



**A THEMATIC AND REFERENCE ANALYSIS OF TOUCHLESS
TECHNOLOGIES**

THESIS

Eric R. Curia, Captain, USAF

AFIT-ENV-MS-22-M-190

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

DISTRIBUTION STATEMENT A.
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government. This material is declared a work of the U.S. Government and is not subject to copyright protection in the United States.

AFIT-ENV-MS-22-M-190

A THEMATIC AND REFERENCE ANALYSIS OF TOUCHLESS TECHNOLOGIES
THESIS

Presented to the Faculty

Department of Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Engineering Management

Eric R. Curia

Captain, USAF

March 2022

DISTRIBUTION STATEMENT A.
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT-ENV-MS-22-M-190

A THEMATIC AND REFERENCE ANALYSIS OF TOUCHLESS TECHNOLOGIES

Eric R. Curia

Captain, USAF

Committee Membership:

Alfred E. Thal, Jr., PhD
Chair

Lt Col Justin D. Delorit, PhD
Member

Brent T. Langhals, PhD
Member

Abstract

The purpose of this research is to explore the utility and current state of touchless technologies, which are simply devices that do not require touch to activate. Five categories of touchless technologies are identified as a result of collecting and reviewing literature: facial/biometric recognition, gesture recognition, touchless sensing, personal devices, and voice recognition. While the total number of articles provided informative research on the topic, specific articles were selected for analysis based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standard formatting procedures. The 31 PRISMA-compliant documents were then analyzed thematically, evaluating the contents of the articles for advantages and disadvantages, as well as their reference sections for matches and similarities between articles. Thematically, touchless sensing technologies had the greatest advantage to disadvantage ratio, followed by personal devices, voice recognition, facial/biometric recognition, and gesture recognition. For both the direct and indirect reference analyses, the categories were shown to have differences in similarity within their reference sections. The references for gesture recognition technologies shared the most similarities, followed by voice recognition, facial/biometric recognition, personal devices, and touchless sensing. Comparing the results of the two analyses, the conclusion was that newer technologies likely had lower advantage counts due to less known application and higher reference similarities because of the fewer articles written on them. The reverse applies to older technologies, which had higher advantages and greater applicability.

This thesis is dedicated to my best childhood friend, who sadly passed away during my enrollment at AFIT.

Acknowledgments

I would like to take the opportunity to express my appreciation towards my thesis committee, Dr. Al Thal, Lt Col Justin Delorit, and Dr. Brent Langhals. I offer my thanks to Dr. Al Thal for being an excellent advisor and mentor throughout the thesis process, as he provided me extensive reviews of submittals, offered me valuable vector checks when I required help, and guided me towards finishing a well-written and beneficial product for the USAF. I offer my thanks to Lt Col Justin Delorit for being an initiative-taking and outstanding role model during the thesis process, as he would go out of his way to provide me precious feedback and useful material for my thesis. I offer my thanks to Dr. Brent Langhals for his honest feedback and cheerful outlook, giving me both the direction and encouragement I needed for authoring this thesis. I would like to recognize the faculty that I had the privilege of learning from. All of the faculty demonstrated the upmost professionalism and strong character, and I thoroughly enjoyed learning from them and developing as an officer. I would like to thank my fellow classmates as they made my entire AFIT journey an incredibly fun and gratifying experience. Lastly, I would like to thank my family, for they have always supported me and gave me the encouragement I needed throughout my entire academic life.

Eric Russell Curia

Table of Contents

	Page
Abstract.....	iv
Dedication.....	v
Acknowledgements.....	vi
Table of Contents.....	vii
List of Figures	ix
List of Tables	xi
I. Introduction	1
Background	2
Problem Statement	5
Research/Investigative Questions.....	8
Methodology	9
Assumptions & Limitations.....	11
Significance of Study	12
Remaining Chapters	13
II. Literature Review	14
Introduction to Touchless Technology.....	14
Functional Categories.....	15
Facial/Biometric Recognition.....	15
Gesture Recognition	19
Touchless Sensing.....	23
Personal Devices	26
Voice Recognition.....	29
Key Themes from Review.....	33
Conclusions from Review	34
III. Methodology	35
Collecting PRISMA Literature.....	36
Identifying PRISMA Literature.....	36
Modeling PRISMA Literature.....	39

