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Expert Opinion: Potential Barriers of PPG Sensor Booth for Combatting U.S. Rural Healthcare Gap

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ABSTRACT

Rural areas lack sufficient access to healthcare. Previous studies have shown that this issue, known as the rural healthcare gap, is a result of the following factors: physician shortages in rural areas, traditional healthcare facilities being far away from rural communities, and a lack of patient affordability of health screenings. This qualitative survey study aimed to explore the barriers to a solution to the rural healthcare gap combining two existing technologies: PPG sensors and telehealth booths. Twelve professionals from rural health, telehealth, and PPG sensor backgrounds were recruited to answer a questionnaire inquiring about the different social, economic, and political barriers that potentially exist to this solution. Analysis identified 8 major barriers: 1) Fear of Confidentiality Breach, 2) Wariness of technology, 3) Implementation cost, 4) Maintenance Cost, 5) Funding, 6) Insurance Access, 7) Partisanship, and 8) Pressure from Healthcare Organizations. Rural health, telehealth, and PPG sensor professionals were more likely to state the wariness of technology, implementation cost, maintenance cost, funding, and healthcare organization pressure as the major barriers to the implementation of the PPG sensor booth. Understanding these barriers will not only inform future direction to mitigate hurdles to the PPG Sensor booth, but also other novel technologies that are applied in the rural setting as well.

Introduction

The medical field has evolved significantly over the past century and is still continuously growing with the advent of new technologies and information. Around the early 20th century, the introduction of treatments like penicillin to fight bacterial infections spurred the development of modern medicine. Today, faster and more effective healthcare procedures and screenings have improved the quality of life for patients across the US. Unfortunately, not everyone has access to these resources, especially in rural areas. According to an article, written by Barbara Ann Graves, from the Online Journal of Rural Nursing and Health Care, rural Americans often contend with understaffed hospitals, a problem that has persisted since the turn of the century (Graves, 2008). Analysis from as early as 2002 indicates that even primary care specialties faced a decrease in physicians, as finding and retaining doctors in rural areas consistently posed a challenge to healthcare providers (Farley et al., 2002). Moreover, the federal government predicts a shortage of over 20,000 physicians in rural areas by 2025 (Nielsen et al., 2017). In addition, with lower average incomes and a widespread lack of health insurance relative to urban Americans, rural residents struggle to access preventative care, resulting in a “sicker” population (Bushy, 2000), especially considering that 15% of rural communities are below the poverty line (USDA, 2021). Furthermore, some states may not cover this population through Medicaid programs; in particular, more than 10 states have not adopted Medicaid expansion (NASHP, 2022), meaning that many impoverished rural populations may be left uninsured. Even if a rural resident can afford healthcare, medical facilities are typically far away from rural areas (Graves, 2008). These factors illustrate the need for cheap, easily accessible alternatives to traditional healthcare screenings.

Literature Review

Current technology allows for the construction of remote health screening products that could significantly improve rural healthcare access. One such product could combine these technologies to conduct preventative care health screening to compile and interpret data on blood flow, oxygen absorption, and other vital signs. Although, as with any proposed solution, there are possible barriers that prevent it from working to its full potential.

First Component: Photoplethysmography (PPG) Sensors

According to Review on Wearable Photoplethysmography Sensors, written by Castaneda, D., Esparza, A., Ghamari, M., Soltanpur, C., & Nazeran, H, Photoplethysmography (PPG) sensors emit infrared/green light onto tissue and measure the amount of reflected light to analyze blood flow and oxygen absorption. PPG sensors can also monitor other vital signs such as respiratory activities and vascular aging (Castaneda et al., 2018). PPG sensors coupled with machine learning algorithms can also potentially identify cardiovascular diseases (CVDs), sleep disorders, fitness screenings, diabetes, and neurological diseases, according to Diagnostic

Features and Potential Applications of PPG Signal in Healthcare: A Systematic Review, conducted by Malak Abdullah Almarshad, Md Saiful Islam, Saad Al-Ahmadi, and Ahmed S. BaHammam. The availability of imaging photoplethysmography (iPPG) ensures that PPG signals can also be remotely measured using a face imaging sequence taken from a regular video. With the possibility of spreading pathogens through physical equipment, especially after the COVID-19 pandemic, iPPG completely eliminates the spread of diseases and the need for any cleansing systems, decreasing maintenance costs. This technology is already being applied in outpatient care but is only being used for minor procedures requiring the provision of medical staff. With the proper machine learning techniques, PPG sensors could automatically detect and interpret the collected data without continuous monitoring. While they show great potential to improve rural healthcare access, the sensors need a larger system to process and transmit collected information to local hospitals.

