Measuring Engagement in Provider-guided Digital Health Interventions: Development of a Conceptual and Analytical Framework Using Nurse WRITE as an Exemplar

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Abstract

Background: Limited guidance exists for analyzing participant engagement in provider-guided digital health interventions (DHIs). System usage is commonly used, with acknowledged limitations in measuring socio-affective and cognitive aspects of engagement. Nurse WRITE, an online nurse-guided DHI for managing symptoms among women with recurrent ovarian cancer, offers an opportunity to develop a framework for assessing multi-dimensional engagement.

Objective: This study aims to develop a conceptual and analytic framework to measure socio-affective, cognitive, and behavioral engagement with provider-guided DHIs. We then illustrate the framework's ability to describe and categorize engagement using Nurse WRITE as an example.

Methods: A sample of 68 participants from Nurse WRITE who posted on the message boards were included. We adapted a prior framework for conceptualizing and operationalizing engagement across three dimensions and finalized a set of six distinct measures. Utilizing patients' posts, we created two socio-affective engagement measures—total count of socio-affective engagement classes (e.g., sharing personal experience) and total word count—and two cognitive engagement measures—total count of cognitive engagement classes (e.g., asking information-seeking questions) and average response rate. Additionally, we devised behavioral engagement measures using website data—the total count of symptom care plans and plan reviews. K-means clustering categorized the participants into distinct groups based on levels of engagement across three dimensions. Descriptive statistics and narratives were used to describe engagement in three dimensions.

Results: On average, participants displayed socio-affective engagement 34.7 times, writing 14,851 words. They showed cognitive engagement 19.4 times with a 78.3% response rate to nurses' inquiries. Participants also submitted an average of 1.6 symptom care plans and 0.7 plan reviews. Participants were clustered into high (n = 13), moderate (n = 17), and low engagers (n = 38) based on the six measures. High-engagers wrote a median of 36,956 words. They demonstrated socio-affective engagement approximately 81 times and cognitive engagement around 46 times, approximately six times that of the low engagers and twice that of the moderate engagers. High engagers had a median 91.74% response rate to the nurses' queries, whereas moderate engagers had 86.36%, and low engagers had 68.32%. High engagers completed a median of three symptom care plans and two reviews, while moderate engagers completed two plans and one review. Low-engagers completed a median of one plan and no reviews.

Conclusions: This study developed and reported an engagement framework to guide behavioral intervention scientists to understand and analyze participants' engagement with provider-guided DHIs. Significant variations in engagement levels across three dimensions highlight the importance of measuring engagement with provider-guided DHIs in socio-affective, cognitive,

and behavioral dimensions. Future studies should validate the framework with other DHIs, explore the influence of patient and provider factors on engagement, and investigate how engagement influences intervention efficacy.

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Results: On average, participants displayed socio-affective engagement 34.7 times, writing 14,851 words. They showed cognitive engagement 19.4 times with a 78.3% response rate to nurses' inquiries. Participants also submitted an average of 1.6 symptom care plans and 0.7 plan reviews. Participants were clustered into high (n = 13), moderate (n = 17), and low engagers (n = 38) based on the six measures. High engagers wrote a median of 36,956 words. They demonstrated socio-affective engagement approximately 81 times and cognitive engagement around 46 times, approximately six times that of the low engagers and twice that of moderate engagers. High engagers had a median 91.74% response rate to the nurses' queries, whereas moderate engagers had 86.36%, and low engagers had 68.32%. High engagers completed a median of three symptom care plans and two reviews, while moderate engagers completed two plans and one review. Low engagers completed a median of one plan and no reviews.

Conclusions:

This study developed and reported an engagement framework to guide behavioral intervention scientists to understand and analyze participants' engagement with provider-guided DHIs. Significant variations in engagement levels across three dimensions highlight the importance of measuring engagement with provider-guided DHIs in socio-affective, cognitive, and behavioral dimensions. Future studies should validate the framework with other DHIs, explore the influence of patient and provider factors on engagement, and investigate how engagement influences intervention efficacy.

