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Abdullah Wahbeh

Tyler Howes

Omar El-Gayar

Raed Seetan

Mohammad A. Al-Ramahi

See next page for additional authors

Authors

Abdullah Wahbeh, Tyler Howes, Omar El-Gayar, Raed Seetan, Mohammad A. Al-Ramahi, and Ahmed Al-Omari

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Abdullah Wahbeh
Slippery Rock University of Pennsylvania, abdullah.wahbeh@sru.edu

Tyler Howes
Slippery Rock University of Pennsylvania, twh1009@sru.edu

Omar El-Gayar
Dakota State University, omar.el-gayar@dsu.edu

Raed Seetan
Slippery Rock University of Pennsylvania, raed.seetan@sru.edu

Mohammad Al-Ramahi
Texas A&M University - San Antonio, mohammad.abdel@tamusa.edu

See next page for additional authors

Presenter Information
Abdullah Wahbeh, Tyler Howes, Omar El-Gayar, Raed Seetan, Mohammad Al-Ramahi, and Ahmed Al-Omari

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Abdullah Wahbeh
Slippery Rock University
abdullah.wahbeh@sru.edu

Tyler Howes
Slippery Rock University
twh1009@sru.edu

Omar El-Gayar
Dakota State University
omar.el-gayar@dsu.edu

Raed Seetan
Slippery Rock University
raed.seetan@sru.edu

Mohammad Al-Ramahi
Texas A&M University-San Antonio
mrahman1@tamusa.edu

Ahmad Al-Omari
Our Lady of the Lake University
aal-omari@ollusa.edu

Abstract

Telehealth mobile apps and telehealth services are increasingly used by patients, particularly, post-COVID-19. This study examines factors related to users' satisfaction with these apps and services by analyzing reviews from actual telehealth app users. A total of 53,209 reviews were collected from nine telehealth apps on the Google Play store. Using BERT embeddings, UMAP, and HDBSCAN, topics were generated and labeled to identify these factors. Results showed that telehealth app users expressed several factors related to satisfaction with telehealth apps, which could impact the acceptability and adoption of such apps. These include usability (ease of use), usefulness, convenience and efficiency, cost and affordability, technical performance and connectivity, professionalism and expertise, and comprehensive care support.

Keywords

Telehealth, Mobile Apps, Topic Modeling, BERTopic, Text Mining.

Introduction

The rapid advancement of technologies resulted in many tools and systems currently used in the healthcare domain for the rapid exchange of information and the support for patient physicians communications (Ganapathy et al. 2020; Lin et al. 2018). These technologies include mobile devices, mobile health (mHealth), and mobile apps (Hilty et al. 2019; Tuckson et al. 2017). mHealth refers to the applications of smart technologies for the management and delivery of care, anytime, anywhere, while overcoming barriers to healthcare delivery (Hilty et al. 2019). A widely popular health service that took advantage of advancement in mHealth and healthcare technologies is telehealth. Telehealth is defined in different ways, but it generally refers to the exchange of patients' information using communication technologies (Pollard et al. 2023). The aim is to improve patients' health (Tuckson et al. 2017). In essence, "promote long-distance clinical health care, and patient and professional health-related education" (Pollard et al. 2023).

Telehealth apps are one of the popular examples of digital transformation in the healthcare sector. These apps align very well with the four key dimensions of digital transformation outlined by Matt et al., (2015). When it comes to the use of technologies, transforming health services using telehealth and telehealth apps requires the use of advanced technologies, technology standards, and technology infrastructure (Wosik et al. 2020a) that can help provide remote medical consultation and real-time healthcare monitoring. With respect to changes in value creation, telehealth apps have completely changed the healthcare delivery model, especially for remote or underserved populations. This shift resulted in greater economic benefits of a telehealth product (Velayati et al. 2021a; Wosik et al. 2020a) for patients and care providers, such as increasing profits, reducing costs, and saving time (Velayati et al. 2021a). For structural changes, the

implementation of telehealth requires significant changes in the healthcare facility as well as changes in patient and clinical care processes (Wosik et al. 2020a), the need to increase access to underserved populations (Dorsey and Topol 2016) as well as the need to provide access to low socioeconomic status patients (Wosik et al. 2020a). Finally, concerning financial aspects, the use of telehealth apps is considered a major investment, especially with advances in technology. Telehealth services may impose some financial challenges and restrictions on healthcare service providers, but at the same time may could result in significant savings in costs and time (Cannon 2018; Dorsey and Topol 2016) and increasing return on investment in many cases (Snoswell et al. 2020a).

Telehealth services revolutionized the healthcare industry where patients need to schedule in-person appointments and meet with physicians to seek medical care (Snoswell et al. 2020b). Such services include patient care, tele-education, and teleconsultation (Velayati et al. 2021b). It became a popular alternative to outpatient and community-based programs (Michaelchuk et al. 2022). The advent of mobile technologies has empowered healthcare professionals to share information, provide care, and support patients in various locations, yielding positive healthcare outcomes (Ren et al. 2020). However, mobile-based telehealth has not been used to its full capacity, necessitating an exploration of existing barriers hindering the application of mobile telehealth practices in healthcare. Therefore, the increasing significance of telehealth, particularly heightened by the challenges posed by the COVID-19 pandemic, necessitates a thorough exploration of factors influencing users' satisfaction with telehealth apps. Existing literature on technology adoption and acceptance has predominantly focused on assessing users' experiences with mHealth technologies through small-scale survey data. Such data might be limited in providing the perspective of users of mHealth and telehealth solutions. Therefore, to fill this gap, our study aims to analyze users' reviews of popular telehealth apps, providing a rich source of information about users' satisfaction with the use of telehealth mobile solutions on a large scale. By delving into the experiences of actual users, this data and analysis aim to offer insights that can guide the development of telehealth apps, ultimately enhancing user experiences and healthcare outcomes.