Thematic Analysis.....	40
Reference Analysis.....	44
Direct Reference Analysis.....	45
Indirect Reference Analysis (Total)	47
Indirect Reference Analysis (Per Category).....	49
Comparing Analyses	51
IV. Results.....	53
Collecting PRISMA Literature.....	53
Identifying PRISMA Literature.....	53
Modeling PRISMA Literature.....	55
Thematic Analysis.....	58
Reference Analysis.....	64
Direct Reference Analysis.....	65
Indirect Reference Analysis (Total)	68
Indirect Reference Analysis (Per Category).....	73
Comparing Analyses	78
V. Conclusion	80
Answers to Investigative Questions	80
Answer to Investigative Question 1	80
Answer to Investigative Question 2	81
Application to U.S. Air Force	84
Future Research.....	86
Appendices.....	88
Appendix A. Thematic Data.....	88
Appendix B. Reference Correlation Data.....	101
Appendix C. Clip Art Sources.....	112
References.....	113

List of Figures

	Page
Figure 1. Virus Transmission to Hands of the Susceptible.....	4
Figure 2. Visual of Facial/Biometric Recognition.....	16
Figure 3. Visual of Gesture Recognition	20
Figure 4. Visual of Touchless Sensing	23
Figure 5. Visual of Personal Devices.....	26
Figure 6. Visual of Voice Recognition	30
Figure 7. Methodology Flowchart	35
Figure 8. Visual of Identifying PRISMA Literature	37
Figure 9. Visual of Thematic Analysis	41
Figure 10. Visual of Direct Reference Analysis	45
Figure 11. Visual of Indirect Reference Analysis (Total).....	48
Figure 12. Visual of Indirect Reference Analysis (Per Category)	50
Figure 13. Visual of Comparing Analyses.....	51
Figure 14. Model of PRISMA Literature (Authors)	56
Figure 15. Model of PRISMA Literature (Content)	57
Figure 16. Results of Thematic Analysis.....	59
Figure 17. Results of Direct Reference Analysis.....	66
Figure 18. Results of Indirect Reference Analysis (Total)	70
Figure 19. Histogram of Pearson Correlations	72
Figure 20. Results of One-Way ANOVA	74
Figure 21. Results of ANOVA Equal Variance.....	76

Figure 22. Results of ANOVA Normal Residuals.....	76
Figure 23. Results of Comparing Analyses	78

List of Tables

	Page
Table 1. Table of PRISMA-Compliant Literature	54
Table 2. Table of Indirect Reference Analysis (Total)	71

A THEMATIC AND REFERENCE ANALYSIS OF TOUCHLESS TECHNOLOGIES

I. Introduction

Touchless technologies are devices that can be operated without having to utilize physical touch, and in recent years, they have been increasing in application, development, functionality, and implementation (Cronin & Doherty, 2019). Initially, the main purposes of implementing touchless technologies have been towards energy efficiency, slowing the spread of contagious diseases, and general convenience (Taylor, 2020). For example, several public spaces around the United States, to include offices and airports, have long ago implemented hand-waving sensors in restrooms for these reasons (Taylor, 2020). These types of sensors have also been integrated with facility lighting systems, where the simple entering of a room would activate the lights without having to flip a switch (Nicol, 2020). With that said, the constantly evolving technology sector has dramatically raised the potential for applying touchless technologies in different ways. For example, simple touchless technologies that trigger binary operations (i.e., on or off) by tripping a sensor have evolved into devices that require high-quality cameras to interpret movement and produce complex outputs (Liu et al., 2020). To further push the boundaries of touchless technologies, there are examples of devices that do not even require human interaction. For instance, smart sensors integrated in facilities can measure a facility's life-cycle health automatically (Landgrebe, 2011). On that note, fixtures within medical areas can emit powerful rays of light that disinfect pathogens

automatically as well (Landgrebe, 2011). Even though the availability and functionality of touchless technologies continue to grow, many people still do not view them as mandatory for facilities. However, this perception towards touchless technologies is beginning to change. The background section will further discuss this shift in mindset.