Keywords: Engagement; Digital health intervention; Symptom management; eHealth; mHealth; Gynecological cancer

Introduction

Active participant engagement is pivotal to maximizing intervention benefits and enhancing health outcomes [1]. Therefore, measuring and evaluating engagement levels is essential for valid conclusions about intervention efficacy. In recent decades, digital technologies, including mHealth and eHealth, have been extensively integrated into interventions targeting symptom management [2,3] and behavior change promotion [4-6]. Studies indicate that cancer survivors' use of technology and engagement with digital health interventions (DHIs) tends to decline over time [7,8], possibly due to participant intervention fatigue, cognitive overload, habituation to frequent contact, and negative emotions [9]. While human support is often considered a potential remedy for this issue in provider-guided DHIs [10], previous research has not adequately accounted for the complexity of patient engagement with provider-guided DHIs.

Additionally, prior studies heavily relied on assessing engagement through system usage patterns, such as website visits, app usage, or posting frequency [11-19], which has been criticized in recent systematic reviews [20]. Research indicates that solely measuring system usage does not guarantee that participants are receiving the intended dosage of an intervention or that their interactions with the intervention are meaningful and effective, despite its common use as an engagement marker [21,22]. Attempts have been made to gauge participants' cognitive and affective engagement through subjective measures such as self-report questionnaires, ecological momentary assessments (EMAs), and qualitative methods like interviews and think-aloud activities conducted during or after the intervention. However, these measures have notable limitations. Exit interviews, for instance, fail to capture participants' real-time experiences during the intervention and may be compromised by recall bias. This issue was highlighted in a previous study on cancer survivors' engagement with an app where participants struggled to recall app functions or usage details [23]. Complementing this line of research, many researchers emphasized the importance of employing multiple methods and integrating diverse datasets that encompass cognitive and socio-affective engagement alongside usage data to unravel the complexities inherent in the concept and measurement of engagement [20, 24]. Building on these studies, we sought to develop a comprehensive conceptual and analytic framework to describe and assess patient engagement with a provider-guided DHI based on a more conceptual understanding of dimensions of engagement, including socio-affectivity [25], cognition [25] and behavior.

The WRITE Symptoms Study (NRG Oncology's GOG-259; NR010735) was a three-arm online intervention designed for women with recurrent cancer [26]. The Nurse WRITE intervention arm was a nurse-guided DHI conducted on online asynchronous message boards. A study nurse guided participants using the Representational Approach to patient education [27, 28], which encompasses seven key elements, including representational assessment; identifying and exploring gaps, errors, and confusions; creating conditions for conceptual change; introducing replacement information; summary; goal setting and planning; and goal and strategy review and revision. This disease-agnostic approach thoroughly assesses participants' symptom beliefs before offering personalized symptom management recommendations and individualized problem-solving support. Nurse WRITE demonstrated efficacy in improving symptom control compared to enhanced usual care. However, there was a notable high variation in patient completion of the intervention. Importantly, all interactions between the nurses and participants are documented verbatim on the message board, providing an excellent opportunity to examine the complexity of the engagement.

In a previous study, we constructed the "MedNgage Dataset" [25] that covers coded cognitive and socio-affective engagement from the library of nurse-participant posts on asynchronous message boards in Nurse WRITE. Drawing from the social presence model [29], cognitive science of grounding in communication [30], and linguistic discourse theories [31], we collaborated with linguists and used iterative coding to develop the socio-affective and cognitive engagement (SACe) conceptual framework to capture these dimensions of engagement. We then applied the SACe framework to identify linguistic signals and categorize engagement within patient-nurse communication on Nurse WRITE's asynchronous message boards. This analysis revealed eight different socio-affective engagement classes (e.g., expressing positive sentiment, sharing cancer-related experiences, showing interest in continued communication) – behaviors representing participants' efforts to build emotional connections with nurses. Additionally,, we identified seven cognitive engagement classes (e.g., answering intervention questions, agreeing with the nurse' suggestions, asking information-seeking questions) – behaviors that reflected participants' collaborative content and process coordination with nurses through written communication during the intervention [25].