User reviews provide several advantages over traditional methods, like surveys, where user reviews could facilitate the study of phenomena on a large scale, while at the same time, the collected data reflects users' experience with telehealth apps. Studying telehealth apps is critical, especially after the COVID-19 pandemic. This study attempts to inform improvements in telehealth app design and functionality, influence policy and regulatory frameworks, and contribute to the transformation of healthcare delivery. Analyzing insights from users' reviews could further support the integration of telehealth apps into healthcare settings, provide effective and affordable healthcare services, and make healthcare more accessible whenever it is needed.

Background and Related Studies

Telehealth services have become more prevalent, particularly during the COVID-19 pandemic, with research focusing on technology acceptance, user engagement, and insights from social media. Overall, the adoption of telehealth has been closely linked to various factors influencing its acceptance and usage. For example, Anderson et al. (2022) demonstrated how social acceptance of telehealth grew during the pandemic, driven by increased network connectivity and information distribution on platforms like Twitter, while Choi et al. (2022) found that perceived vulnerability and response efficacy were significant predictors for telehealth uptake, suggesting that users were influenced by their perceived health risks and the effectiveness of telehealth services. Further, An et al. (2021) applied an extended TAM to study telehealth acceptance, revealing that increased accessibility, ease of use, and privacy contributed positively to telehealth's perceived usefulness. Similarly, focusing on elderly patients, Zhou et al. (2019) discovered that satisfaction, ease of use, and information quality were crucial determinants of telehealth acceptance, while Wade et al., (2012) found that there was no difference in terms of ease of use and perceived usefulness of the telehealth service before and after training sessions to use the service. However, ease of use of telehealth before training had a positive impact on future compliance. Moreover, Tsai et al. (2019), highlighted the role of enablers and inhibitors in telehealth adoption, with cost and anxiety acting as significant barriers.

Healthcare professionals' and patients' perspectives also play a role in technology acceptance. Keenan et al. (2021) examined the divergence between these groups, finding that telehealth satisfied the need for autonomy, while relatedness and competence were areas of divergence. Woo & Dowding (2018) conducted a systematic literature review and showed that heart failure patients generally had positive feelings toward

telehealth, with key factors including cost, access to care, and privacy. Further, Poder et al. (2015) using survey data, emphasized that both patients and healthcare providers expressed high confidence and acceptance of telehealth, indicating its potential for widespread adoption.

As social media platforms have become valuable sources for understanding public perceptions of telehealth, Pool et al. (2022) utilized topic modeling, sentiment analysis, and emotion analysis to reveal public opinions on telehealth during the pandemic. Their findings indicated that public sentiment was generally positive, though some negative sentiments emerged due to lockdown-related issues. Further, Massaad et al. (2020) analyzed Twitter data to understand telehealth trends, highlighting common topics such as "COVID," "health care services," and "mental health." These studies suggest that social media platforms offer unique insights into public perceptions of telehealth, providing a broader context for understanding its acceptance and engagement.

Despite several studies on telehealth, certain limitations persist. Most existing studies in the literature focused on surveys to study users' experience with telehealth apps and identify factors that could affect users' satisfaction with these apps. However, many of these studies were limited in terms of the limited number of interviewees (Velayati et al. 2021b), focusing on specifying age group, race, or ethnicity (Choi et al. 2022; Kruse et al. 2017), covering a short timeframe for examining user adoption intention of telehealth (Tsai et al. 2019), the use of social media data, such as Twitter, which might not reflect opinions from the actual use of telehealth apps (Anderson et al. 2022; Pool et al. 2022). Our study aims to overcome these limitations by analyzing user reviews of popular telehealth apps to provide a more comprehensive understanding of user satisfaction and engagement.

Research Methodology

This study aims to determine the factors affecting users' satisfaction with telehealth apps. To determine such factors, users' review data from the Google Play Store about popular telehealth apps were collected and analyzed. Such user reviews could help provide direct insights from the actual use of the apps while at the same time helping determine the factors related to satisfaction with telehealth apps. Figure 1 shows the research methodology for generating topics using Bidirectional Encoder Representations from Transformers (BERT) (Devlin et al. 2019), BERTopic (Grootendorst 2020), and Latent Dirichlet Allocation (LDA) (Blei et al. 2003).

