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Activity Tracking and Perceived Loneliness in People with Visual Disabilities

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Abstract

Loneliness is common among individuals with visual disabilities due to social and mobility barriers, which are further exacerbated by inaccessible traditional assessment methods. This study introduces a Kinect-based in-home gait tracking system to monitor and mitigate loneliness, grounded in James-Lange Theory and Bandura's Social Cognitive Theory. Over 14 days, 13 sighted individuals and 14 individuals with visual disabilities used the system to track their gait while accessing their gait data via the NVDA screen reader. Pre- and post-study loneliness levels were measured using the UCLA Loneliness Scale. Results from Kruskal-Wallis and post-hoc Mann-Whitney U tests revealed that participants with visual disabilities who used the Kinect reported significantly reduced loneliness compared to both sighted participants and those with visual disabilities who did not use the system. These findings highlight the Kinect system's potential as an effective intervention for monitoring and reducing loneliness, ultimately contributing to the emotional well-being of individuals with visual disabilities.

Keywords
Emotional Ergonomics, Human Factors, Self-Care, Emotional Well-Being

1. Introduction

Loneliness presents a significant public health challenge, particularly for individuals with visual disabilities who encounter distinct barriers in social engagement and independent mobility [1]. These barriers often include difficulty navigating unfamiliar environments and limited opportunities for spontaneous social interactions. Visual impairment significantly hinders an individual's ability to navigate their surroundings and engage in physical activities, which can lead to increased isolation and loneliness [2, 3]. Furthermore, conventional measures of loneliness often rely on inaccessible survey formats or require assistance from sighted individuals, making them unsuitable for self-assessment of emotional wellness among people with visual disabilities.

This study investigates the potential of in-home, technology-based interventions to mitigate loneliness in people with visual disabilities by monitoring gait patterns. The approach draws upon the well-established connection between physical activity and emotional well-being, as framed by the James-Lange theory, which posits that physical states significantly influence emotional experiences [4]. For individuals with visual disabilities, physical activity offers both psychological benefits and opportunities for enhancing their sense of independence. For instance, engaging in regular physical activities such as walking is associated with reduced levels of loneliness and improved psychological health. Prior research [5, 6] underscores this inverse relationship, highlighting that individuals who engage in frequent walking or other forms of physical activity report lower levels of loneliness. However, much of the existing literature focuses on sighted populations, with limited attention paid to how physical activity might affect emotional well-being in individuals with visual disabilities. Existing research also seldom explores how such interventions can be tailored to accommodate the specific needs of this visual disability group, leaving a critical gap in both practical and theoretical understanding. To address this gap, this study introduces a novel system that facilitates in-home self-monitoring of emotional states—specifically loneliness—through the analysis of gait patterns. By tailoring the system to the needs of individuals with visual disabilities, this study not only extends the application of physical activity research but also explores the feasibility of creating accessible solutions to promote emotional wellness in this population.

Grounded in Bandura's Social Cognitive Theory [7], which emphasizes the critical role of self-regulation through self-monitoring, judgment, and subsequent behavioral response, this study examines the extent to which enhanced self-awareness of physical activity contributes to emotional well-being. Self-regulation is pivotal for fostering autonomy and self-efficacy, particularly for individuals who face barriers to independent living, as is often the case with visual disabilities. By continuously monitoring gait parameters, such as walking speed, the proposed system encourages users to reflect on their physical state, providing actionable insights that could enhance their psychological well-being. For instance, monitoring walking speed might help users identify patterns associated with low energy levels or emotional distress, prompting them to take proactive measures. This study posits that heightened self-awareness of one's physical activity could lead to greater self-efficacy, ultimately improving emotional states such as loneliness. Additionally, continuous tracking of gait parameters not only aids in fostering a sense of control and independence but also serves as an accessible feedback mechanism that may empower individuals with visual disabilities to manage their emotional and physical health more effectively. The proposed approach uniquely integrates self-monitoring technology with principles of psychological theories, creating a holistic framework that simultaneously addresses physical and emotional dimensions of health. The integration of these theoretical principles into a practical, technology-based system holds potential to address significant psychosocial challenges faced by this underserved population.