Expanding on this foundation, the current study has two primary objectives. First, it aims to finalize a conceptual and analytic framework, building on the SACe, that quantifies engagement levels with provider-guided DHIs across socio-affective, cognitive, and behavioral dimensions. Secondly, it applies the framework to measure and categorize patients' engagement patterns with the Nurse Write intervention as an exemplar. This provides guidance and insights for future evaluations of engagement in provider-guided DHIs.

Methods

Overview

This study was an ancillary analysis of 68 patients with recurrent ovarian cancer from the Nurse WRITE arm of the WRITE Symptoms Study. The study included data from patients' asynchronous message boards and the website.

Setting and Sample

The parent trial enrolled 497 women with recurrent ovarian cancer from various GOG/NRG Oncology-affiliated sites [26]. The study received institutional review board approval from the University of Pittsburgh and each participating clinical site. To be eligible for the parent study, participants had to be 18 years or older, diagnosed with recurrent or persistent ovarian, fallopian, or primary peritoneal cancer, and possess a Gynecologic Oncology Group (GOG) performance status of less than 3, indicating that they are ambulatory and capable of self-care but unable to perform work activities, with more than 50% of waking hours spent up and about [32, 33]. Additionally, they were required to experience at least three symptoms associated with cancer or its treatment (e.g., pain, fatigue, neuropathy), and be able to read and write in English. Details of the study design, protocol for Nurse WRITE (intervention group), and results have been described elsewhere [26]. Among the 166 participants randomized to Nurse WRITE, 141 women met the study criteria and posted at least once on the message board. For this study, we selected a convenience sample of the first 68 participants randomized to Nurse WRITE, representing 50% of total message board posts.

Asynchronous message boards

Nurse WRITE was delivered by nurses highly trained to the protocol and delivered the intervention with high fidelity, offering information and support tailored to each participant's needs [34]. Through open-ended prompts and protocolized questions, participants engaged in dynamic interactions with nurse interventionists on a private asynchronous message board, including expressing symptom perceptions, reflecting, discussing coping efforts, and collaborating with nurses in developing personalized symptom care plans for three participant-identified target symptoms during the 8-week intervention period. To create a care plan, participants needed to go through six out of seven key intervention elements, and the last key element was to review and revise the care plan after two weeks. Then, participants were instructed to try the revised plan and review the results following the same approach until they felt comfortable with it.

Data collection

Participant Data

Patient demographic characteristics were assessed with the Center for Research in Chronic Disorders Socio-Demographic Survey [35] for age, education, race, marital status, and employment.

Engagement measures

Figure 1 illustrates how engagement is conceptualized and operationalized in socio-affective, cognitive, and behavioral dimensions. The diagram progresses from left to right, beginning with conceptualizing engagement into three dimensions, each with its accompanying definition. Subsequently, socio-affective engagement is operationalized into eight distinct classes of behaviors; then, cognitive engagement is similarly operationalized into seven classes, each with a corresponding description. Behavioral engagement is measured by two intervention milestones: symptom care plan creation and review. This process culminated in the development of six measures to assess engagement within these three dimensions quantitatively.

