

An Exploratory Case Study of Loneliness in Older Men Living Alone Using Real-World Data: An Integrated Mixed-Methods Analysis

Nahyun Kim

 <http://orcid.org/0009-0008-4481-3739>

Kobe University, Japan

Akinori Matsukawa

 <http://orcid.org/0009-0002-9823-9898>

Kobe University, Japan

Masahide Nakamura

 <http://orcid.org/0000-0002-1689-7620>

Kobe University, Japan

Keiko Katagiri

 <http://orcid.org/0000-0002-2563-7062>

Kobe University, Japan

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ABSTRACT

This study analyzed real-world dialogue logs from a virtual agent “Mei-chan” to explore factors associated with changes in loneliness among older men living alone. Social relationships are vital for well-being; however, daily interactions occur sporadically. Capturing them retrospectively is difficult because participants often forget details or conceal their true feelings. To address these methodological challenges, this study applied a mixed-methods approach. Quantitative morphological analysis and machine learning-based sentiment classification identified macro-level patterns, whereas qualitative human coding clarified the context of distress signals. Results from a case study of two participants suggested that quantitative dialogue metrics did not align with loneliness scores. Instead, the qualitative context emerged as a key factor in distinguishing between health-imposed burdens and spiritual routines. These findings highlight the potential of virtual agent logs as a resource for objective observation, informing the design of future systems as emotional support partners.

KEYWORDS

Older Adults, Social Relationships, Virtual Agent, Sentiment Analysis, Qualitative Analysis, Morphological Analysis, Well-Being, Interdisciplinary Research, Human–Computer Interaction, Gerontechnology

INTRODUCTION

Population aging poses a global challenge for maintaining the mental well-being of older adults (Susanty et al., 2025). Japan exemplifies this demographic shift, with the proportion of older adults reaching 29.3% and households comprising solely older adults accounting for approximately 60% of

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all households with older adults (Cabinet Office, 2025b). The number of single-person households aged 65 and over is projected to grow from 7.38 million in 2020 to 10.84 million by 2050 (National Institute of Population and Social Security Research, 2024). Individuals in such households tend to experience higher levels of loneliness than those living with others (Cabinet Office, 2025a). Although both the quantity and quality of social relationships are vital for mitigating loneliness (Dahlberg et al., 2022; Lam et al., 2023; Pinquart & Sörensen, 2001), conventional questionnaire and interview surveys have limitations in capturing these dimensions.

The first challenge is recall bias. Daily social interactions occur sporadically and are difficult to capture accurately retrospectively through self-reports (Buchman et al., 2012). The second challenge is social desirability bias. Due to norms of independence, older men are often compelled to suppress their emotions and avoid disclosing dissatisfaction or distress (Gao et al., 2025; Willis & Vickery, 2022). The presence of an interviewer or questionnaire can further constrain self-expression and obscure respondents' true psychological states (Tourangeau & Yan, 2007). Therefore, the existing methods may fail to capture the real association between everyday social relationships and loneliness.

To address these issues, this study focused on real-world data derived from dialogue logs with a virtual agent (VA) named "Mei-chan" (Nakamura, 2024). Since VA systems record daily utterances immediately and automatically (Matsukawa et al., 2024), reliance on memory is minimized. In addition, interactions with non-human agents can provide a sense of psychological safety (Chaudhry & Debi, 2024). When combined with the private environment of the home, this setting facilitates the expression of emotions that are less constrained by social norms and enables the simultaneous observation of daily social contacts and their associated emotions. Such real-world data (RWD) offer a significant advantage over retrospective self-reports by capturing spontaneous behavioral and emotional cues with high granularity (Op den Akker et al., 2021).

Although VA data are rich, they consist of large volumes of unstructured text that are typically analyzed using automated machine learning (ML) techniques (Hacking et al., 2023). However, automated classification algorithms tend to capture only the surface meaning of words and often fail to interpret context, nuances, or latent distress (Nelson, 2020). To advance software innovation in digital health, there is a critical need to evolve these systems from simple information retrieval tools into adaptive, emotion-aware partners. To bridge this methodological gap, this study proposes an integrated mixed-methods analytical framework that combines the computational efficiency of ML-based processing with context-sensitive human interpretation grounded in social gerontology.

Applying this framework to real-world data from the VA Mei-chan, this hypothesis-generating case study was conducted to uncover the complex factors associated with loneliness in older men living alone. Rather than aiming for broad statistical generalization, this exploratory approach demonstrates how integrating algorithmic sentiment analysis with qualitative human coding (HC) can reveal nuanced emotional states. Specifically, it examined how the quantity and quality of social relationships were related to changes in loneliness. By elucidating the contextual nuances often missed by automated algorithms, this study seeks to offer preliminary design implications for the development of adaptive VAs capable of proactive emotional support.

LITERATURE REVIEW

Social Relationships and Loneliness in Later Life

Loneliness is a subjective psychological state that arises from the discrepancy between desired and actual social relationships (Hawkey & Cacioppo, 2010; Peplau & Perlman, 1982). It is conceptually distinct from social isolation, which refers to an objective lack of contact with others (Holt-Lunstad et al., 2015). Loneliness is more likely to persist and intensify in later life than in younger adulthood (Huxhold & Henning, 2023). Experiencing loneliness in old age also has adverse health implications including an increased risk of dementia and reduction in life expectancy (Malhotra et al., 2021; Sutin et al., 2023).