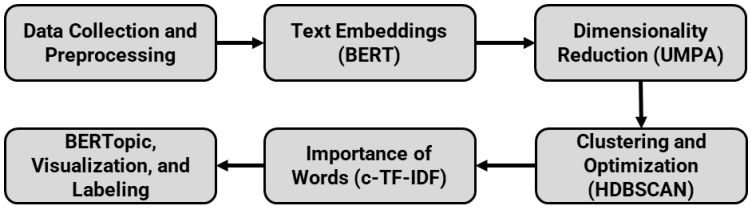

Figure 1. Topic Modeling using BERTopic

Data was collected from multiple telehealth apps based on the criteria that such apps must have a minimum of one million downloads and an average rating of 4+ stars. Such criteria were used to help determine users' satisfaction factors with telehealth apps based on widely used apps that were highly reviewed and accepted by the users. We used a custom Web scraper in Python to collect users' reviews. A total of 53,209 reviews were collected from a total of nine apps. These apps include Doctor On Demand, HealthTap - Online Doctors, MDLIVE: Talk to a Doctor 24/7, BetterHelp, K Health, Teladoc Health: Virtual care, Telehealth by SimplePractice, Amwell: Doctor Visits 24/7, and Doctor Anywhere – Telehealth. The collected reviews were preprocessed by removing any hashtags, stop words, punctuation marks, special characters, alphanumeric words, numbers, non-English words, words with less than three characters in length, and then the reviews were lemmatized.

Text embedding in BERT refers to the process of representing text as numerical vectors that capture their semantic meaning in a high-dimensional space (Zhang and Yu 2012). BERT provides better representation and performance compared to traditional techniques as well as similar techniques for word embeddings (Alsentzer et al. 2019; Karande et al. 2021). In this study, we used BertTokenizer and BertModel from the

transformers' library as well as bert-base-uncased variant of BERT, a pre-trained model on the English language, to perform text embedding.

Uniform Manifold Approximation and Projection (UMAP) was used to reduce the dimensionality of the data. UMAP is a well-known dimensionality reduction learning technique (Becht et al. 2019; McInnes et al. 2018, 2020) that has been widely used in different domains including machine learning (Espadoto et al. 2019, 2020) and bioinformatics (Becht et al. 2019; Cao et al. 2019). Topic modeling based on the UMAP technique demonstrated better performance and helped achieve precise context-based features (George and Sumathy 2023). Without any computational restrictions, UMPA is considered a viable technique for dimensionality reduction (McInnes et al. 2018, 2020) and is known for its speed and ability to preserve the structure of the data in lower dimensions (George and Sumathy 2023).

Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) is used to create dense clusters (Abuzayed and Al-Khalifa 2021). In this context, the HDBSCAN algorithm was used to cluster reviews with similar content to facilitate topic detection within the dataset (Becht et al. 2019). To find the optimal number of clusters for HDBSCAN, we used the Silhouette score (Rousseeuw 1987), which can help determine the minimum cluster size, which in turn "controls the balance between the preservation of global and local structures in the low dimensional embedding" (Silveira et al. 2021).

A variation of term frequency inverse document frequency (TF-IDF), named cluster TF-IDF (c-TF-IDF) (Mazzei and Ramjattan 2022; Orellana and Bisgin 2023) was adapted to have a single representation of all reviews in a single cluster (Grootendorst 2022) using the following formula:

$$c - TF - IDF_i = \frac{t_i}{w_i} \times \log \frac{r}{\sum_j^n t_i} \quad \text{..... (1)}$$

Where the word frequency, t, is extracted for each cluster, i, and then divided by the total number of words, w. Next, the total number of reviews, r, is divided by the total frequency of the word, t, across all classes, n. Once the minimum cluster size had been identified, BERTopic was used to generate the list of topics. Topics were visualized as word clouds and then labeled by two independent researchers to ensure validity and consistency in the labeling process. Inter-rater reliability (kappa statistic) (Landis and Koch 1977) was evaluated to ensure that the researchers assigning topic labels would eventually obtain similar evaluations. The final list topics was labeled and merged into a higher-level topic that represents factors that affect users' acceptability and usability of mobile telehealth apps.

Results

We analyzed a total of 53,209 reviews, representing 36,954 5-star rating reviews, 4,158 4-star rating reviews, 1,937 3-star rating reviews, 1,625 2-star rating reviews, and 8,563 1-star rating reviews. Optimization using the Silhouette score suggested an optimal minimum cluster size of 14. BERTopic generated a total of 186 topics. The labeling process by the two researchers resulted in Cohen's Kappa statistics of 0.90, which reflects almost perfect agreement among different raters (Landis & Koch, 1977). The resulting topics were reduced to seven high-level topics/themes that reflect factors that affect users' satisfaction with telehealth apps. These factors include usability (ease of use), usefulness, convenience and efficiency, cost and affordability, technical performance and connectivity, professionalism and expertise, and comprehensive care support. The factors show that usability is a widely popular factor that could affect any mobile app including telehealth apps. In this context, usability is related to the ease of using the mobile app to get access, navigate through the app, and have a simple and intuitive user interface. Figure 2 shows a high-level representation of the "usability (ease of use)" factor using a word cloud.

Figure 2. Word cloud for the high-level topic "usability (ease of use)".

Example reviews that support this factor include: "*Very user friendly and easy to navigate*", "*Easy to navigate and great doctor experience. Will definitely use again.*", "*Easy to use friendly and professional service. Awesome app*", "*The app is user friendly, and easy to use. The telehealth method has met every need that an in-office visit could have. Highly recommend!*", and "*This app and the steps process is so quick and easy to use. Awesome app!*"

Figure 3. Word cloud for the high-level topic "usefulness."