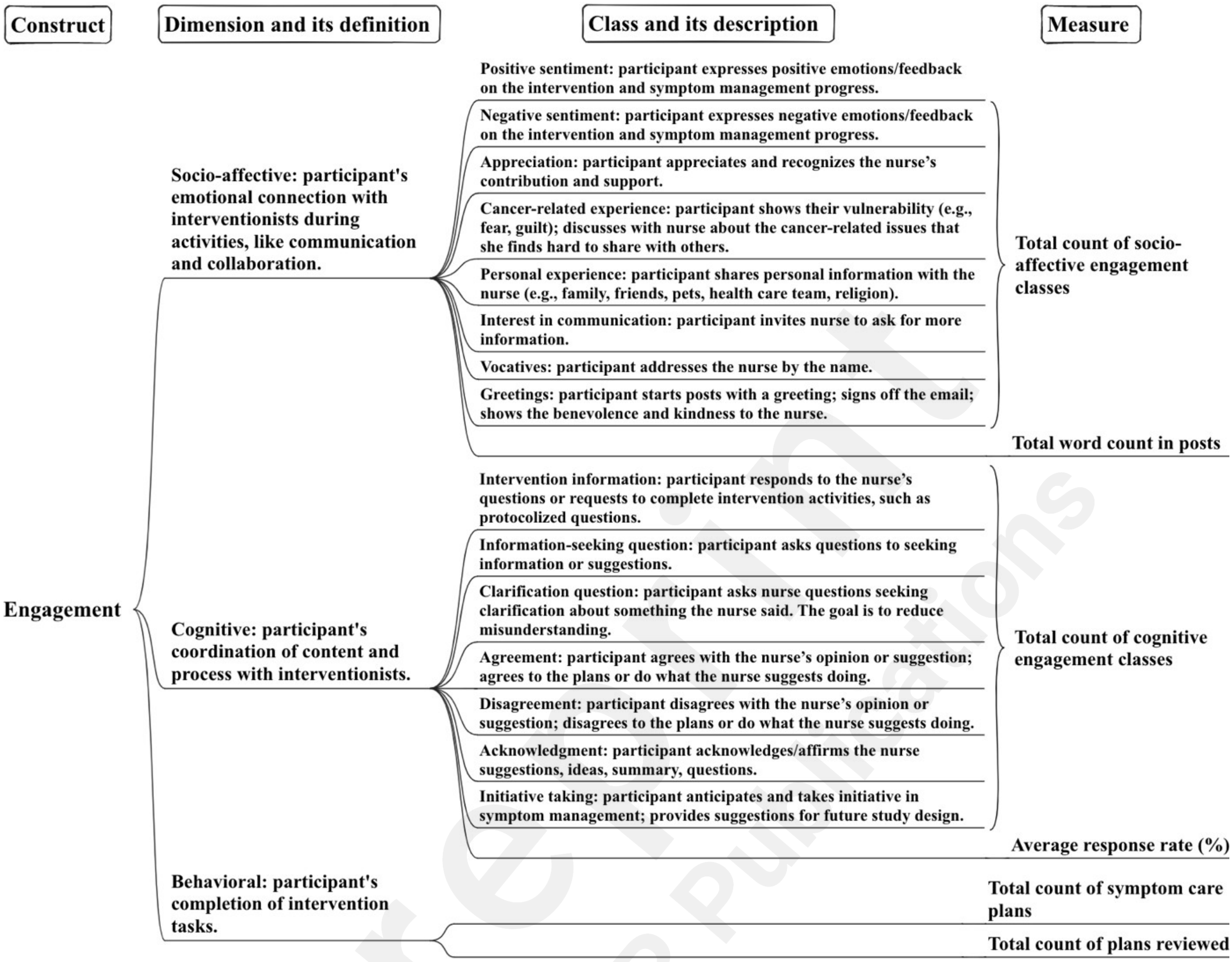

Figure 1. Conceptualizing and operationalizing engagement with provider-guided DHIs across socio-affective, cognitive, and behavioral dimensions.

Socio-affective dimension

In our prior study [25], we identified eight classes of behaviors in the socio-affective dimension, representing participants' emotional connection efforts with the nurse. To quantify engagement in this dimension, we developed two measures. First, the total count of socio-affective engagement classes was computed by summing the number of instances of each class. Further descriptions of socio-affective engagement classes in participant posts can be found in Figure 1. Additionally, the total word count served as a proxy for overall participant effort in communication with nurses [36], constituting the second socio-affective engagement measure.

Cognitive dimension

In our prior study [25], we also identified seven classes in the cognitive dimension, demonstrating participants' efforts in coordinating intervention content and process with nurses. Engagement was quantified by summing the number of instances of each class, yielding the first cognitive measure: the total count of cognitive engagement classes. Full descriptions of each cognitive engagement class can be found in Figure 1. To obtain the second cognitive engagement measure, in this study, two trained raters independently analyzed the patients' posts to determine the response rate—reflecting cognitive engagement—by calculating the percentage of nurses' questions and requests addressed by each participant on message boards. Inter-rater reliability of the average response rate, assessed on

178 posts, yielded a Cohen Kappa score of 0.84.