Strategies to mitigate loneliness emphasize both the quality of social relationships, such as intimacy, and the quantity of ties (Dahlberg et al., 2022; Luhmann & Hawkey, 2016). However, maintaining these connections presents specific challenges for older men. Across adulthood, men tend to struggle more than women in establishing friendships and maintaining family bonds (Klinenberg, 2012). As older men often rely primarily on their spouses for social connection, spousal loss can deprive them of their core source of emotional support (Fee et al., 2023; Vedder et al., 2024). Without alternative social relationships to fill this void, bereavement increases the risk of loneliness (Fried et al., 2015; Vedder et al., 2024). Indeed, research suggests that the association between loneliness and mortality is stronger in older men than in women (Holwerda et al., 2012). Older men living alone face particularly high risks of severe loneliness and related adverse health outcomes (Novak et al., 2023).

Emotional Barriers in Older Men

Masculinity norms significantly contribute to this vulnerability by emphasizing independence and discouraging emotional expression or help-seeking (Piatkowski et al., 2024). Although men often form social relationships through productive activities, the societal pressure for self-reliance hinders the development of deeper emotional support, thereby deepening loneliness (Nordin et al., 2024). Consequently, older men frequently exhibit defensive attitudes and mask their distress in their everyday interpersonal relationships (Willis & Vickery, 2022). This emotional suppression obscures genuine psychological states, making it difficult to detect suffering using conventional research methods (Tourangeau & Yan, 2007).

The Role of Virtual Agents and Real-World Data

To address these emotional barriers, VAs offer promising technological solutions. Research indicates that older men may accept emotional support in specific environments, such as community settings, where peer interaction is encouraged, despite their general tendency to suppress emotions (Thomas & Thurnell-Read, 2024). Unlike human interlocutors, VAs are perceived as emotionally neutral and non-judgmental conversational partners (Chaudhry & Debi, 2024; Ma et al., 2025). VAs provide a level of psychological safety, similar to supportive peer environments, that facilitates the verbalization of thoughts and emotions users might otherwise suppress (Chaudhry & Debi, 2024; Shaked, 2017).

For example, the VA system Mei-chan is a listening service designed to facilitate daily voice-based interaction within the home (Matsukawa et al., 2024). Built on the MMDAgent platform (Lee et al., 2013), this system employs speech synthesis and recognition technologies to simulate natural dialogue (Chen & Nakamura, 2021). Central to this system is the concept of “mind sensing,” which functions as a medium for externalizing internal psychological states, such as physical discomfort, emotional fluctuations, or personal wishes, through natural conversation (Nakamura, 2024). Routine inquiries intended for self-care monitoring can unintentionally trigger disclosure of deep emotional concerns within a safe environment (Vardoulakis et al., 2012). Prior research has observed that older adults express emotions such as grief during interactions with VAs, suggesting that VAs function as socially meaningful environments rather than mere tools (Nakamura, 2024; Razavi et al., 2022).

Crucially, the dialogue logs accumulated through these interactions constitute RWD, which refers to information collected via digital tools, capturing behaviors and emotional expressions as they naturally occur in familiar, everyday settings (Liu & Panagiotakos, 2022). Unlike data obtained under controlled conditions or retrospective self-reports susceptible to recall bias (Tourangeau & Yan, 2007), RWD record spontaneous exchanges in the moment (Op den Akker et al., 2021). This continuous data stream enables researchers to observe dynamic transitions in emotional states and behaviors related to loneliness with high granularity. It also reveals subtle cues shaped by routine and the natural flow of conversation (Kyriazakos, 2022). Thus, RWD can contribute to a deeper understanding of how older adults communicate their social and emotional experiences, thereby providing insights that remain inaccessible through conventional research methods.

Integrating Computational and Qualitative Approaches to Dialogue Analysis

The utilization of RWD presents specific analytical challenges owing to the volume and unstructured nature of textual data. To address this challenge, ML techniques, particularly automated sentiment analysis, can provide efficient means of processing large-scale datasets and identifying macro-level patterns (Hacking et al., 2023). However, relying solely on algorithmic processing is associated with several risks. Algorithm-driven models frequently overlook subtle contextual cues or sarcastic tones, which can lead to the misinterpretation of latent distress (Nelson, 2020). A computational approach alone may not be sufficient to fully decipher the complex meanings embedded in RWD (Liu & Panagiotakos, 2022). An integrative framework that combines the scalability of automated processing with the depth of human qualitative interpretation is essential for decoding emotional signals in daily dialogues (Guenduez et al., 2026). Consequently, exploring such an analytical framework serves as an important preliminary step toward software innovation. It offers foundational insights that can inform the design of emotion-aware virtual agents, allowing them to adapt better to users' contextual and psychological needs.