Figure 4. Word cloud for the high-level topic "convenience and efficiency"

Usefulness is another key factor that could impact satisfaction with telehealth mobile apps and services. In this context, usefulness is related to how users perceive the usefulness of the provided care services by the telehealth app. In this context, users are mainly interested in the app being useful in general, being helpful, and providing them with great experience while using the app and being informative. Figure 3 shows a high-level representation of the "usefulness" factor using a word cloud. Example reviews that support this factor include: "*Very useful and helpful. Friendly and always asking the right questions*", "*I find it very useful and helpful*", "*useful, helpful and ask plenty of questions to get diagnosis, but still quick and to the point. much appreciated!*", "*Extremely helpful and useful. Easy to use. Great care provided*", "*Excellent experience. Very useful, helpful, safe and secure*", and "*It was really helpful and useful experience.*"

Convenience and efficiency are considered a key factor in adopting and using telehealth mobile apps and services. In this context, convenience and efficiency are related to accessibility. It is related to remote access to healthcare services, convenient access to care from home, prompt service, and the ability to access different health-related information. Figure 4 shows a high-level representation of the "convenience and efficiency" factor using a word cloud. Example reviews that support this factor include: "*Quick and helpful care! Was treated quickly and professionally while sitting at home*", *I love this app very helpful no long wait times and wait at home!*", "*Easy to use. I am homebound. This site makes mental health care accessible to me! Thank yo*u", "*Fast response time. Professional help from home*", and "*Always prompt and professional. What an excellent way to access a doctor from home.*"

Figure 5. Word cloud for the high-level topic "cost and affordability ."

Figure 6. Word cloud for the high-level topic "professionalism and expertise."

Cost in general could impact users' satisfaction with telehealth mobile apps and services. In this context, the cost is related to the fact that telehealth service is covered by insurance, is worth the money, and the ability to save money given the affordable prices. Figure 5 shows a high-level representation of the "cost and affordability" factor using a word cloud. Example reviews that support this factor include: "*So fast and my insurance covered so no cost*", "*Quick, to-the-point visit, cost with insurance was good. Doctor was great, very nice and very helpful.*", "*Great time and money saving App! If your insurance will cover it, it is*", "*My insurance covered the cost, and the Dr visit was less than 5 minutes!! Definitely convenient and worth it*!", and "*Very easy to use and with my insurance the cost was very economical*!!"

Professionalism and expertise have been widely discussed by telehealth apps and seem to play a significant role in users' satisfaction with these apps. In this study, professionalism and expertise refer to the users'

ability to see professional, knowledgeable, and friendly doctors, therapists, and care providers. Users stated that these professionals were extremely helpful, trustworthy, and shared useful knowledge about their health conditions as if they were attending the appointment in person. Figure 6 shows a high-level representation of the "professionalism and expertise" factor using a word cloud. Example reviews that represent this factor include: "*Great experience doctor was professional and knowledgeable*", "*Doctor was very professional and knowledgeable*", "*Knowledgeable professionals", "It was my first time. I had a great experience. Dr. was very friendly, professional and care*", "*Great experience very timely response very knowledgeable care givers*", "*Easy to use with professional & knowledgeable providers & short wait times*", and "*Always an experienced medical professional from the convenience of my home*."

Figure 7. Word cloud for the high-level topic "comprehensive care support."

Figure 8. Word cloud for the high-level topic "technical performance and connectivity."

Comprehensive care support is a critical factor for the success of the telehealth app. In this context, comprehensive care support is all about integrated healthcare services that support different patients' needs including but not limited to prescription refills, mental care provision, therapy sessions, and question/answer sessions. Figure 7 shows a high-level representation of the "comprehensive care support" factor using a word cloud. Example reviews that support this factor include: "*A very good experience. Easy to answer questions speak with the doctor and see her as well*", "*Has a lot of answers from speaking with the doctors. Helps with medical and mental health concerns*", "*Need a quick telehealth or mental health appointment…this is the place! So many professional caring people*", "*The therapist are great! They even have psychologists for therapy. Professional and informative staff*", "and "*Great service! Saved time and money for an ear infection.*"

Given the unique features of any mobile app, technical performance and connectivity are crucial to the success of several apps, especially in the healthcare domain. In this study, technical performance and connectivity are related to users' ability to connect with the service provider flawlessly without any connectivity issues as well as having clear and quality audio/video connections. Figure 8 shows a high-level representation of the "technical performance and connectivity" factor using a word cloud. Example reviews that represent this factor include: "*Great audio. The quality of the video is awesome*", "*Pretty good video and audio quality, overall good app*", "*No lagging, no buffering, great video and audio quality*", "*I have had zero problems with connectivity or reliability. Great way to do therapy*", "*Great experience, it was easy to use, and connectivity really wasn't an issue*", and "*Easy to access, great connectivity and functionality.*"

Discussion

In this study we aim to study factors that affect users' satisfaction with telehealth mobile apps. We analyzed users' reviews of popular telehealth apps from the Google Play Store. Such reviews reflect opinions and experiences from the actual use of the apps compared to approaches that study a small sample size of users. According to the results from BERTopic analysis, we have identified seven key factors related to usability and satisfaction with telehealth apps, these factors include usability (ease of use), usefulness, convenience and efficiency, cost and affordability, technical performance and connectivity, professionalism and expertise, and comprehensive care support.