Second Component: Telemedicine Booth

While PPG sensors may seem sufficient enough as a solution to bridging the rural healthcare gap, they won't completely serve all the functions of a traditional health screening by themselves. It must be placed in a hardware system that transmits all the screening information to a medical record. Fortunately, telehealth, a remote health service that enables the communication between patients and healthcare providers according to Telehealth Interventions and Outcomes Across Rural Communities in the United States: Narrative Review, written by Michael Butzner and Yendelela Cuffee, may contain a blueprint for the implementation of remote PPG sensors. Furthermore, telehealth helps cut down financial burdens, such as gas costs, on rural patients when accessing healthcare. When used for health screenings, the booth will have a video conferencing screen and hardware such as medical equipment. According to the study, Telemedicine Expanding the Scope of HealthCare Information, conducted by David Balch and John M. Tichenor, telemedicine booths consist of telediagnostic tools such as a stethoscope, an otoscope, an ophthalmoscope, and a dermatology camera. This interface between hardware and software enables proper screenings to take place.

In addition, the researchers worked on a healthcare information exchange (HIE) system that would gather all the information from the screening and send it to an encrypted medical record software. Similarly, if this hardware (booth and tools) and software interface is applied to PPG sensors, the greater product would serve all of the functions of a traditional health screening. However, since rural areas have a comparatively lower infrastructure, lower internet connectivity often poses a major hurdle to patients attempting to video conference

with their healthcare providers (Butzner & Cuffee, 2021). Fortunately, this doesn't apply to PPG sensors, as they will independently collect the data, thereby eliminating the need to videoconference a healthcare professional during the patient's visit.

Integration

If both of these components are integrated, outpatient care/health screenings could be conducted automatically without the supervision of a physician. As mentioned earlier, PPG sensors can serve a multitude of functions when coupled with machine learning techniques (Almarshad et al., 2022). Therefore, not only will health screenings conducted by PPG sensors be more complete in terms of measuring all vital signs, but the need for physicians to collect patient vital data will no longer be necessary because of machine learning techniques. As a result, using the integrated product (PPG sensor booth) as an alternative to traditional health screenings could reduce the burden on the limited workforce in rural healthcare facilities. Considering the portability aspect of the telehealth booth, the PPG sensor booth can be placed in close proximity to rural counties, which would remove the long-distance costs (gasoline) that rural patients incur when going to traditional health screenings. Overall, the PPG sensor booth could potentially make the process of going to and acquiring a health screening much more affordable for the rural population.

Barriers to Novel Technology

When introducing new technologies, however, there tend to be barriers that exist that prevent them from working to their full potential. According to a study on the non-technical and technical barriers to new renewable technology, there has always been competition between different energy suppliers; yet, they tend to adhere together to oppose new forms of renewable energy (Ionel et al., 2009). In the case of implementing the PPG sensor booth in rural healthcare, this could imply that organizations whose purposes align with those of the PPG sensor booth could potentially oppose this product's implementation.

Especially in the rural healthcare field, adopting any technology depends on its observable impact (Garrett et al., 2006). Therefore, there is no guarantee that healthcare providers will readily accept a relatively new product such as the proposed PPG sensor booth. This could also suggest that a potential barrier to the implementation of the PPG Sensor booth could be the reluctance of healthcare professionals to adopt this technology.

Legally, as seen with the advent of Healthcare Information Technology (HIT), there is no assurance of privacy or security of digital healthcare information without the Health Insurance Portability and Accountability Act (HIPAA) applying to computerized informatics tools (Theodos & Sittig, 2020). This means that consumer health information could be disclosed or used by third parties without violation of HIPAA. Considering that the PPG sensor booth utilizes digital information techniques to transfer health screening data to the provider, the problem with privacy could be a potential hurdle. However, considering that patient information is being transmitted to a medical record that is encrypted (EMR), there is also a possibility that privacy would not be an issue.