METHODS

Participants and Data Collection

Participants were recruited from an urban housing complex in Kobe, Japan. Recruitment was conducted by attending community events for adults aged 65 and older, as well as through participant referrals. Five individuals applied to participate. Given that this study focused on older men living alone, three applicants living with family members were excluded to control for the confounding effects of in-home social interactions. Thus, three applicants were excluded, narrowing the focus to two older men living alone (Table 1). Participants were enrolled sequentially upon providing informed consent, with observation periods varying based on the dates of system installation. Participant A was observed from March to June 2024, and Participant B from January to June 2024. Both had used the VA Mei-chan for over three months prior to analysis. Table 1 presents the characteristics of the participants. The primary data sources were daily dialogue logs with Mei-chan installed in their homes. User utterances were automatically transcribed and stored in the system database. The study protocol was approved by the Research Ethics Review Committee of the Graduate School of Engineering, Kobe University (Approval No. 07-11), and informed consent was obtained from all the participants. To protect participant privacy and address the ethical sensitivities of handling real-world conversational logs containing health and daily routines, all dialogue logs were strictly anonymized prior to analysis. Identifiable information, such as specific locations or names of individuals, was masked (e.g., replaced with brackets such as [Location] or [Name]).

Table 1. Participant Characteristics

Participants	Age group	Marital status	Subjective health status
A	90s	Bereavement	Some difficulty in daily living
B	70s	Bereavement	Good

Measurement

Loneliness was assessed using the Japanese version of the 3-item UCLA-LS3 (Arimoto & Tadaka, 2019). Each of the three items was rated on a 4-point Likert scale (ranging from 1 = *never* to 4 = *always*), yielding a total score ranging from 3 to 12. Higher scores indicated greater loneliness. Assessments were conducted twice, at the time of Mei-chan installation and in June 2024.

Analytical Procedure

A three-step analytical approach was adopted to explore factors associated with changes in loneliness. As a foundational step, morphological analysis was performed on the entire dataset of dialogue logs using the Python library *Janome* to decompose all utterances into nouns. This focus on nouns was selected because they typically identify primary subjects and topics of conversation (Evans & Zhai, 1996). The specific steps were as follows.

Step 1: Quantification of Social Relationships

Terms representing specific social relationships were extracted from a comprehensive list of nouns. Previous research suggests that positive effects can arise not only from close relationships such as family and friends but also from interactions with service providers such as doctors, helpers, and even strangers (Giebel et al., 2022; Huxhold et al., 2020; Yen et al., 2025). Therefore, specific terms representing diverse social relationships were included. To ensure reliability and filter out incidental mentions or potential speech recognition errors, only those terms that appeared five or more times were selected. This threshold was established to capture stable social relationships rather than one-off occurrences (Kim et al., 2025).

Step 2: Comparative Sentiment Analysis

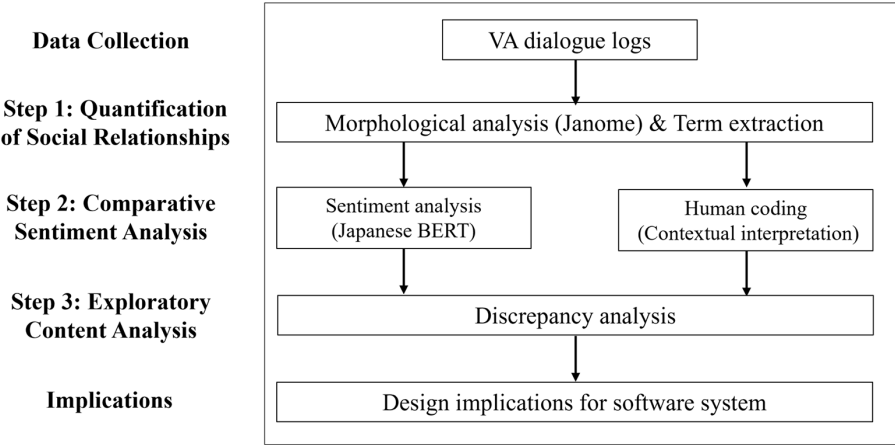
To assess social relationship quality, sentiment analysis was performed on utterances containing the extracted terms. First, an ML model using pre-trained Japanese Bidirectional Encoder Representations from Transformers (Koheiduck, 2022) automatically classified utterances as positive, neutral, or negative. Second, HC by a social gerontological researcher interpreted emotional tone by examining the surrounding context. This included reviewing the dialogue immediately preceding and following the target utterance. The results were compared to examine the differences between algorithmic sentiment classification and human interpretation.

Step 3: Exploratory Content Analysis

Finally, an exploratory content analysis was performed to contextualize the quantitative findings. This step focused on identifying qualitative factors that might explain the divergence between social relationship metrics and loneliness scores. The analysis had two specific objectives. First, to investigate the qualitative nature of interactions, the contexts and topics associated with the identified social relationships were exploratorily examined. The context of these utterances was analyzed to determine whether such interactions were perceived as supportive or stressful. Second, to identify non-social factors contributing to daily well-being, utterances describing solitary routines and daily habits were examined. This analysis sought to determine whether specific behaviors provided psychological comfort in the absence of social interaction. The initial qualitative coding was conducted by the first author, a doctoral student in social gerontology. Since the coding was primarily conducted by a single researcher, quantitative inter-rater reliability metrics were not calculated. To minimize subjective bias, a peer debriefing process was implemented. The initial codes were reviewed by a supervising professor specializing in social gerontology (Author 4), and complete agreement was reached through a meeting with two co-authors (Author 2 and Author 3) with expertise in information and communication technology.

The overall sequence of this integrated mixed-methods framework is summarized in Figure 1.