Recent advances in technology, such as Microsoft Kinect motion-sensing devices, offer promising applications in healthcare [8, 9]. For instance, Kinect's capability to track human movement without requiring visual interaction supports the development of accessible interventions for individuals with visual disabilities. This study investigates the degree to which a Kinect-based walking tracking tool can shape loneliness levels in individuals with visual disabilities compared to sighted individuals. The proposed system is designed to promote self-regulation by enabling users to monitor gait parameters and gain insight into their physical and emotional health. Through Kinect's data on walking speed, made accessible with screen readers, individuals with visual disabilities can monitor their physical state, fostering self-judgment and self-efficacy. Although prior research [10] has explored Kinect's efficacy in gait analysis, its impact on psychosocial factors such as loneliness, particularly among individuals with visual disabilities, remains insufficiently examined.

This study aims to bridge this knowledge gap by investigating whether a Kinect-based walking tracking tool can influence perceived loneliness in both visually impaired and sighted individuals. This study contributes to the growing field of technology-based interventions for enhancing the quality of life in individuals with visual disabilities. The findings will ultimately inform the design of accessible, home-based tools to address emotional challenges and foster self-care, with broader relevance for rehabilitation and monitoring systems.

2. Methodology

2.1. Participants

The study included a convenience sample of 27 participants (14 individuals with visual disabilities and 13 sighted counterparts) across North Carolina, USA. For those with visual disabilities, the visual acuity levels should be worse than 20/70 with the best possible correction, as defined by the World Health Organization [11]. Table 1 contains detailed characteristics of all participants.

Table 1: Characteristics of the participants

Group	Participants with visual disabilities (n = 14)	Sighted participants (n = 13)
Users with the proposed system	6	7
Users without the proposed system	8	6
Vision		
Visual Disabilities (visual acuity equal to or worse than 20/70)	14	0
Sighted Vision (visual acuity better than 20/70)	0	13
Living with vision loss (year)	16.00 ± 16.76	0
Onset age of vision loss (year)	42.00 ± 19.33	0
Age (year)	60.21 ± 15.90	31.33 ± 7.07
Male	13	29
Female	28	9
Race and ethnicity		
American Indian or Alaska Native	1	0
Asian	0	2
Black or African American	12	10
White	1	1

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Education		
K-12 education (or equivalent)	10	1
Certificate or training program	2	0
Associate	1	0
Bachelor's degree	1	2
Master's degree	0	8
Doctoral degree	0	2

2.2. Materials

This study used a Kinect device, a motion sensing input device manufactured by Microsoft. The Kinect incorporates RGB cameras, infrared projectors, and detectors that employ structured light or time-of-flight calculations to determine the location and distance of objects or individuals in the environment. These technologies enable real-time gesture recognition and body skeletal detection. The Kinect was programmed to track human gait characteristics, such as walking speed variability. The program's core function involved collecting raw three-dimensional coordinates of the human body's center of mass (COM). By using the COM as a reference point, the device could capture body measurements even when participants were partially obstructed by household objects (e.g., couches, TV sets, or desks). This method allowed the Kinect sensors to continuously monitor and calculate participants' walking speed, as the COM is typically located in the upper body of a human, which is positioned above the height of most household items.

Participants had access to the system dashboard, where they could review their walking speed data via Non-Visual Desktop Access (NVDA), a screen reader software, until their participation session concluded. To address privacy concerns, the system was designed not to store any data. The research team ensured that all data from the Kinect device were completely deleted after each participant completed their session.