One of the major organizational barriers to the implementation of novel technologies in healthcare is the high start-up and maintenance costs (Garrett et al., 2006). According to the book The Changing Economics of Medical Technology, newly introduced technologies add to healthcare costs through not only capital costs but also operating costs. However, some new technologies that replace expensive alternatives may result in reduced costs (Neumann & Weinstein, 1991). Considering that the PPG Sensor Booth attempts to replace traditional health screenings in rural areas, it could potentially reduce the cost to some extent, but there is also a possibility that the capital cost for installation and the operating cost for maintenance could contribute to an overall increase in expenses.

Research Gap

Despite there being research on PPG sensors and Telehealth Booths individually, a knowledge gap regarding the implementation and research on the integration between both of these existing technologies is present. Therefore, because the PPG Sensor Booth has not been implemented, another knowledge gap on the potential barriers specific to this solution also exists. By establishing a discussion about the potential use of ppg sensor booths in rural areas, this paper aims to answer the following question: based on expert opinion, what are the potential barriers to the PPG sensor booth that make it a nonviable solution in the United States?

Methods

Pre-Survey

In order to understand the complexities of the barriers of PPG sensor booths when implemented in rural health, a video call was conducted among professionals, who were contacted by email, with occupations that entailed rural health or PPG sensors/telehealth booth manufacturing and operation. Subjects in the rural health field were chosen because they have potentially dealt with rural healthcare gap issues and the adoption of new technologies to mitigate these issues, making them accurate sources for finding potential barriers to the PPG sensor booth. Subjects having affiliations with the PPG sensor and telehealth booth industries were chosen to provide barriers specific to the PPG sensor or the telehealth booth considering that both are key components to the PPG sensor booth. Since this concept does not exist, an informative Google slide presentation was used to educate the subjects on this concept. This presentation consisted of slides that individually explained the specific parts of the PPG sensor booth.

Following a title and introduction slide, the third slide utilizes an informative approach to explain the concept of Photoplethysmography (PPG) sensors. Using a flow chart diagram, it shows that the PPG sensor first emits light onto tissue, then measures the amount of reflected light, and finally displays the vital sign. This method of informative approach was chosen to help the subject visualize the process. With the introductory information on PPG sensors explained, the fourth slide lists multiple potential applications that PPG sensors have outside their current functions (measuring oxygen absorption and blood flow). These include diagnosing cardiovascular diseases, sleep disorders, neurological diseases, and fitness screenings (Almarshad et al., 2022). This helps advance the claim that the PPG sensors can potentially conduct health screening by themselves. The fifth slide transitions into talking about the components of current telehealth booths, which conduct health screenings. The first component that is listed is the telediagnostic tools, which are made of otoscopes (monitors ear), stethoscopes (monitors heart), ophthalmoscopes (monitors eyes), and dermatology cameras (monitors skin). The second component that is listed is the videoconferencing monitor, a system that allows the physician to conduct the health screening through video. The third component is the Healthcare Information Exchange (HIE) Software, which transmits information collected during a health screening to an Encrypted Medical Record (EMR) software, which stores all the patient's information. By taking the individual aspects of each component into account, the 6th slide uses a hypothetical approach to discuss the potential advantages of the final product: automatically conducting health screenings and more cost-efficient by reducing external costs for gasoline if installed near rural counties. With all of the preliminary information explained, the 7th slide introduces the research question: what are the barriers that make PPG sensor booths a nonviable solution to bridging the rural healthcare gap?

Qualitative Survey

This study utilized a qualitative survey approach for data collection modeled after another study, Exploring Self-Efficacy in Australian General Practitioners Managing Patient Obesity: A Qualitative Survey Study, conducted by Freya Ashman, Elizabeth Sturgiss, and Emily Haesler. These researchers conducted semi-structured interviews with the participants and used qualitative surveys to understand the factors that influenced the confidence level of General Practitioners in the obesity management of patients (Ashman et al., 2016). In the same way, this study also used a qualitative survey approach to collect data on the barriers to implementing the PPG sensor booth. However, the video calls weren't interviews in which participants would discuss the answer to the research question with the interviewer. Instead, it was used to actively propose the concept of the PPG Sensor booth, since it isn't a known concept, and clarify any questions that the subjects had regarding it. In addition, since there is very little research on the PPG sensor booth, the barriers are also unknown. Therefore, rather than listing possible barriers without any research basis, it was more logical to leave the response open to the participant's explanation.