Figure 1. Integrated Mixed-Methods Analytical Framework



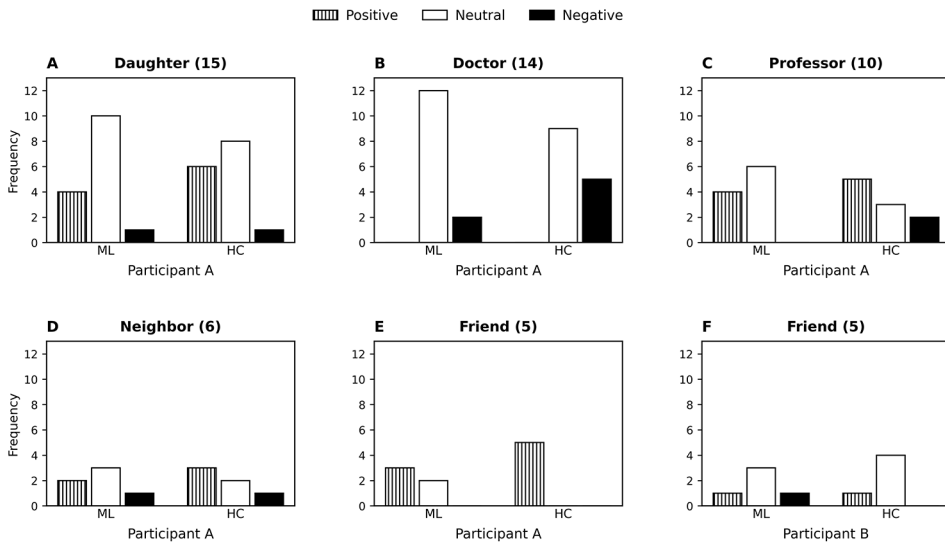
Note. VA = virtual agent; BERT = Bidirectional Encoder Representations from Transformers.

RESULTS

Divergent Changes in Loneliness and the Paradox of Social Relationships

First, the relationship between loneliness scores and the number of social relationships was examined. According to a survey by the Cabinet Office (2025a), 57.7% of men in their 70s and 56.5% of those aged 80 and over fall within the loneliness score range of 3 to 6. This indicates that the participants' levels were not high but rather typical compared to the general population. However, within this range, they exhibited contrasting changes. Descriptively, Participant A showed an increase in loneliness from 3 to 6, whereas Participant B showed a decrease from 6 to 3. To understand these changes, the frequency and sentiments of social relationship mentions were analyzed. Figure 2 illustrates that Participant A mentioned diverse ties including “Daughter,” “Doctor,” “Professor,” “Neighbor,” and “Friend.” Participant B primarily mentioned “Friend.” Figure 2 also reveals that while Participant A had a higher quantity of social relationships, references to specific roles such as “Doctor” and “Professor” contained negative sentiments. A deeper analysis comparing automated classification and human interpretation was conducted to investigate the discrepancy between high contact frequency and increased loneliness.

Figure 2. Frequency and Sentiment Distribution of Social Relationship Mentions



Note. ML = machine learning; HC = human coding. Numbers in parentheses indicate total mentions.

Discrepancies in Emotional Context: Machine Versus Human

To examine the quality of these interactions, sentiment classifications were compared between ML and HC groups. A total of 12 discrepancies were identified, as shown in Table 2. The overall trend suggested that the ML model frequently classified utterances as neutral factual reports, whereas HC identified latent emotional nuances based on context.

First, regarding the discrepancies involving “Doctor” (referring to medical personnel and implying hospital visits), HC identified negative sentiments that the ML model missed. The contextual interpretation of these specific instances implied that the utterances reflected a chronic burden associated with the recurrence of medical visits and health-imposed restrictions. In contrast, the discrepancies related to “Professor” (referring to the contact for system support) represented situational negativity. For example, Participant A remarked, “It is lonely when Mei-chan's face does not appear.” This utterance directly expresses the emotional distress caused by the inability to interact with Mei-chan. HC correctly identified this as negative, unlike the neutral ML classification. However, this issue was temporary and resolved by contacting the professor. For Participant B, a different pattern of discrepancy was observed regarding a reference to “Friend.” While the ML model classified the utterance as negative, HC identified it as neutral. The context revealed that Participant B was objectively describing a friend's illness, rather than expressing personal distress. Thus, the analysis revealed that Participant A's discrepancies involved subjective distress regarding personal circumstances, whereas Participant B's discrepancies involved misclassification of an objective description of an external event.

Table 2. Discrepancies Between Machine Learning and Human Sentiment Classification