Ease of use has a high impact on the users' satisfaction with any technologies or services. In the context of telehealth services via mobile apps, users reported ease of use of the app, ease of navigation, and being user friendly as the main contributors to users' satisfaction, which in turn could affect the acceptance and adoption of telehealth apps and services. The more easy the telehealth app, the more likely the patients will accept the app and use the service provided (Woo and Dowding 2018; Zhou et al. 2019). The usefulness of

the telehealth app is another critical factor that is related to users' satisfaction. The usefulness of the telehealth app is related to how users perceive the usefulness of the provided care services by the telehealth app. According to Ekeland et al., (2010), telehealth services are useful for different conditions including psychological interventions, respiratory conditions, smoking cessation programs, secondary prevention of coronary heart disease, telepsychiatry, therapy for anxiety disorders, cognitive behavioral therapy, chronic diseases, and physical activity interventions (Ekeland et al. 2010).

Convenience and efficiency are related to accessibility. Accessibility is the core of any healthcare app that supports patients who seek care anytime they need it. Accessibility is achieved through prompt services, access to care from anywhere and anytime, including rural areas, and during pandemics, and the ability to access personal health records. The COVID-19 pandemic increased the use of telehealth services due to lockdowns and restrictions imposed by governments. Such use was effective and provided the needed access to care services for different people in different locations, making virtual care a reality (Wosik et al. 2020b). Telehealth services are considered an optimal solution to provide patients with access to care by providing them with a convenient option to seek care services, access healthcare services, and meet with care providers regardless of location (Snoswell et al. 2020b). Accessibility and access to care was also cited as a factor that could positively affect the acceptance and adoption of telehealth services (Woo and Dowding 2018).

Telehealth is increasingly adopted by healthcare providers as well as patients due to potential savings in the overall cost of care, while maintaining the quality of care like in-person care. Cost and affordability in the context of telehealth apps is related to insurance coverage of the telehealth service, ability to save money, and the fact that the service is worth the money being paid. Several studies and reviews showed that telemedicine in general, including telehealth, seemed to be cost-effective (Ekeland et al. 2010). Telehealth could save money on the patients' side while increasing the return on investment (ROI) on the care provider side (Snoswell et al. 2020b). With the COVID-19 pandemic, Medicare has been expanded to cover telehealth services, at no extra costs (Anderson et al. 2022) to encourage patients to use the service. Woo & Dowding, (2018) showed that cost has a significant positive effect on patients' attitudes toward the use of telehealth.

Telehealth video and audio quality connection is a crucial aspect of telehealth apps. The use of such services has increased during the COVID-19 pandemic (Mirone et al. 2023), leading to a need for efficient and accurate video-quality tools. In general, these technologies could help facilitate access to and provision of care to patients in different settings. However, quality issues can affect such services (Tulu 2005) and reduce patients' satisfaction. Professionalism and expertise are crucial for the successful delivery of care using telehealth apps. Telehealth apps provide a platform for leveraging virtual expertise and improving patient care through knowledge sharing (Wan and Alagar 2015; Whaley et al. 2021) as well as the ability of care providers to answer patients' questions. Finally, comprehensive care support is critical for users to adopt and use telehealth apps. Telehealth has been used for different conditions and different settings, including but not limited to diabetes AND neurological conditions (Leonard et al. 2023; Lewinski et al. 2022). For many conditions, telehealth apps could be used as a supplement or adjunct to in-person care (Doarn 2021). Overall, telehealth has shown promise in managing various conditions and needs of patients.

Conclusion

Telehealth mobile apps are considered critical in providing and promoting access to care via telehealth services. In this study, telehealth app users expressed several factors that could impact users' satisfaction with telehealth apps. These include usability (ease of use), usefulness, convenience and efficiency, cost and affordability, technical performance and connectivity, professionalism and expertise, and comprehensive care support. From a practical perspective, the study provides insights into factors that can affect the acceptability and use of telehealth apps, which could also enhance the features of the apps and improve usability. The current findings could also help healthcare facilities managers consider telehealth apps as an opportunity to reduce costs for the care providers and patients, improve return on investment, and reconsider resource allocations, service options, and healthcare delivery options.

REFERENCES

Abuzayed, A., and Al-Khalifa, H. 2021. "BERT for Arabic Topic Modeling: An Experimental Study on BERTopic Technique," *Procedia Computer Science* (189), AI in Computational Linguistics, pp. 191–194. (https://doi.org/10.1016/j.procs.2021.05.096).

Alsentzer, E., Murphy, J. R., Boag, W., Weng, W.-H., Jin, D., Naumann, T., and McDermott, M. B. A. 2019. *Publicly Available Clinical BERT Embeddings*, arXiv. (https://doi.org/10.48550/arXiv.1904.03323).

An, M. H., You, S. C., Park, R. W., and Lee, S. 2021. "Using an Extended Technology Acceptance Model to Understand the Factors Influencing Telehealth Utilization After Flattening the COVID-19 Curve in South Korea: Cross-Sectional Survey Study," *JMIR Medical Informatics* (9:1), p. e25435. (https://doi.org/10.2196/25435).