The underlying question of identifying the barriers was divided into 4 questions inquiring about the political, economic, social, and other barriers to implementing PPG sensor booths in rural health. The reason behind separating the question based on the lens was to help the participant narrow their focus on a particular barrier and explain it as specifically as possible to get the most out of the responses. Additionally, social, economic, and political lenses were chosen because the whole goal of the PPG sensor booth entailed addressing issues within the rural healthcare gap, which mainly consists of socio-eco-political issues. One of the three major problems within the rural healthcare gap is patient unaffordability, which is a socio-eco-political issue where people (social) cannot afford traditional health screenings because of the cost involved (economic). Considering that 15% of rural communities are below the poverty line, many patients are eligible for Medicaid and Medicare insurance. However, based on state legislation and party affiliations (political), there can be varied access to these insurance programs, resulting in some rural populations being unable to afford healthcare. The second major problem is the workforce shortage in rural healthcare facilities, where there is a lack of physicians, contributing to a significant amount of patients left unserved. As a result, there is a "sicker" population in rural areas (Bushy, 2000), which is a social issue. Finally, the last major problem is the incurring of external costs by rural patients.

Patients who turn to urban healthcare facilities have to travel long distances, which wastes time and money (economic) for gasoline to get to the destination.

Grouping Method

There was no intricate grouping method because the data collection was entirely dependent on the availability of professionals. After the data was collected, each participant was assigned to a group based on occupation: rural healthcare official/researcher, PPG sensor manufacturer/operator, and telehealth booth manufacturer/operator. These three occupations constituted the 3 groups. It was more logical to create groups based on occupations because the response was dependent on the participants' expertise, and people with the same occupation would have similar-orientated responses.

Method of Analysis/Formatting

After all of the data was collected, each of the responses was categorized based on the occupation (sample) of the participant and the lens (political, social, and economic) that their responses entailed. AI wasn't used in this process, as the underlying question was already stratified into 4 separate questions about the political, social,

economic, and other barriers that potentially exist, which helped with categorizing the data based on lens beforehand. This same purpose was served for occupation by creating 3 separate copies of the same Google form survey, where each one was dedicated to one of the three groups. Within each group and lens, each response was stratified based on their specific content- barriers that were identified. Using Overleaf, a software editor for writing/editing scientific documents using a programming language called LaTeX, each of the barriers that were stated by 3 or more subjects were inputted into three tables, situated based on political, economic, and social lenses, showing the participants that brought it up. If this was not the case with an identified barrier, it was placed under the "other" category in each of the tables. Finally, the 5 most identified barriers among all three tables were represented using a bar graph to gauge the significance of the barriers that were most frequently brought up. Overleaf was also used for organizing all the sections in the paper, including the tables, into a more professional format without much work needed. Through this method of organization/analysis, the potential barriers of the PPG sensor booth could be extrapolated.

Results

Social Barriers

Participants noted most frequently barriers related to community acceptance of the PPG sensor booth. In terms of acceptance, a significant portion of the participants cited the wariness of technology and the fear of confidentiality breaches as potential barriers. However, there were some participants who stated barriers outside of community acceptance, which included potential language barriers and finding the optimal location to place the PPG sensor booth to serve a large population. As stated, these results are shown in Table 1.

Table 1. A Summary of Social Barriers Identified by Rural Health, Telehealth, and PPG Sensor Professionals

Participants	Community Acceptance		Other
	Fear of Confidentiality Breach	Wariness of Technology	
RH 1		X	
RH 2	X		
RH 3	X		X
RH 4		X	
RH 5			
RH 6			

TH 1		X	
TH 2	X	X	
TH 3			X
PPG 1			
PPG 2		X	X
PPG 3		X	

Economic Barriers

Participants noted most frequently implementation cost as a potential barrier to the viability of the PPG sensor booth. Additionally, several other participants believed that maintenance costs and difficulties finding funding could be major hurdles. Lastly, a smaller proportion of participants cited lack of insurance access as another possible barrier. As stated, these results are shown in Table 2.

Table 2. A Summary of Economic Barriers Identified by Rural Health, Telehealth, and PPG Sensor Professionals

Participants	Implementation Cost	Maintenance Cost	Funding	Insurance Access
RH 1	X	X	X	X
RH 2	X			
RH 3	X		X	

RH 4	X		X	
RH 5	X	X		
RH 6	X		X	X
TH 1		X		
TH 2				X
TH 3	X	X		
PPG 1	X			
PPG 2	X	X		
PPG 3		X		

Political Barriers

Participants noted most frequently pressure from health organizations as a potential barrier to the viability of the PPG sensor booth. Additionally, several other participants believed that partisanship or political division caused variations in the implementation of this product which could be a possible barrier. Lastly, a smaller proportion of participants cited little to no government support due to a lack of research and patient Medicare/Medicaid eligibility as potential hurdles. As stated, these results are shown in Table 3.

