a understanding of the basis of our recommendations, which requires explainability. Additionally, we need to determine what types of interventions would be well-received by the participants.

To tackle these challenges, *iCareLoop* first utilizes sensor and questionnaire data to detect anomalies. We classify these anomalies by type and establish a correlation with interventions, forming the basis for clinicians to decide on personalized interventions that encourage social interaction. We evaluate the receptiveness and effectiveness of the intervention with clinician feedback, continuously monitor progress, and adjust interventions dynamically. The iCareLoop system is depicted in Figure 1.

The remainder of the paper is organized as follows: Section 2 describes the methodology of *iCareLoop*, Section 3 demonstrates a use case of the system, and Section 4 concludes the paper and outlines future work.

2 METHOD

We analyzed the NSHAP dataset [7] and identified critical variables to monitor, including weight, blood pressure, and cardiovascular readings. We also incorporate sleep behavior [5], mobility/activity level [12], usage of home appliances [1], and ambient environment [4] based on related work. These variables were selected to ensure comprehensive monitoring of geriatric well-being.

After collecting sensor and survey data, we use multiple time-series anomaly detection algorithms to identify and classify anomaly types for high-risk individuals. These algorithms can detect data points that deviate significantly from the norm and differentiate between types of anomalies based on changes in social patterns, such as a decrease in social network size or social engagements. We then tailor the intervention to the specific anomaly type identified, providing reasoning for the suggestion and facilitating well-rounded decision-making for the clinician.

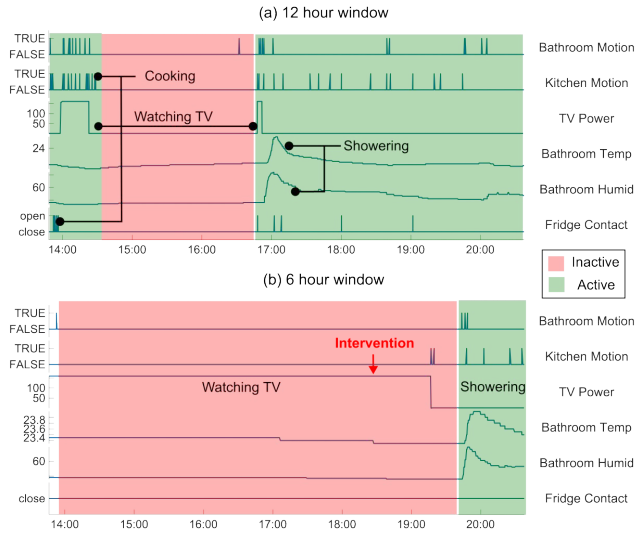

Figure 2: Sensor data visualization.

A variety of effective interventions are available to help alleviate geriatric social isolation and loneliness. These interventions can be delivered in three modalities:

(1) unidirectional alerts and context-specific messages such as push notification for inactivity or reminder of community events;

(2) bidirectional interactive sessions including telephone contact [9] that involve medical or nursing professionals, and the visitation programs [2, 13], where volunteers or family members would visit older adults who score high;

(3) multi-directional interactive sessions across community members involving group interventions [10] that could be conducted online or in-person, and health promotion programs [3, 6] at senior centers.

These interventions are predominately behavioral in nature and may involve reminiscence therapy, positive re-appraisal, and other similar techniques. However, participants may have different response to these interventions. We will use clinician feedback and monitoring outcomes to predict the intervention each participant will be the most receptive to.

After providing personalized interventions, *iCareLoop* continuously monitors sensor readings to assess effectiveness. If improvement is detected, intervention dosage (e.g. frequency, duration, number of visitors) may be adjusted. Otherwise, alternative interventions may be recommended. This iterative process optimizes *iCareLoop*'s approach for each individual, increasing the chances of success in combating social isolation and loneliness.

3 EXPERIMENT

Figure 2 shows a case study that illustrates the intervention function. Figure 2 (a) captures a typical 6-hour window of normal user activity, such as cooking, showering, and restroom use. In contrast, Figure 2 (b) shows an anomalous pattern where an elderly individual was inactive and watched TV for over five consecutive hours. Upon investigation in questionnaire data, the individual scored high for negative emotions and reported being alone all day, we classified the anomaly and suggested a push notification for inactivity. The individual reverted to normal activity, as indicated in the last green section of Figure 2 (b), where showering event was detected. To evaluate the system quantitatively, we are developing a scoring function for anomaly detection and user receptivity.