Background

As of July 2021, the Centers for Disease Control and Prevention (2021) discovered that fomite transmission (i.e., the touching of surfaces) was not a primary method in which COVID-19 spreads. In the past, many touchless technologies were simply viewed as “nice to have” infrastructure and equipment, but the dramatic effects of the pandemic made people reconsider their necessity (Iqbal, 2020). Organizations across the world have experienced a significant decrease in productivity due to the pandemic, and the primary reason is the reduction of working together in person to prevent further spreading of the virus (Grover and Sabherwal, 2020). The reason that human interaction has been minimized is because the virus often remains dormant within a host, showing little to no symptoms, which makes the ability to track its spread challenging (Na et al., 2020). Not only is the virus problematic to contain, but its side effects can be deadly; models signal that an infected individual can die from the virus up to 42 days after exposure (Na et al., 2020). Because of this, the logical and conservative protocol for organizations to implement touchless technologies is for their employees to reduce contact with each other (Na et al., 2020).

While the most generally understood method of transmission is through direct contact with infected individuals, diseases of many kinds can also be contracted

indirectly through the touching of common surface objects (Kurgat et al., 2019). Within offices for example, common surfaces that contain highly concentrated bacteria and/or viruses include the following: door handles, door push bars, drinking fountains, restroom soap dispensers, restroom sinks, kitchen faucets, file cabinets, copiers, microwave ovens, candy jars, refrigerators, coffee pots, drawer handles, and communal keyboards (Kurgat et al., 2019). Additionally, surfaces that are considered for individual use, such as personal desks, keyboards, mice, and chairs, can also contain large concentrations of similar bacteria and/or viruses (Kurgat et al., 2019). Figure 1 shows the transmission susceptibility of various surfaces in a typical office setting.

On one hand, it is important to understand that implementing proper hygiene can effectively fight these diseases; when these surfaces are disinfected regularly, 85.4% of the germs on those surfaces are immediately killed, thereby reducing the probability of infection (Kurgat et al., 2019). On the other hand, the touching of these common surfaces is still inevitable, and although active cleaning is highly effective, any amount of surface contact still exposes users to the risk of infection. Because of this, methods need to be explored to further reduce fomite transmission, which is the scientific term for the spread of disease through touching infected surfaces.