Table 3. A Summary of Political Barriers Identified by Rural Health, Telehealth, and PPG Sensor Professionals

Participants	Partisanship	Pressure from Healthcare Organizations	Other
RH 1		X	
RH 2		X	
RH 3	X		
RH 4	X		
RH 5			X
RH 6		X	
TH 1			X
TH 2	X		
TH 3		X	
PPG 1			X
PPG 2			X

PPG 3		X	

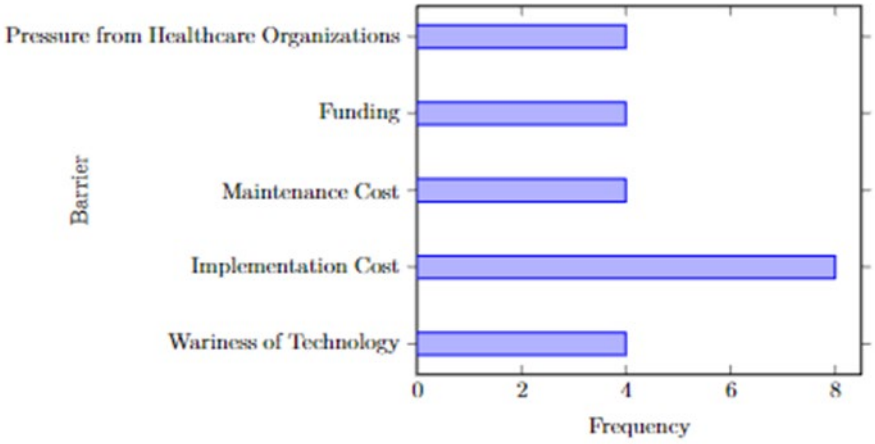

Figure 1. Potential Barriers to the PPG Sensor Booth Most Frequently Cited by Professionals

Analysis

Social

Participant responses indicated that social barriers had strong connections to community-wide reluctance to accept the PPG sensor booth as an alternative to traditional health screenings. These findings particularly suggested that patients could be wary of this technology and worry about the disclosure of confidential information. Because patients traditionally utilize in-person, physician-conducted health screenings, they lack familiarity with automated system diagnoses, a key feature of PPG sensor booths. Additionally, this problem is present among providers and recipients of health screenings, as they lack the education to know how to use and trust the PPG sensor booth as a diagnostic tool. Another reason behind people being wary of this technology is that patients are afraid of their private information being accessed without their consent. Any security breaches would likely result in violations of the Health Insurance Portability and Accountability Act (HIPAA). Educating doctors and patients on the benefits, security, and reliability of PPG sensor booths may help address concerns that participants raised. However, the provision of these educational resources may likely increase implementation costs, which participants noted as a major economic barrier to the utilization of PPG sensor booths in rural areas.

Economic

The majority of the implementation cost-oriented responses raised concerns about local and global factors that may contribute to high PPG sensor booth costs. One participant referenced high export, import, and transportation costs as potential barriers if this product were to be manufactured abroad. This indicates that global economic conditions including supply chain limitations can have indirect but significant impacts on the implementation costs. Locally, maintenance costs for the product's hardware, software, and security and staff salaries pose additional barriers to the implementation of the PPG sensor booth. External funding from many sources would

be required to cover these costs, and because funding from healthcare organizations is not guaranteed, this poses more difficulties in making the product viable.

Political

In addition to funding issues, several participants also noted that rural healthcare organizations could politically assert pressure to inhibit the implementation of the PPG sensor booth. Considering that this product's purpose, bridging the rural healthcare gap, overlaps with that of rural healthcare organizations, there is potential for the initiatives of these organizations to be replaced. This would reduce the need for these groups, resulting in them opposing the implementation of the PPG sensor booth. As a means to suppress the production of this product, rural health organizations could potentially resort to political pressure by colluding with government officials to disapprove of this technology.