4 CONCLUSION AND FUTURE WORK

Our study proposes a closed-loop sensing system, *iCareLoop*, to detect and intervene in social isolation and loneliness among elderly community globally. The system uses advanced anomaly detection algorithms to identify high-risk individuals and suggest targeted interventions for the clinicians. In our future work, we aim to assess the accuracy of the anomaly detection module and provide a robust justification for the proposed interventions to assist clinicians in making informed decisions. We also seek to evaluate the cost-effectiveness of the interventions to maximize the efficacy at a minimal cost to community and individual's family.

ACKNOWLEDGMENTS

This work was supported in part by NSF-2125561 "SCC-IRG JST: Active sensing and personalized interventions for pandemic-induced social isolation."

REFERENCES

[1] M. Bennasar, C. McCormick, B. Price, D. Gooch, A. Stuart, V. Mehta, L. Clare, A. Bennaceur, J. Cohen, A. Bandara, et al. A sensor platform for non-invasive remote monitoring of older adults in real time. In *Innovation in Medicine and Healthcare Systems, and Multimedia*, pages 125–135. Springer, 2019.

[2] G. A. Bogat and L. A. Jason. An evaluation of two visiting programs for elderly community residents. *The International Journal of Aging and Human Development*, 17(4):267–280, 1983.

[3] C. C. Collins and J. Benedict. Evaluation of a community-based health promotion program for the elderly: lessons from seniors can. *American Journal of Health Promotion*, 21(1):45–48, 2006.

[4] A. J. Fay and J. K. Maner. Interactive effects of tactile warmth and ambient temperature on the search for social affiliation. *Social Psychology*, 2019.

[5] N. Goonawardene, X. Toh, and H.-P. Tan. Sensor-driven detection of social isolation in community-dwelling elderly. In *International Conference on Human Aspects of IT for the Aged Population*, pages 378–392. Springer, 2017.

[6] S. Gustafsson, H. Berglund, J. Faronbi, E. Barenfeld, and I. Ottenvall Hammar. Minor positive effects of health-promoting senior meetings for older community-dwelling persons on loneliness, social network, and social support. *Clinical Interventions in Aging*, pages 1867–1877, 2017.

[7] L. C. Hawkley and L. J. Waite. National social life, health, and aging project (NSHAP). In *Encyclopedia of Gerontology and Population Aging*, pages 3394–3401. Springer, 2022.

[8] National Academies of Sciences, Engineering, and Medicine and others. *Social isolation and loneliness in older adults: Opportunities for the health care system*. National Academies Press, 2020.

[9] E. E. Office, M. S. Rodenstein, T. S. Merchant, T. R. Pendergrast, and L. A. Lindquist. Reducing social isolation of seniors during covid-19 through medical student telephone contact. *Journal of the American Medical Directors Association*, 21(7):948–950, 2020.

[10] N. Savikko, P. Routasalo, R. Tilvis, and K. Pitkälä. Psychosocial group rehabilitation for lonely older people: favourable processes and mediating factors of the intervention leading to alleviated loneliness. *International journal of older people nursing*, 5(1):16–24, 2010.

[11] W. Sepúlveda-Loyola, I. Rodríguez-Sánchez, P. Pérez-Rodríguez, F. Ganz, R. Torralba, D. Oliveira, and L. Rodríguez-Mañas. Impact of social isolation due to covid-19 on health in older people: mental and physical effects and recommendations. *The journal of nutrition, health & aging*, 24(9):938–947, 2020.

[12] A. Site, S. Vasudevan, S. O. Afolaranmi, J. L. Martinez Lastra, J. Nurmi, and E. S. Lohan. A machine-learning-based analysis of the relationships between loneliness metrics and mobility patterns for elderly. *Sensors*, 22(13):4946, 2022.

[13] M. Stewart, D. Craig, K. MacPherson, and S. Alexander. Promoting positive affect and diminishing loneliness of widowed seniors through a support intervention. *Public health nursing*, 18(1):54–63, 2001.