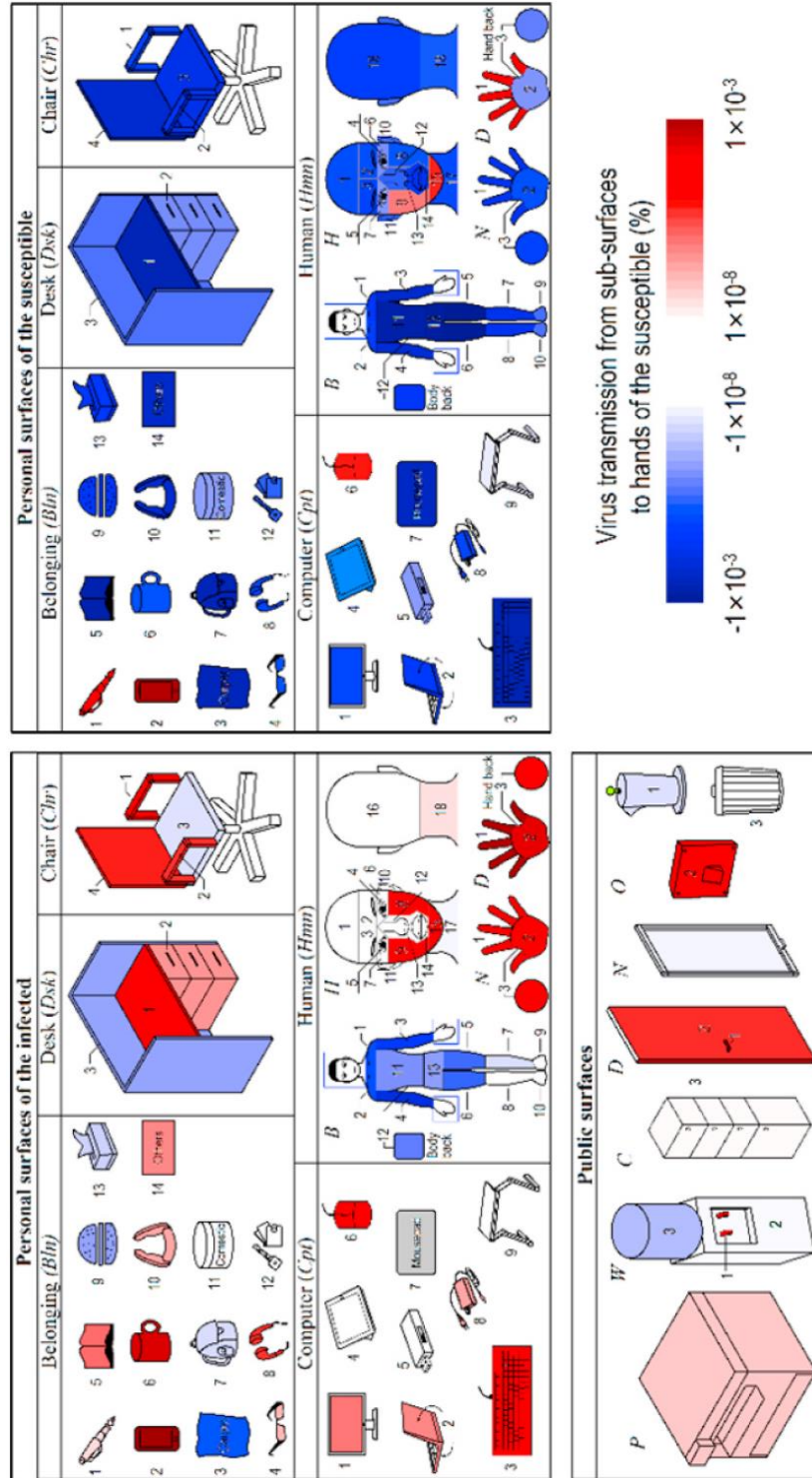


Figure 1. Virus Transmission to Hands of the Susceptible (Kurgat et al., 2019)

While “easier to implement” mitigation efforts, such as lockdowns, have helped minimize the spread of COVID-19, they have also resulted in a severe economic downturn (Coccia, 2021). Lockdowns have produced adverse effects on several nations' economies, where global productivity declined between 13% and 21% during just the second quarter of 2020 (Coccia, 2021). Similarly, there are organizations turning to telework in efforts to adapt, but recreating work environments solely around telework has also been shown to have negative effects, specifically regarding the mental health of employees (Bufquin et al., 2021). The lack of opportunities for employees to interact, collaborate, and create friendships during the pandemic has likely caused the spike in reported psychological distress and substance abuse during 2020 (Bufquin et al., 2021). In efforts to find a smarter solution that addresses safety, economic productivity, and mental health concerns, it may be worth pursuing touchless technologies. Stein (2020) identified five categories of commonly used touchless technology: facial/biometric recognition technologies, gesture recognition technologies, touchless sensing technologies, personal devices, and voice recognition technologies. These categories, which served as a framework for the research, will be further explained in the literature review chapter.

Problem Statement

The purpose of this research is to explore touchless technologies by collecting literature on or related to the topic, thoroughly reviewing the literature for background information, and conducting both a thematic and reference analysis on that literature. The findings from meeting these objectives will be used to draw conclusions and answer

the investigative questions. The purpose of the investigative questions is to address the overarching problem, which is understanding the capabilities, conveniences, and drawbacks associated with touchless technologies.

To search the literature, the resources found on the AFIT online library, primarily Science Direct Open Access Journals, will be utilized. An additional resource that will also be used for both finding and citing literature will be Google Scholar. From there, these resources will help build the framework of background/related information in the introduction, and it will later be used for the literature review process.

To conduct the literature review effectively, it will need to be collected in an organized and efficient manner. After finding general background information, it will be important to structure the categories of touchless technologies in a manner that would make sense for eventual analysis. This coordination of searching for literature is used to prevent searches that may go off on an irrelevant tangent; every found article will be used to gain an understanding of a specified category of touchless technology.