Cross Categorical Connections

Partisanship/Healthcare Organization Pressure and Funding/Insurance Access

Although many of the aforementioned barriers are designated to a particular category (social, economic, and political), many of them have connections with each other. One such example of this is between major political and economic barriers. Several participants noted that partisanship was a political barrier to the implementation of the PPG sensor booth because differing political party affiliations for each state could cause variations in federal funding, a major economic barrier, for this product. In addition, Medicaid and Medicare eligibility (insurance access) depends on state policies that are subject to political differences, which could limit the population that PPG sensor booths can serve. Not only is partisanship a cause for both variations in federal funding and insurance access but so is healthcare organization pressure. As mentioned earlier, groups that oppose their need being reduced by the PPG sensor booth could collude with government officials to disapprove of the technology. In this process, government officials could decrease funding or potentially alter laws for Medicaid/Medicare eligibility in the long term to disrupt the production and outreach of this product.

Social Acceptance and Government Acceptance

Although there is no clear cause-effect relationship between government and social acceptance based on the subject responses, there is a correlation between both barriers that is established. One participant noted that without adequate research and pilot studies, there is no chance for the government to accept the implementation of the PPG Sensor booth. In parallel, another participant stated this same reason of not having enough rigorous evaluation for why there would not be much social acceptance. In some ways, social opinions can influence government acceptance. If society is wary of the automated health screening conducted by the PPG sensor booth, the government, especially in the United States, will do anything in its power to fit the needs of its people. Therefore, it could potentially ban the production of this product unless there is sufficient research and an observable impact that it has had on the population.

Language Barriers and Medicare/Medicaid

As one of the participants noted, there are people from culturally specific backgrounds that could potentially experience language barriers when operating the PPG sensor booth. However, this is not the only issue that results from language barriers. Culturally specific people may lack proper communication skills, due to language disparities, to acquire higher positions in the corporate field. This would in turn result in them accumulating less

wealth potentially to an extent that makes them well below the poverty level in the United States, making them eligible for the Medicare/Medicaid programs. Unfortunately, as mentioned earlier, insurance policies for Medicare/Medicaid are not constant among all states, meaning that there are some state legislations that do not fund as much for these programs. Therefore, underprivileged people with language barriers may not be able to afford the health screening conducted by PPG sensor booths depending on their state.

Conclusion

Based on analysis of the findings, major barriers identified among all 3 lenses included pressure from healthcare organizations, funding, maintenance costs, implementation costs, and wariness of technology. In addition, many barriers either correlated or had a cause-effect relationship with each other such as partisanship and insurance access, showing that the PPG sensor booth could be non-viable as a result of multiple related barriers.

Fulfillments of the Gaps in the Research

This study addresses two major gaps in the pre-existing research. First, the barriers to a product integrating two existing technologies when applied to rural healthcare: many studies address the individual functions of PPG sensors (Almarshad et al., 2022), telehealth booths, and their applications to rural healthcare (Balch & Tichenor, 1997). However, there is no research on the integration between both of these technologies and the application of this solution to rural healthcare, meaning that the true aspects and hurdles to this integrated product are unknown. This research study addresses this gap by posing the PPG Sensor Booth as a potential solution to bridging the rural healthcare gap and finding barriers such as the wariness of technology and partisanship that mitigate this solution from being viable. Additionally, since there is no pre-existing research on the PPG sensor booth, the widespread method to research this product's application in the rural setting is unknown. Therefore, this research project establishes a potentially standardized method (the format of the qualitative survey) that can be used to find the barriers to a combination of novel technologies when implemented in rural healthcare.

Implications

The basis of this study can spur the development of medical devices as well as their implementation in rural areas. With knowledge of barriers to the PPG sensor booth identified by qualified professionals, there is potential to modify this product in a way that addresses each barrier to make it a more viable solution to bridging the rural healthcare gap. The introduction of healthcare automation as a key component to the PPG sensor booth could increase awareness of the application of machine learning techniques to medical devices. Resultedly, the advent of more novel technologies that attempt to address barriers not only in rural healthcare but potentially urban areas as well is also possible.

Limitations

Since the subjects were all professionals, it was difficult to get in contact with all of them even after constant follow-up emails. This limitation was the main reason why there wasn't an even distribution of participants in each of the groups. There were 6 participants in the rural health group, whereas there were only 3 participants in each of the telehealth and PPG sensor groups. In addition, three participants omitted the question in the questionnaire/survey inquiring about the potential social barriers to the PPG sensor booth due to uncertainty. Therefore, more data could have been analyzed had all the subjects answered every part of the questionnaire.