Anderson, J. T., Bouchacourt, L. M., Sussman, K. L., Bright, L. F., and Wilcox, G. B. 2022. "Telehealth Adoption during the COVID-19 Pandemic: A Social Media Textual and Network Analysis," *Digital Health* (8), SAGE Publications Sage UK: London, England, p. 20552076221090041.

Becht, E., McInnes, L., Healy, J., Dutertre, C.-A., Kwok, I. W. H., Ng, L. G., Ginhoux, F., and Newell, E. W. 2019. "Dimensionality Reduction for Visualizing Single-Cell Data Using UMAP," *Nature Biotechnology* (37:1), Nature Publishing Group, pp. 38–44. (https://doi.org/10.1038/nbt.4314).

Blei, D. M., Ng, A. Y., and Jordan, M. I. 2003. "Latent Dirichlet Allocation," *Journal of Machine Learning Research* (3:Jan), pp. 993–1022.

Cannon, C. 2018. "Telehealth, Mobile Applications, and Wearable Devices Are Expanding Cancer Care Beyond Walls," *Seminars in Oncology Nursing* (34:2), Technology in Cancer Care, pp. 118–125. (https://doi.org/10.1016/j.soncn.2018.03.002).

Cao, J., Spielmann, M., Qiu, X., Huang, X., Ibrahim, D. M., Hill, A. J., Zhang, F., Mundlos, S., Christiansen, L., and Steemers, F. J. 2019. "The Single-Cell Transcriptional Landscape of Mammalian Organogenesis," *Nature* (566:7745), Nature Publishing Group UK London, pp. 496–502.

Choi, S. L., Hites, L., Bolland, A. C., Lee, J., Payne-Foster, P., and Bissell, K. 2022. "Telehealth Uptake among Middle-Aged and Older Americans during COVID-19: Chronic Conditions, Social Media Communication, and Race/Ethnicity," *Aging & Mental Health*, Taylor & Francis, pp. 1–9.

Devlin, J., Chang, M.-W., Lee, K., and Toutanova, K. 2019. *BERT: Pre-Training of Deep Bidirectional Transformers for Language Understanding*, arXiv. (https://doi.org/10.48550/arXiv.1810.04805).

Doarn, C. R. 2021. "Telemedicine in Austere Conditions," *Telemedicine, Telehealth and Telepresence: Principles, Strategies, Applications, and New Directions*, Springer, pp. 471–483.

Dorsey, E. R., and Topol, E. J. 2016. "State of Telehealth," *New England Journal of Medicine* (375:2), Massachusetts Medical Society, pp. 154–161. (https://doi.org/10.1056/NEJMra1601705).

Ekeland, A. G., Bowes, A., and Flottorp, S. 2010. "Effectiveness of Telemedicine: A Systematic Review of Reviews," *International Journal of Medical Informatics* (79:11), pp. 736–771. (https://doi.org/10.1016/j.ijmedinf.2010.08.006).

Espadoto, M., Hirata, N. S. T., and Telea, A. C. 2020. "Deep Learning Multidimensional Projections," *Information Visualization* (19:3), SAGE Publications Sage UK: London, England, pp. 247–269.

Espadoto, M., Rodrigues, F. C. M., and Telea, A. C. 2019. *Visual Analytics of Multidimensional Projections for Constructing Classifier Decision Boundary Maps.*, presented at the VISIGRAPP (3: IVAPP), pp. 28–38.

Ganapathy, S., Korne, D. F. de, Chong, N. K., and Car, J. 2020. "The Role of Text Messaging and Telehealth Messaging Apps," *Pediatric Clinics* (67:4), Elsevier, pp. 613–621. (https://doi.org/10.1016/j.pcl.2020.04.002).

George, L., and Sumathy, P. 2023. "An Integrated Clustering and BERT Framework for Improved Topic Modeling," *International Journal of Information Technology* (15:4), pp. 2187–2195. (https://doi.org/10.1007/s41870-023-01268-w).

Grootendorst, M. 2020. "BERTopic: Leveraging BERT and c-TF-IDF to Create Easily Interpretable Topics," *Zenodo, Version Vo* (9).

Grootendorst, M. 2022. *BERTopic: Neural Topic Modeling with a Class-Based TF-IDF Procedure*, arXiv. (https://doi.org/10.48550/arXiv.2203.05794).

Hilty, D. M., Chan, S., Torous, J., Luo, J., and Boland, R. J. 2019. "A Telehealth Framework for Mobile Health, Smartphones, and Apps: Competencies, Training, and Faculty Development," *Journal of Technology in Behavioral Science* (4:2), pp. 106–123. (https://doi.org/10.1007/s41347-019-00091-0).

Karande, H., Walambe, R., Benjamin, V., Kotecha, K., and Raghu, T. 2021. "Stance Detection with BERT Embeddings for Credibility Analysis of Information on Social Media," *PeerJ Computer Science* (7), PeerJ Inc., p. e467.