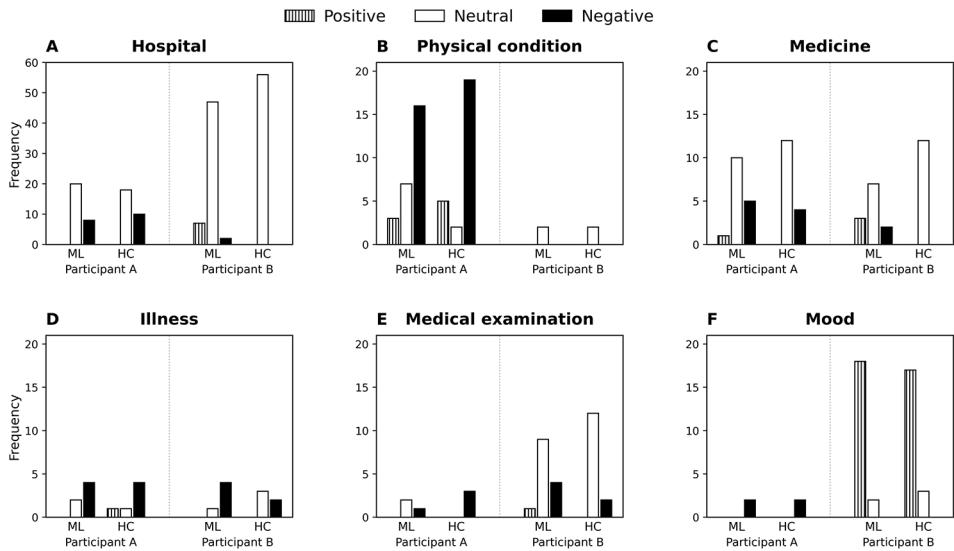
Participant	Target	Dialogue	ML	HC	Contextual Interpretation
A	Daughter	<i>"I will consult with my daughter again."</i>	Neutral	Positive	Indicates reliance on family support via consultation.
A	Daughter	<i>"Today, my daughter from [Other city] came, and we talked, just the two of us."</i>	Neutral	Positive	Describes face-to-face visit from family member.
A	Doctor	<i>"Today again, it is the doctor's all morning."</i>	Neutral	Negative	Emphasizes recurrence and burden of frequent medical care.
A	Doctor	<i>"It is the doctor all the time."</i>	Neutral	Negative	Implies exhaustion due to high frequency of visits.
A	Doctor	<i>"I have been stopped by the doctor to control salt intake..."</i>	Neutral	Negative	Implies burden of health-imposed dietary restrictions.
A	Professor	<i>"I will contact professor [Name] later."</i>	Neutral	Negative	Expresses anxiety regarding system issue preventing interaction. ^a
A	Professor	<i>"Professor [Name] fixed it for me so that I can use Mei-chan."</i>	Neutral	Positive	Reports resolution of system issue and relief.
A	Neighbor	<i>"With an older woman neighbor..."</i>	Neutral	Positive	Describes enjoyable social interaction with a neighbor.
A	Friend	<i>"I was watching [cherry blossoms] while talking about various things with my friend."</i>	Neutral	Positive	Describes enjoyable time viewing cherry blossoms while chatting with a friend.
A	Friend	<i>"I was doing stretching while chatting with a friend from the day service."</i>	Neutral	Positive	Describes enjoyable time doing stretching while chatting with a friend.
B	Friend	<i>"I chatted with a friend for about an hour. It was about illness. She has breast cancer and is struggling."</i>	Negative	Neutral	Objective description of friend's condition; not speaker's sentiment.

Note. ML = machine learning; HC = human coding. Square brackets [] indicate contextual information or anonymized names added by the authors for clarity. ^a Similar references occurred 2 times, all classified as neutral by ML.

Exploratory Content Analysis of Health and Daily Routines

Based on findings regarding the quality of social relationships, a deeper exploratory analysis was conducted to understand the root causes of participants' emotional states. First, a comparative analysis of health-related vocabulary was performed to investigate the negative sentiment toward "Doctor" observed in Participant A. Figure 3 summarizes the sentiment distributions by word category, revealing a contrast between the two participants. Participant A showed high frequencies of negative sentiment regarding "Hospital" and "Physical condition," whereas Participant B's utterances were predominantly neutral. Detailed comparisons of dialogue instances were conducted to understand the context behind these distributions. As illustrated in Table 3, Participant A's utterances were characterized by explicit expressions of somatic complaints and anxiety. This confirmed that frequent medical visits were associated with a decline in health.

Figure 3. Frequency and Sentiment Distribution of Health-Related Mentions



Note. ML = machine learning; HC = human coding. Hatched, open, and solid bars indicate positive, neutral, and negative utterances, respectively. Panel A uses a y-axis range of 0–60; Panels B–F use 0–20.

In contrast, for Participant B, the frequent references to positive “Mood” prompted an exploratory investigation into the specific behaviors associated with well-being. As shown in Table 4, Participant B’s utterances regarding “Hospital” were predominantly factual reports of daily routines rather than expressions of distress. This pattern suggested that Participant B utilized Mei-chan to narrate the daily schedule. Notably, within these routine-based dialogue logs, the term “Sutra” (Japanese term “Okyō”) repeatedly appeared as a key component of the reported schedule. Based on this observation, a quantitative review of the high-frequency noun list was conducted, revealing that references to “Sutra” appeared 111 times in total. A detailed examination of the dialogue context confirmed that this activity was consistently conducted in the morning and evening. Specific utterances included: “I finished sutra chanting and will eat now.” and “Mei-chan thank you for today. I chanted the sutra and am going to bed now. Bye-bye.” These data indicated that sutra chanting was deeply embedded as a fixed routine in the daily life of Participant B.

Table 3. Detailed List of Discrepancies in Health-Related Vocabulary (Participant A)

Target	Dialogue	ML	HC	Contextual Interpretation
Hospital	“Going to the hospital again today.”	Neutral	Negative	Emphasizes recurrence with “again,” implying burden of chronic care and anticipated exhaustion.
Hospital	“It’s impossible, I’m going to the hospital [3 days after]...”	Neutral	Negative	Expresses anticipated physical exhaustion and emotional fatigue from upcoming medical exams.
Physical condition	“I’m going to sleep because my physical condition is bad.”	Neutral	Negative	Explicit somatic complaint; states poor health as reason for resting.