Areas for Future Research

By eliminating the limitations, this study could focus on new areas of research. The rural health subject pool can be more focused on rural clinicians to potentially reflect on more applicable and accurate responses because of their first-hand experience with the rural healthcare gap. In addition, the subject pool can be expanded to have more than 12 participants to acquire more data to analyze. One could also analyze rural areas outside the United States to see if the PPG sensor booth is applicable globally.

The findings of this research not only revealed barriers to the PPG sensor booth but also the potential solutions that can mitigate these hurdles. Solutions that were noted included assessing potential economic benefits/savings to mitigate the high implementation/maintenance costs and having a needs assessment involving rural communities to find ways to address each barrier. Future studies could incorporate these findings on the barriers and potential solutions to make adjustments to the PPG Sensor Booth in order to make the product more viable.

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References

Almarshad, M. A., Islam, M. S., Al-Ahmadi, S., & BaHammam, A. S. (2022). Diagnostic Features and Potential Applications of PPG Signal in Healthcare: A Systematic Review. *Healthcare (Basel, Switzerland)*, *10*(3), 547. https://doi.org/10.3390/healthcare10030547

Ashman, F., Sturgiss, E., & Haesler, E. (2016). Exploring Self-Efficacy in Australian General Practitioners Managing Patient Obesity: A Qualitative Survey Study. *International journal of family medicine*, *2016*, 8212837. https://doi.org/10.1155/2016/8212837

Balch, D. C., & Tichenor, J. M. (1997). Telemedicine expanding the scope of health care information. *Journal of the American Medical Informatics Association : JAMIA*, *4*(1), 1–5. https://doi.org/10.1136/jamia.1997.0040001

Bushy, A. (2000). Orientation to nursing in the rural community. SAGE Publications, Inc., https://doi.org/10.4135/9781452204871

Butzner, M., & Cuffee, Y. (2021). Telehealth Interventions and Outcomes Across Rural Communities in the United States: Narrative Review. *Journal of medical Internet research*, *23*(8), e29575. https://doi.org/10.2196/29575

Castaneda, D., Esparza, A., Ghamari, M., Soltanpur, C., & Nazeran, H. (2018). A review on wearable photoplethysmography sensors and their potential future applications in health care. *International journal of biosensors & bioelectronics*, *4*(4), 195–202. https://doi.org/10.15406/ijbsbe.2018.04.00125

Farley, D., Shugarman, L., Taylor, P., & Ashwood, J. (2002, July). *Medicare rural payment issues: Primary care services and geographic definitions* (Tech. Rep.). RAND. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/Research-Reports-Items/CMS023183

Garrett, P., Brown, C. A., Hart-Hester, S., Hamadain, E., Dixon, C., Pierce, W., & Rudman, W. J. (2006, Oct). Identifying barriers to the adoption of new technology in rural hospitals: A case report. *Perspectives in Health Information Management*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2047308/

Graves, B. A. (2008). Rural healthcare access: Issues for consideration in rural health research. *Online Journal of Rural Nursing & Health Care*. https://doi.org/10.14574/ojrnhc.v8i2.110

Ionel, I., Popescu, F., & Badescu, D. (2009). Non-technical barriers versus technical barriers to implement a new renewable technology. *Proceedings of the 3rd International Conference on Energy and Development Environment - Biomedicine, EDEB'09*, 96-104. https://www.researchgate.net/publication/289702349_Non-technical_barriers_versus_technical_barriers_to_implement_a_new_renewable_technology

NASHP. (2022, Dec). Where states stand on medicaid expansion. https://nashp.org/where-states-stand-on-exchanges/

Neumann, P. J., & Weinstein, M. C. (1991). The changing economics of medical technology. In A. Gelijns & E. Halm (Eds.), (p. 21-34). National Academies Press (US). https://pubmed.ncbi.nlm.nih.gov/25121284/

Nielsen, M., D'Agostino, D., & Gregory, P. (2017). Addressing rural health challenges head on. *Missouri Medicine*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6140198/

Theodos, K., & Sittig, S. (2020). Health information privacy laws in the digital age: Hipaa doesn't apply. *Perspectives in Health Information Management*. https://pubmed.ncbi.nlm.nih.gov/33633522/

USDA. (2021, Aug). Data show u.s. poverty rates in 2019 higher in rural areas than in urban for racial/ethnic groups. https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=101903#:~:text=Across%20all%20races%20and%20ethnicities%2C%20U.S.%20poverty%20rates,percent%20for%20that%20demographic%20group%20in%20urban%20areas.