Keenan, J., Rahman, R., and Hudson, J. 2021. "Exploring the Acceptance of Telehealth within Palliative Care: A Self-Determination Theory Perspective," *Health and Technology* (11:3), pp. 575–584. (https://doi.org/10.1007/s12553-021-00535-9).

Kruse, C. S., Krowski, N., Rodriguez, B., Tran, L., Vela, J., and Brooks, M. 2017. "Telehealth and Patient Satisfaction: A Systematic Review and Narrative Analysis," *BMJ Open* (7:8), British Medical Journal Publishing Group, p. e016242. (https://doi.org/10.1136/bmjopen-2017-016242).

Landis, J. R., and Koch, G. G. 1977. "The Measurement of Observer Agreement for Categorical Data.," *Biometrics* (33:1), pp. 159–174. (https://doi.org/10.2307/2529310).

Leonard, C., Liu, W., Holstein, A., Alliance, S., Nunnery, M., Rohs, C., Sloan, M., and Winchester, D. E. 2023. "Informing Use of Telehealth for Managing Chronic Conditions: Mixed-Methods Evaluation of Telehealth Use to Manage Heart Failure During COVID-19," *Journal of the American Heart Association* (12:4), Am Heart Assoc, p. e027362.

Lewinski, A. A., Walsh, C., Rushton, S., Soliman, D., Carlson, S. M., Luedke, M. W., Halpern, D. J., Crowley, M. J., Shaw, R. J., and Sharpe, J. A. 2022. "Telehealth for the Longitudinal Management of Chronic Conditions: Systematic Review," *Journal of Medical Internet Research* (24:8), JMIR Publications Toronto, Canada, p. e37100.

Lin, C.-C. C., Dievler, A., Robbins, C., Sripipatana, A., Quinn, M., and Nair, S. 2018. "Telehealth In Health Centers: Key Adoption Factors, Barriers, And Opportunities," *Health Affairs* (37:12), Health Affairs, pp. 1967–1974. (https://doi.org/10.1377/hlthaff.2018.05125).

Massaad, E., Cherfan, P., Massaad, E., and Cherfan, P. 2020. "Social Media Data Analytics on Telehealth During the COVID-19 Pandemic," *Cureus* (12:4), Cureus. (https://doi.org/10.7759/cureus.7838).

Matt, C., Hess, T., and Benlian, A. 2015. "Digital Transformation Strategies," *Business & Information Systems Engineering* (57:5), pp. 339–343. (https://doi.org/10.1007/s12599-015-0401-5).

Mazzei, D., and Ramjattan, R. 2022. "Machine Learning for Industry 4.0: A Systematic Review Using Deep Learning-Based Topic Modelling," *Sensors* (22:22), Multidisciplinary Digital Publishing Institute, p. 8641. (https://doi.org/10.3390/s22228641).

McInnes, L., Healy, J., and Melville, J. 2020. *UMAP: Uniform Manifold Approximation and Projection for Dimension Reduction*, arXiv. (https://doi.org/10.48550/arXiv.1802.03426).

McInnes, L., Healy, J., Saul, N., and Großberger, L. 2018. "UMAP: Uniform Manifold Approximation and Projection," *Journal of Open Source Software* (3:29).

Michaelchuk, W., Oliveira, A., Marzolini, S., Nonoyama, M., Maybank, A., Goldstein, R., and Brooks, D. 2022. "Design and Delivery of Home-Based Telehealth Pulmonary Rehabilitation Programs in COPD: A Systematic Review and Meta-Analysis," *International Journal of Medical Informatics* (162), p. 104754. (https://doi.org/10.1016/j.ijmedinf.2022.104754).

Mirone, V., Abate, M., Fusco, G. M., Cirillo, L., Napolitano, L., Morra, S., Di Bello, F., Califano, G., Mirone, C., and La Rocca, R. 2023. "Telemedicine and YouTube™: Video Quality Analysis before and after COVID-19 Pandemic," *Archivio Italiano Di Urologia e Andrologia* (95:2).

Orellana, S., and Bisgin, H. 2023. "Using Natural Language Processing to Analyze Political Party Manifestos from New Zealand," *Information* (14:3), Multidisciplinary Digital Publishing Institute, p. 152. (https://doi.org/10.3390/info14030152).

Poder, T. G., Bellemare, C. A., Bédard, S. K., and Lemieux, R. 2015. "Social Acceptance and Population Confidence in Telehealth in Quebec," *BMC Health Services Research* (15:1), p. 72. (https://doi.org/10.1186/s12913-015-0727-1).

Pollard, J., Quigley, S., O'Brien, M., Peterson, S., and Casey, S. 2023. "Telehealth and Applied Behavior Analysis: An Overview and Examples of Application," *Handbook of Applied Behavior Analysis: Integrating Research into Practice*, Springer, pp. 759–785.

Pool, J., Namvar, M., Akhlaghpour, S., and Fatehi, F. 2022. "Exploring Public Opinion about Telehealth during COVID-19 by Social Media Analytics," *Journal of Telemedicine and Telecare* (28:10), pp. 718–725. (https://doi.org/10.1177/1357633X221122112).

Ren, X., Zhai, Y., Song, X., Wang, Z., Dou, D., and Li, Y. 2020. "The Application of Mobile Telehealth System to Facilitate Patient Information Presentation and Case Discussion," *Telemedicine and E-Health* (26:6), Mary Ann Liebert, Inc., publishers, pp. 725–733. (https://doi.org/10.1089/tmj.2020.0084).