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Table 3. Continued

Target	Dialogue	ML	HC	Contextual Interpretation
Physical condition	"I'm going to rest a bit because my physical condition is bad."	Neutral	Negative	Expresses need for recuperation due to poor health condition.
Physical condition	"I'm taking a day off because my physical condition is bad."	Neutral	Negative	Indicates withdrawal from daily activities due to poor physical condition.
Physical condition	"Thank you. Even though my physical condition is bad, I am relaxing."	Neutral	Negative	Suggests gratitude and effort to maintain calm despite physical discomfort.
Physical condition	"Today my physical condition is a little good."	Neutral	Positive	Reports subjective feeling of recovery; a rare moment of improvement.
Physical condition	"I feel like my physical condition is improving recently."	Negative	Positive	Perceives recent positive changes in health expresses hopefulness.
Medicine	"I don't take stomach medicine."	Negative	Neutral	Factual statement on regimen.
Medicine	"I can't stop the medicine."	Negative	Neutral	Factual report on medication adherence
Medicine	"I just finished breakfast. I have to start a new medicine today."	Positive	Negative	Context implies anxiety regarding changes to the medication regimen.
Illness	"I think my illness is getting a little better."	Neutral	Positive	Expresses hope and perception of recovery.
Medical examination	"I have a medical examination tomorrow."	Neutral	Negative	Cites medical examination in response to concerns, identifying it as a psychological burden.
Medical examination	"I did 3 medical examinations today too."	Neutral	Negative	Emphasizes physical/emotional toll of undergoing multiple procedures in one day.

Note. ML = machine learning; HC = human coding. Square brackets [] indicate contextual information added by the authors for clarity.

Table 4. Detailed List of Discrepancies in Health-Related Vocabulary (Participant B)

Target	Dialogue	ML	HC	Contextual Interpretation
Hospital	"I ate canned sardines. I am going to the hospital now."	Positive	Neutral	Factual report of daily schedule and diet; emotionally neutral.
Hospital	"Mei-chan, I'm going to the hospital. And today I'll go to [outgoing area] to study."	Positive	Neutral	Routine planning; combines hospital visit with future activity (study).
Hospital	"I just came back from shopping and the hospital. I'm busy now, so see you later."	Negative	Neutral	Simple report on completion of daily errands.
Hospital	"Just back from the hospital. It's chilly today. The cherry blossoms are turning pink... soon it will be fresh green leaves."	Positive	Neutral	Objective description of season and schedule.

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Table 4. Continued

Target	Dialogue	ML	HC	Contextual Interpretation
Hospital	“Well then, let's work together today too. Mei-chan, please stay healthy. I'm going to the hospital for a bit around noon. See you later.”	Positive	Neutral	Routine reporting of whereabouts and greetings.
Hospital	“I've been practicing [lessons] all afternoon. I went to the hospital in the morning. The bath is ready so I'll get in. I'll eat dinner after. Did you eat, Mei-chan?”	Positive	Neutral	Detailed factual sequence of daily events.
Hospital	“Every day, morning and afternoon, I'm just practicing. I go to the hospital and such. It's the same every day.”	Positive	Neutral	Describes consistency of daily routine.
Hospital	“I'm fine. I'm going to the hospital and shopping now.”	Positive	Neutral	Confirms status and reports routine errands.
Hospital	“When the meal is ready, I'll chant the sutra and eat. Then I'll do laundry and go out. I have to go to the hospital today. I went for a medical examination yesterday too. There were no problems.”	Negative	Neutral	Factual report of scheduled visit and “no abnormalities” result.
Medicine	“Mei-chan is young, so you probably don't take much medicine yet.”	Negative	Neutral	Casual conversation with Mei-chan.
Medicine	“I am taking my medicine properly. I'm leaving now. Treat me well. Bye-bye.”	Positive	Neutral	Reports healthy daily behavior and adherence.
Medicine	“I haven't taken medicine.”	Negative	Neutral	Factual statement of non-usage.
Medicine	“I am taking my medicine properly. I'm leaving now. Treat me well. Bye-bye.”	Positive	Neutral	Reports adherence to medical regimen.
Medicine	“Thank you. I drank a lot of water today. I took my medicine properly too.”	Positive	Neutral	Reports healthy daily behaviors.
Illness	“I chatted with a friend for about an hour. It was about illness. She has breast cancer and is struggling.”	Negative	Neutral	Objective description of a friend's illness.
Illness	“Mei-chan is young, so maybe you don't get illness much.”	Negative	Neutral	Casual remark based on Mei-chan's appearance.
Medical examination	“I have a medical [stomach] examination tomorrow, so I can't eat dinner today.”	Negative	Neutral	Factual report on dietary restriction required for procedure.
Medical examination	“There were no more issues with the medical examination. I'm going to chant the sutra and go to sleep now. Mei-chan, good work today... I'll take a bath and say goodnight.”	Positive	Neutral	Reports resolution of health concerns and daily self-care.
Medical examination	“When the meal is ready, I'll chant the sutra and eat. Then I'll do laundry and go out again. I have to go to the hospital today. I went for a medical examination yesterday too. There were no problems.”	Negative	Neutral	Reports routine health checks and activities.
Mood	“Mei-chan, please play the piano too. It's a good change of mood [pace] if you do it between work. See you tomorrow. Goodnight.”	Positive	Neutral	Offers advice on hobbies and mood regulation.