Loneliness was measured using the UCLA Loneliness Scale (short version) [12], which includes three items assessing subjective feelings of loneliness. This scale is widely used in research to measure individuals' perceived lack of social relationships and levels of personal loneliness. It assesses emotional and social loneliness, which are key indicators of psychological well-being. The short version provides a quick and reliable method of evaluating loneliness in various settings.

2.3. Procedures

The Kinect device was installed in participants' homes. To address privacy concerns, the living room was selected as the installation location, rather than more personal areas such as bedrooms. To further protect their privacy, participants were given the option to turn the device on and off at their discretion. The study duration was set at 14 days, with some flexibility (± a few days) to accommodate external factors, such as participants' availability and the research team's logistical constraints. Participants were recruited from across North Carolina, including areas distant from the research team's home institution, requiring long-distance travel. At the conclusion of the study period, the research team revisited participants' home to retrieve the device. Before and after the study period, participants completed the UCLA Loneliness Scale. To ensure comprehension and address potential challenges related to literacy or visual disabilities, the research team verbally administered the questionnaires, reading each item aloud to the participants.

3. Results

The Kruskal-Wallis test found a significant difference in perceived loneliness among participants based on both vision status and Kinect usage (see Table 2).

Table 2: Kruskal-Wallis test

Group	Vision status	Before study	After study
Kinect Users	Sighted	5.14 ± 1.345	4.86 ± 1.574
	Visual Disability	4.33 ± 1.751	3.33 ± 0.816
Non-Users	Sighted	5.00 ± 0.894	5.50 ± 0.837
	Visual Disability	5.75 ± 1.982	6.38 ± 1.847
Kruskal-Wallis Test within each study period		H(3) = 2.39, $p = 0.49$	H(3) = 10.98, $p = 0.01$*

Note. The symbol * indicates statistical significance at $\alpha = 0.05$ level.

The post-hoc assessment using Mann-Whitney U tests revealed significant differences (see Table 3). Among participants who used the Kinect system – *both sighted participants and participants with visual disabilities* – those with visual disabilities reported a significantly lower level of perceived loneliness compared to their sighted counterparts. In addition, among participants with visual disabilities, those who used the Kinect system showed a significantly lower level of perceived loneliness compared to their counterparts who did not use the Kinect system.

Table 3: Post-hoc assessment via Mann-Whitney U test

		Kinect Users		Non-Users	
Group	**Vision Status**	**Sighted**	**Visual Disability**	**Sighted**	**Visual Disability**
Kinect Users	**Sighted**	-	U = 8.5, z = -1.948, $p = 0.05$*	U = 16.00, z = -0.755, $p = 0.45$	U = 15.50, z = -1.466, $p = 0.143$
	Visual Disability	-	-	U = 1.5, z = -2.798, $p = 0.005$*	U = 2.50, z = -2.798, $p = 0.004$*
Non-Users	**Sighted**	-	-	-	U = 19.00, z = -0.662, $p = 0.508$
	Visual Disability	-	-	-	-

Note. The symbol * indicates statistical significance at $\alpha = 0.05$ level.