Rousseeuw, P. J. 1987. "Silhouettes: A Graphical Aid to the Interpretation and Validation of Cluster Analysis," *Journal of Computational and Applied Mathematics* (20), pp. 53–65. (https://doi.org/10.1016/0377-0427(87)90125-7).

Silveira, R., Fernandes, C., Neto, J. A. M., Furtado, V., and Pimentel Filho, J. E. 2021. "Topic Modelling of Legal Documents via Legal-Bert," *Proceedings Http://Ceur-Ws Org ISSN* (1613), p. 0073.

Snoswell, C. L., North, J. B., and Caffery, L. J. 2020a. "Economic Advantages of Telehealth and Virtual Health Practitioners: Return on Investment Analysis," *JMIR Perioperative Medicine* (3:1), p. e15688. (https://doi.org/10.2196/15688).

Snoswell, C. L., North, J. B., and Caffery, L. J. 2020b. "Economic Advantages of Telehealth and Virtual Health Practitioners: Return on Investment Analysis," *JMIR Perioperative Medicine* (3:1), p. e15688. (https://doi.org/10.2196/15688).

Tsai, J.-M., Cheng, M.-J., Tsai, H.-H., Hung, S.-W., and Chen, Y.-L. 2019. "Acceptance and Resistance of Telehealth: The Perspective of Dual-Factor Concepts in Technology Adoption," *International Journal of Information Management* (49), pp. 34–44. (https://doi.org/10.1016/j.ijinfomgt.2019.03.003).

Tuckson, R. V., Edmunds, M., and Hodgkins, M. L. 2017. "Telehealth," *New England Journal of Medicine* (377:16), Massachusetts Medical Society, pp. 1585–1592. (https://doi.org/10.1056/NEJMsr1503323).

Tulu, B. 2005. *Designing Multimedia Quality-Based Advanced Videoconferencing Applications for Telemedicine over the Internet*.

Velayati, F., Ayatollahi, H., Hemmat, M., and Dehghan, R. 2021a. "Key Components and Critical Factors for Developing a Telehealth Business Framework: A Qualitative Study," *BMC Medical Informatics and Decision Making* (21:1), p. 339. (https://doi.org/10.1186/s12911-021-01707-3).

Velayati, F., Ayatollahi, H., Hemmat, M., and Dehghan, R. 2021b. "Key Components and Critical Factors for Developing a Telehealth Business Framework: A Qualitative Study," *BMC Medical Informatics and Decision Making* (21:1), p. 339. (https://doi.org/10.1186/s12911-021-01707-3).

Wade, R., Cartwright, C., and Shaw, K. 2012. "Factors Relating to Home Telehealth Acceptance and Usage Compliance," *Risk Management and Healthcare Policy* (5), Dove Medical Press, pp. 25–33. (https://doi.org/10.2147/RMHP.S30204).

Wan, K., and Alagar, V. 2015. *Context-Aware, Knowledge-Intensive, and Patient-Centric Mobile Health Care Model*, presented at the 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), IEEE, pp. 2253–2260.

Whaley, C. M., Crespin, D. J., and Sherry, T. B. 2021. "Smartphone Application Allowing Physicians to Call Patients Associated with Increased Physician Productivity," *Journal of General Internal Medicine* (36), Springer, pp. 2307–2314.

Woo, K., and Dowding, D. 2018. "Factors Affecting the Acceptance of Telehealth Services by Heart Failure Patients: An Integrative Review," *Telemedicine and E-Health* (24:4), Mary Ann Liebert, Inc., publishers, pp. 292–300. (https://doi.org/10.1089/tmj.2017.0080).

Wosik, J., Fudim, M., Cameron, B., Gellad, Z. F., Cho, A., Phinney, D., Curtis, S., Roman, M., Poon, E. G., Ferranti, J., Katz, J. N., and Tcheng, J. 2020a. "Telehealth Transformation: COVID-19 and the Rise of Virtual Care," *Journal of the American Medical Informatics Association* (27:6), pp. 957–962. (https://doi.org/10.1093/jamia/ocaa067).

Wosik, J., Fudim, M., Cameron, B., Gellad, Z. F., Cho, A., Phinney, D., Curtis, S., Roman, M., Poon, E. G., Ferranti, J., Katz, J. N., and Tcheng, J. 2020b. "Telehealth Transformation: COVID-19 and the Rise of Virtual Care," *Journal of the American Medical Informatics Association* (27:6), pp. 957–962. (https://doi.org/10.1093/jamia/ocaa067).

Zhang, Y., and Yu, H. 2012. "An Entropy-Based Comment Ranking Method with Word Embedding Clustering," in *Advances and Innovations in Statistics and Data Science*, Springer, pp. 99–119.

Zhou, M., Zhao, L., Kong, N., Campy, K. S., Qu, S., and Wang, S. 2019. "Factors Influencing Behavior Intentions to Telehealth by Chinese Elderly: An Extended TAM Model," *International Journal of Medical Informatics* (126), pp. 118–127. (https://doi.org/10.1016/j.ijmedinf.2019.04.001).