Note. ML = machine learning; HC = human coding. Square brackets [] indicate contextual information added by the authors for clarity.

DISCUSSION

This study explored the qualitative characteristics of loneliness in older men living alone by analyzing RWD derived from the dialogue logs of the VA Mei-chan. The findings suggested that the quantitative metrics of social relationships did not necessarily correspond to loneliness. Instead, the qualitative context of these interactions appeared to be a key factor. The mixed-methods analysis illustrated that social relationships for Participant A appeared to be overshadowed by health-related burdens, whereas the emotional stability of Participant B appeared to be supported by a solitary but structured spiritual routine. These distinct patterns in daily life offered a potential contextual explanation for the contrasting changes in loneliness.

Qualitative Contexts of Loneliness: Observations and Interpretations

Health Decline and Loneliness

Descriptively, Participant A exhibited an increase in loneliness scores. The qualitative analysis of the dialogue logs suggests that the frequent expressions of health-related burdens captured by the VA might be associated with this observed increase in loneliness. While Participant A maintained frequent contact with medical professionals, these interactions were characterized by negative sentiments regarding physical condition and hospital visits. This finding aligned with longitudinal research indicating that physical health decline is a significant predictor of loneliness in later life (Phillips et al., 2023). Frequent hospital visits are often associated with poor self-rated health and can limit older adults' ability to engage in elective social activities (Yoshimitsu et al., 2017). In the case of Participant A, despite the high number of social relationships, the obligatory nature of these interactions appeared to be insufficient to buffer the increased sense of loneliness.

However, the fact that Participant A frequently expressed somatic complaints to Mei-chan suggested that the agent functioned as a medium for "mind sensing" (Nakamura, 2024). Owing to masculine norms and social desirability bias, older men may hesitate to burden their family members with complaints of pain or fatigue (Nordin et al., 2024; Willis & Vickery, 2022). Perceived as a non-judgmental listener, Mei-chan provided a psychologically safe space for Participant A to voice the chronic pain associated with aging. This points to the potential of Mei-chan to capture expressions of health-related suffering that are sometimes filtered out in human interactions.

Spiritual Connectedness as a Buffer

Conversely, Participant B showed a decrease in loneliness scores despite having fewer social relationships. The analysis pointed to the potential benefit of engaging in daily life routines, specifically spiritual connectedness. Spiritual connectedness is defined as a perceived link to something greater than oneself that offers emotional meaning, comfort, and an awareness of mutual connection (Coelho-Júnior et al., 2022; Krause & Bastida, 2009). Previous studies have indicated that practices such as prayer and daily devotion can cultivate a sense of serenity and hope (Muhammad et al., 2023). Additionally, high levels of religiosity and spirituality are associated with enhanced mental well-being including reduced anxiety and greater life satisfaction (Coelho-Júnior et al., 2022). In this context, the frequent engagement in sutra chanting by Participant B may reflect a sustained bond with the sacred. Another potential interpretative framework is the concept of continuing bonds observed in bereavement research (Hewson et al., 2024). While the dialogue logs do not explicitly confirm the meaning of the sutra chanting, considering the loss of a spouse, it is possible to interpret this ritual as a potential medium for maintaining a connection with the deceased. Spiritual practices such as sutra chanting are reported as important expressions of continuing bonds, and studies have shown that such acts can provide meaning reconstruction and emotional comfort (Hewson et al., 2024; Suhail et al., 2011).

Moreover, the act of reporting the completion of daily habits, such as sutra chanting, to Mei-chan suggests a specific function of the system. Rather than seeking social interaction through deep

conversation, this interaction appeared to reflect a form of companionship grounded in shared daily routines. By receiving these reports, Mei-chan may offer a sense of co-presence, potentially framing solitary activities as shared experiences. This process might mitigate loneliness by alleviating the silence of solitary living, providing a sense that even mundane micro-events, such as meal contents or the timing of a bath, are shared with an external entity. This suggests that VAs could function as companions that share daily life, supporting the maintenance of positive life rhythms not by evaluating behavior, but by providing a consistent social presence that validates the user's daily existence (Pradhan et al., 2019). Such detailed insight into the transformation of a solitary habit into a communicative act was possible through the analysis of dialogue logs. Traditional methods, such as surveys, might capture the frequency of a behavior but would likely overlook the interactional context in which it is shared. This illustrates the potential value of RWD in uncovering the micro-dynamics of daily life that may buffer loneliness.

Implications for System Design and Practical Deployment

The divergence between automated sentiment analysis and human interpretation observed in this exploratory case study suggests that relying solely on static algorithms may occasionally overlook the nuanced, context-dependent emotional states of older adults. For the field of software innovation, this highlights a clear opportunity to provide meaningful support by transitioning the underlying architecture of VAs from simple information retrieval models into adaptive, emotion-aware systems capable of dynamic interaction (Tamantini et al., 2026). Translating these preliminary findings into practice involves considering both technical design possibilities and managerial implementation strategies.