Behavioral dimension

Website data was extracted to determine behavioral engagement measures: total count of symptom care plans and total count of care plan reviews and revisions.

Analysis

After we quantified participants' engagement with Nurse WRITE using the six measures across socio-affective, cognitive, and behavioral dimensions, we used k-means clustering to categorize participants into distinctive groups based on these six measures. K-means clustering is an unsupervised machine learning algorithm that aims to group data based on feature similarity, with the number of groups represented by K [37].

Results

Sample characteristics

The majority of the 68 participants included in this analysis were white (92.7%), married/cohabitating (75%), middle-aged (mean= 59.7, SD = 9.5, range= 24-83), and had a bachelor's degree (median = 16, IQR = 4, range = 11-22 years of formal education). More than half of the participants were not working (54.4%), including individuals who were disabled/unable to work, retired, and unemployed. On average, participants reported moderate symptom severity (5.33 out of 10) and symptom distress (2.16 out of 4). Over half of the sample (55.6%) had at least one comorbidity.

Engagement Measures

On average, participants exhibited socio-affective engagement classes of behaviors, such as expressing positive sentiment and appreciation, 34.7 times (SD = 28.8). The participants also contributed substantially to the message boards, with an average word count of 14,851 (SD = 14,064). Participants demonstrated dimensions of cognitive engagement behaviors such as answering protocolized questions, seeking information through inquiries, and agreeing with the nurse's opinions, on average, 19.4 times (SD = 16.3). Furthermore, they maintained an average response rate of 78.3% (SD = 14.9 %) when addressing nurses' questions or fulfilling intervention tasks. Regarding behavioral engagement, on average, participants completed 1.6 symptom care plans (SD = 0.2) and 0.7 plan reviews (SD = 0.9). Table 1 includes the mean, standard deviation, median, and interquartile range (IQR) for the six measures of engagement across three dimensions.

Table 1. Patients' engagement in socio-affective, cognitive, and behavioral dimensions (n =68)

Dimension	Measures	Mean (SD)	Median (IQR)
Socio-affective	Total count of socio-affective engagement classes	34.7 (28.8)	27 (32.8)
	Total word count	14,851 (14,064)	9,226 (13,766)
Cognitive	Total count of cognitive engagement classes	19.4(16.3)	14.5 (22)
	Average response rate (%)	78.3 (14.9)	78.1 (26)
Behavioral	Total count of symptom care plans	1.6 (1.2)	1 (2)
	Total count of plan reviews	0.7 (0.9)	0 (1)

Abbreviations: SD = standard deviation, IQR = interquartile range.

Engagement patterns

K-means clustering analysis revealed the formation of three main groups characterized by their level of engagement in the three dimensions (i.e., total count of socio-affective engagement classes, total word count, total count of cognitive engagement classes, response rate, total count of symptom care plans and care plan reviews completed). Given the non-normal distribution of each engagement measure, we used the median and IQR to describe the engagement levels within each main group. Table 2 presents the median and IQR values for measures in the three engagement dimensions across each main group.

Table 2. Median and IQR of six engagement measures across three dimensions for high, moderate, and low engagers.

Group	Total count of socio-affective classes	Total word count	Total count of cognitive classes	Average response rate (%)	Total count of symptom care plans	Total count of plan reviews
N	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)
High engagers (n = 13)	81 (19)	36,956 (20,066)	46 (12)	91.74 (11.6)	3 (0)	2 (1)
Moderate engagers (n = 17)	39 (11)	18,034 (5,787)	25 (8)	86.36 (16.4)	2 (1)	1 (0)
Low engagers (n = 38)	13.5 (16)	6315.5 (4,722)	7.5 (8.3)	68.32 (19.5)	1 (1)	0 (0)

Abbreviations: Mdn = median, IQR = interquartile range.