4. Discussion

4.1. Participants with Visual Disabilities

Among participants who used the Kinect system, participants with visual disabilities reported a significantly lower level of perceived loneliness compared to sighted participants. This finding suggests that the Kinect system is more likely to be beneficial for individuals with visual disabilities than for their sighted counterparts. Furthermore, within the group of participants with visual disabilities, those who used the Kinect system reported a significantly lower level of perceived loneliness compared to those who did not use it. These results indicate that the Kinect system is an effective intervention for reducing loneliness in individuals with visual disabilities. This observation aligns with previous studies highlighting the willingness of individuals with visual disabilities to adopt technology for health and well-being. Miller and Jerome [13] observed that most participants with visual disabilities (17 out of 18, 94%) were willing to adopt and use mobile apps, electronic notes, smartphones, and wearable devices to track their physical activity levels daily. Lee, et al. [14] surveyed 156 people with visual disabilities to assess their perceptions of tracking personal health using technology. A significant number of participants used smartphone apps (n = 90, 68%), wearable devices (n = 68, 52%), computer programs (n = 32, 24%), and web-based tools (n =11, 8.3%). They tracked physical activity metrics, such as exercise (n = 115, 87%), weight (n = 101, 76%), sleep (n = 63, 47%), and heart rate (n = 61, 46%). They also expressed interest in tracking psychological well-being metrics, such as stress (n = 36, 27%) and mood (n = 29, 22%), though they had not yet done so. This suggests a strong desire among people with visual disabilities to track their psychological health. Prior research suggests that using a health self-tracking app, particularly one designed for mood tracking, can help people manage their emotions by increasing self-awareness of their emotional states and patterns, enabling them to identify triggers and develop coping mechanisms, potentially leading to improved emotional well-being [15]. As our Kinect-based study demonstrates an interrelationship between physical activity and psychological well-being, the Kinect system has the potential to evolve to track both individuals' physical activities and their associated emotional well-being, which is likely to be adopted by individuals with visual disabilities. Future research could investigate reasons for the differences in adoption and usability of the Kinect system across various user groups, such as sighted individuals, individuals with residual vision, and those with severe vision loss. Identifying these differences could help optimize the system for a broader range of users and enhance its overall effectiveness.

4.2. Sighted Participants using the System versus not using

We found no significant difference in perceived loneliness among sighted participants who used the Kinect system and those who did not. Sighted participants were able to freely walk around the community and interact with others. As a result, their perceived loneliness may have been relatively lower and less influenced by the Kinect system. Prior research has similarly reported that sighted individuals experience a lower degree of loneliness compared to individuals with visual disabilities. For example, Brunes, et al. [16] assessed perceived loneliness among sighted individuals and their peers with visual disabilities living in Norway. They discovered that sighted individuals reported significantly lower levels of loneliness than their peers with visual disabilities. They argued that the higher levels of loneliness among those with visual disabilities could be attributed to factors such as increased risk of disability, poor health, low income, and difficulties in interpersonal interactions. Furthermore, it is well documented that people with visual disabilities often perceive their visual disabilities as the root cause of negative emotions, including loneliness [17]. Therefore, the Kinect system may have had a greater impact on participants with visual disabilities compared to sighted counterparts.

4.3. Study Limitations

This study has a few limitations that should be acknowledged. First, privacy concerns were raised by participants with regard to the Kinect sensor camera, as they worried that the camera might capture personal details. To address this concern and protect privacy, the Kinect device was installed exclusively in the living room. As a result, gait patterns from other areas of participants' residences were not captured, which may have limited the comprehensiveness of the gait analysis. Participants could have exhibited different walking behaviors in various settings. Second, loneliness was assessed through self-reported measures. It is possible that participants were not entirely forthcoming in reporting their perceived levels of loneliness, which could introduce response bias and affect the accuracy of the data collected.

Despite these limitations, this study provides valuable insights into the relationship between gait patterns and loneliness. Future research could build on these findings by using non-intrusive methods to capture a broader range of physical movements or by integrating more objective measures of loneliness to enhance data reliability. Nonetheless, the present study contributes to understanding the application of motion-sensing technologies in psychological assessment, highlighting the potential of Kinect-based analysis to identify behavioral indicators in everyday settings.

5. Conclusions

This study examined the effectiveness of an in-home Kinect-based gait-tracking system in mitigating loneliness among individuals with visual disabilities. The findings indicate that participants with visual disabilities who used the Kinect system reported significantly lower levels of perceived loneliness compared to their sighted counterparts, as well as compared to participants with visual disabilities who did not use the system. This outcome underscores the potential for technology-powered, in-home interventions to address emotional challenges faced by individuals with visual disabilities. This research contributes to the growing body of evidence supporting the use of technology to empower individuals with disabilities, enhance self-care, and improve quality of life.

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