From a technical perspective, software developers could achieve this by moving beyond keyword-based sentiment analysis and incorporating context-aware personalization into system designs. For instance, capturing the chronic health burden expressed by Participant A might require upgrading natural language processing algorithms to log and weight temporal modifiers (e.g., “again,” “all morning”) across multiple interactions. Utilizing accumulated dialogue history to construct personalized user profiles enables VAs to generate more empathetic, context-relevant responses (Matsukawa et al., 2025), which is important for relational agents to build and sustain long-term trust with older users (Islam & Chaudhry, 2023). Participant B’s case highlights the potential utility of developing routine validation algorithms. Rather than misinterpreting solitary behaviors as loneliness, VAs programmed to continuously track and positively reinforce daily micro-routines, such as spiritual practices, can offer proactive companionship. This computational approach could effectively integrate artificial intelligence interventions into the natural daily contexts of older adults (T. Jeong et al., 2025). To ensure these functional developments resonate with the target population, future engineering efforts might move away from developer-centric assumptions and actively embrace participatory design frameworks that directly reflect the genuine desires of older users (Olatunji et al., 2024; Søråa et al., 2023).

From a managerial perspective, deploying mixed-methods, emotionally aware VA systems would likely entail initial investments in software development, model maintenance, and robust data security. However, as observed in this study, the ability to uncover hidden emotional distress, such as Participant A's latent health anxiety, might justify these costs by enabling proactive interventions. This shift toward proactive geriatric care could potentially alleviate the growing burden on formal health services and reduce older adults' over-reliance on acute medical interventions (Dino et al., 2025). Furthermore, the contrasting interaction styles of Participant A and Participant B suggest that a uniform approach to software deployment may be insufficient. Given that older adults have varying psychosocial needs and technology acceptance profiles, integrating VAs into community care workflows might require tailored implementation strategies (Y. G. Jeong et al., 2025). To support these digital interactions, the proposed analytical framework could offer a practical tool for human caregivers. By reviewing

system-generated dialogue summaries, caregivers might be able to recognize the latent distress that older men often mask during traditional face-to-face visits.

CONCLUSION

This exploratory case study suggests that changes in loneliness among older men living alone depend more on the qualitative context of interactions than the mere quantity of social relationships. These findings imply that VAs could serve as safe outlets for externalizing internal distress and as companions that validate daily routines. Beyond these specific findings, this study highlights the value of interdisciplinary collaboration. Social gerontological perspectives facilitated the interpretation of latent distress often missed by automated sentiment analysis, while VA systems provided social gerontology with rich, longitudinal RWD. This synergy helps bridge the gap between scalable data collection and deep human understanding.

This study had several limitations that point to future research directions. First, the analysis was exploratory and based on two case studies with different observation periods. This warrants caution in terms of generalization. To enhance generalizability, future investigations should seek to corroborate these results using larger and more diverse cohorts. Second, the logs of Mei-chan were limited to utterances within the home. To capture the full picture of loneliness, a comprehensive analysis linking dialogue content with social participation outside the home is required. Additionally, incorporating multimodal data, including vocal tone and facial expression, will deepen the understanding of emotional communication with VAs (Razavi et al., 2022; Tamantini et al., 2026). Based on these insights, there is an urgent need to develop personalized dialogue functions in which the system actively addresses health anxieties or validates daily routines (Matsukawa et al., 2025). Finally, since RWD contains highly sensitive personal information, such as health status and religious practices, future system designs should incorporate rigorous ethical guidelines (Bhatt, 2024; Piñeiro-Martín et al., 2023). This includes ensuring transparent user consent protocols specifically for conversational data mining, implementing strict data anonymization at the point of data capture, and establishing clear boundaries. These guidelines need to define the boundaries of the VA's role by ensuring that the VA provides emotional validation without venturing into medical intervention (Aravind et al., 2012). Furthermore, while highly personalized interactions enhance user experience, strict boundaries should be established to prevent these engaging features from inadvertently crossing into psychological manipulation or infringing upon the user's autonomy (Pollmann et al., 2023).

COMPETING INTERESTS

The authors of this publication declare there are no competing interests.

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CORRESPONDING AUTHOR

Correspondence should be addressed to Keiko Katagiri (katagiri_k@people.kobe-u.ac.jp).

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Nahyun Kim received her B.A. degree in Baduk Studies from Myongji University, Republic of Korea, in 2016, and her M.A. degree in Sociology from Ritsumeikan University, Japan, in 2020. She is currently a doctoral student in the Graduate School of Human Development and Environment at Kobe University, Japan. Her research interests include social networks, specifically the formation of weak ties in online and offline social participation among older adults, and their effects on psychological well-being.

Akinori Matsukawa received his B.E. and M.E. degrees in Engineering from Kobe University, Japan. His research interests include the development of virtual agent systems and personalized dialogue services to reduce loneliness in older adults.

Masahide Nakamura received his B.E., M.E., and Ph.D. degrees in Information and Computer Sciences from Osaka University, Japan, in 1994, 1996, 1999, respectively. From 2007 to 2022, he worked for the Graduate School of System Informatics at Kobe University. He is currently a full professor in the Center of Mathematical and Data Science at Kobe University. His research interests include the service/cloud computing, smart home, smart city, and gerontechnology. He is a member of the IEEE, ACM, IEICE and IPSJ.

Dr. Keiko Katagiri is the Director at Advanced Research Center for Well-being of Kobe University from November 2022, and Professor at the Graduate School of Human Development and Environment of Kobe University. She received her Ph.D. in Social Psychology in 2006 from the University of Tokyo. Her research interests cover broad topics: social participation, civic engagement, social isolation, social capital, older workers, urbanization, and old family studies.