There were 13 high engagers, 17 moderate engagers, and 38 low engagers. Regarding socio-affective engagement classes and the total word count, high engagers showed approximately six times higher engagement than low engagers and twice that of moderate engagers. More specifically, high engagers established rapport by addressing nurses by name, expressing sincere appreciation, sharing personal experiences, displaying vulnerability, and expressing positive emotions towards the intervention, resulting in a high median total count of socio-affective engagement behaviors of 81 times (IQR = 19). One patient wrote, “It was the first time I actually felt normal. When going to the doc --these symptoms have never even come up. I felt like I belonged! And really wasn't off my rocker.” This newfound perspective motivated her to pursue improved symptom management actively. In contrast, moderate (Mdn = 39, IQR = 11) and low engagers (Mdn = 13.5, IQR = 16) showed less interest in building personal connections with the nurse. Regarding the total word count, highly engaged participants wrote a median of 36,956 words (IQR = 20,066) to their nurse, compared to moderate engagers (Mdn = 18,034, IQR = 5,787) and low engagers (Mdn = 6,315.5, IQR = 4,722).

Cognitively, high engagers actively participated and demonstrated a strong commitment to learning symptom management techniques. They more consistently responded to nurses' questions and requests (Mdn = 91.7%, IQR = 11.6%) compared to moderate engagers (Mdn = 86.4%, IQR = 16.4%) and low engagers (Mdn = 68.3%, IQR = 19.5%); sought information, acknowledged nurses' posts, agreed with suggestions, showing a median frequency of cognitive engagement behaviors of 46 (IQR = 12), which is 6.1 times more often than low engagers and 1.8 times that of moderate engagers. Some high engagers even independently initiated second and third symptom care plans, sharing effective strategies and leading the intervention without prompts from the nurse. For example, one participant shared with the nurse the significance of prayer (which was not formally integrated as a strategy within the intervention), emphasizing its role in symptom management and coping with cancer. Compared to high engagers, the moderate engagers primarily focused on answering part of the intervention protocolized questions and agreeing with the nurse without gaining the confidence to lead themselves through the intervention.

Regarding behavioral engagement, high engagers completed a median of three symptom care plans and two revisions. Some of them exceeded intervention targets by working on the fourth or fifth symptoms. In contrast, moderate engagers completed a median of two symptom care plans and one review, whereas low engagers only completed a median of one symptom care plan and no reviews.

Discussion

Principal Results

Significant variations existed among engagers in socio-affective, cognitive, and behavioral dimensions, providing insights into how a provider-guided DHI operates. High engagers demonstrated approximately sixfold higher total word counts and socio-affective and cognitive engagement behaviors than low engagers and twice as much as moderate engagers. A positive feedback loop may exist between participant engagement and behavior change and symptom management [1, 38, 39]. Enhanced emotional connections with nurses and increased written communication (socio-affective engagement) appear to contribute to a deeper understanding of intervention content and improved problem-solving skills (cognitive engagement). This synergy of socio-affective and cognitive engagement streamlines the development of highly personalized symptom management care plans (behavioral engagement) and the implementation of various strategies to adopt healthy behaviors and manage symptoms. Consequently, these factors motivate participants to engage further with the nurse and the intervention, as the literature suggests [38]. Prior reviews also underscored the significance of connecting engagement with a DHI to desired behavior change [1,20]. Using a combination of measures, we have taken the first steps in measuring this meaningful engagement within a provider-guided DHI. However, further research is warranted to investigate and validate the relationship between engagement across these three dimensions and patient symptom outcomes, including patient-perceived symptom control.

The observed variations in participants’ word counts may be related to the Nurse WRITE intervention's writing-intensive nature and differences in education levels among the groups. Limited computer literacy and busy work schedules may also have constrained participants’ ability and available time for message board contributions, aligning with prior research showing that education level, computer literacy, and employment can influence participants’ engagement with DHIs [38, 40]. While significant differences in participants’ average response rates were found among high, moderate, and low engagers, these differences were not as substantial as observed in other cognitive and socio-affective engagement measures. This is likely because some low and moderate engagers answered all the questions in their posts but logged on to the message board less frequently (and therefore had fewer posts), which artificially inflated their average response rate.

Regarding behavioral engagement, variations in the number of plans and plan reviews may be related to participants' perception of symptom severity and burden. Those who perceive more severe symptoms may be more likely to seek assistance from nurse interventionists to manage symptoms. In contrast, those who perceive milder symptoms may have prioritized work and family responsibilities or considered the intervention unnecessary. Further research is necessary to investigate and validate the impact of patient factors such as education, employment, and symptom perception on engagement levels.

Applying the DHI engagement framework to Nurse WRITE also provided valuable insights regarding the optimal duration and timing of provider-guided DHI for symptom management among highly disease-burdened individuals. Although the intervention aimed to address three target symptoms, 50% of high engagers couldn't complete the intervention goal (three “target” care plan reviews), indicating a need for a more extended intervention period. Moderate and low engagers took longer to respond than high engagers, suggesting their potential to achieve the intervention goals with more time. These findings resonate with prior research on web-based distress management programs for cardiovascular patients, emphasizing the importance of investigating intervention duration and timing [41]. Our findings suggest that future digital symptom management interventions for advanced cancer patients should extend beyond eight weeks to ensure maximum benefit.

Limitations

This study adopted an exploratory, iterative approach to assessing patient engagement patterns owing to the limited sample size of 68 participants. Qualitative analysis unveiled subtleties in engagement patterns that extend beyond the three main groups identified by K-means clustering. Certain participants exhibited high levels of socio-affective engagement but demonstrated lower to moderate levels of cognitive engagement. Their emphasis leaned towards expressing emotions rather than active involvement with the intervention content aimed at care plan development, albeit such occurrences were infrequent. Future investigations with larger sample sizes are imperative to elucidate and build upon these findings comprehensively.

Comparison with Prior Work

Compared to traditional measures of cognitive and socio-affective engagement dimensions, such as exit interview interventions [23] or the number of postings [19], our engagement framework offers a more nuanced perspective. Socio-affective and cognitive engagement classes of behaviors provide real-time insights into participants' focus, interests, emotions, and actions on message boards, allowing us to quantify the intrinsic aspects of two-way communication. These measures, along with the other socio-affective (total word count) and cognitive (average response rate), guide behavioral intervention scientists in assessing participants' efforts and the outcomes of two-way interactions in a complex provider-guided DHI.

Expanding on this research direction, it's crucial to advance tools (e.g., built upon MedNgage models [25]) to efficiently capture various engagement metrics in near real-time and provide suggestions for intervention tailoring. This advancement targets the reduction of labor-intensive retrospective qualitative analysis and addresses methodological challenges outlined in the recent review [20]. One potential strategy is to incorporate a large language model (like ChatGPT or locally accessible alternatives) into the analysis of qualitative transcripts while taking measures to ensure patient data confidentiality. Such an approach could include summarizing patient-provider conversations and leveraging the outputs of MedNgage models [25] to produce detailed, easily comprehensible qualitative reports for nurse interventionists.

Conclusions

Expanding upon prior research, we have developed a comprehensive framework for behavioral intervention scientists to analyze patient engagement in provider-guided DHIs. Employing this framework on Nurse WRITE—a provider-guided DHI—we classified participants as high, moderate, and low engagers across the three dimensions of engagement (socio-affective, cognitive, and behavioral). This provides insights into the operational intricacies of a successful provider-guided DHI across various levels of participant engagement. Further research is essential to validate this framework with other provider-guided DHIs, explore the impact of patient factors (e.g., education, employment, and symptom perception) on engagement, and assess how engagement influences the efficacy of the intervention. In the context of DHIs for symptom management among advanced cancer survivors, extending the intervention period beyond eight weeks should be considered so that participants have more opportunities to engage and obtain the full benefits of the intervention.

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Conflicts of Interest

The authors have no conflict of interest to disclose.

Abbreviations

DHI: digital health intervention
RCT: randomized controlled trial
IQR: interquartile range
Mdn: median

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