After collecting the literature, performing both thematic and reference analyses needs to be done. The generalized idea/theory behind the thematic and reference analyses will be further explained in the methodology section of this chapter. To briefly discuss the approach of the thematic analysis, the total collection of literature will be filtered down to a smaller group. This reduced sample of articles will be structured in a manner that meets Preferred Reporting Items for Systematic reviews and Meta-Analyses, or PRISMA, standards. The purpose for eliminating articles that do not meet the preferred format is so that this process can be more easily repeatable for future researchers. From there, the articles will be thoroughly read to identify clear and obvious

themes. The themes would need to communicate the pros and cons of touchless technologies, so the themes that will be extracted will be each category's advantages and disadvantages. When all of the themes are collected, an advantage to disadvantage ratio of each category will be calculated. Along with that, the advantage to disadvantage ratio for touchless technologies, as a whole, will also be assessed. The thematic analysis process will be further explained in the methodology chapter. The thematic analysis results will be further explained and shown in the results chapter.

After conducting the thematic analysis, the reference analysis for the collection of PRISMA literature will be done. To summarize the process, the reference analysis compares the articles' reference sections for similarities. This will be accomplished using two different methods: direct and indirect. The direct reference analysis compares the articles for exact matches within their reference sections. This process will be conducted through Microsoft Excel, where the program will compare references of each article as separate data points. In contrast, the indirect reference analysis compares any two articles by reading their reference sections and correlating them by word similarity. The recognized word similarities will compare the article's contributing authors, titles, and journal issues. This process, being executed in the program NVivo, will be conducted for each of the five categories and for touchless technologies as a whole, where Pearson correlation (R^2) values for each category will be obtained. This will then be exported into the program JMP, where the correlation data will undergo statistical tests to analyze their differences in mean correlation and variance. The reference analysis process will be further explained in the methodology chapter. The reference analysis results will be further explained and shown in the results chapter.

Once results are obtained from the thematic and reference analyses, the two completed data sets will be compared. The two results will be plotted on a singular graph, where each point on the graph will represent the five touchless technology categories and touchless technologies as a whole. The combined plot will be further explained and shown in the results chapter.

All of the efforts put into this thesis will be used to create observations, draw conclusions, and answer the investigative questions. These findings will be further explained in the conclusions chapter. These investigative questions will be stated in the upcoming section.

Research/Investigative Questions

The overarching umbrella research question, which is not addressed or answered directly, is instead addressed by answering a series of investigative questions, which help “paint the picture” that focuses on tackling the issues stated in the background section. Simply put, the point of this research is to discuss touchless technologies as an industrial advancement of tools in the modern workplace. Therefore, the investigative questions are the reasons that people would be interested in learning about the topic. To support the overarching research question, which is to gain a full understanding of the capabilities, conveniences, and drawbacks of touchless technologies, the following investigative questions were addressed.

- 1) What is the current state of touchless technologies?
- 2) How are the results of the thematic and reference analyses related? What can be concluded from evaluating the results of the two analyses together?

By answering these questions, this research will explain the current state of touchless technologies, how the scientific community views them, the discoveries made comparing the literature's themes and references, and the feasibility of applying the topic to real-world scenarios.

Methodology

The purpose of this section is to provide a high-level summary of the methodology chapter. This section will briefly explain the process used for this research, to include the broader theory of both analyses, literature collection, clustering, correlation, and statistical processes. This section helps ensure that the reader understands the legitimacy and utility of using both analyses within the overall methodology.

The umbrella term which incorporates both thematic and reference analysis, bibliometric analysis, is the process in which statistical and mathematical methods are used to analyze scientific literature (Diodato, 1994). In this overarching process, scientific books, journals, and articles are collected, and information within the literature is used as data (Diodato, 1994). It is commonly used in the scientific community to investigate the composition of a particular topic with existing literature, and this field of study is frequently implemented in both subjective evaluations (i.e., thematic analysis) and objective evaluations (i.e., reference analysis) (Donthu et al., 2021).

Data, being literature articles, were collected based on using common terms and phrases (i.e., touchless technologies, benefits, costs, fomite transmission, biometric recognition, gesture recognition, touchless sensing, personal devices, voice recognition,

etc.) and without the intention of reaching a conclusion artificially. All of the articles that were collected were numbered and saved within a folder, which served as the database for the research. This strategy proved to be effective because regardless of the iterations taken, it was easy to identify iterations to the database by simply creating folders within folders. Additionally, the number assigned to a journal article remained consistent throughout the research process, which made the data easily recognizable when adapting to different platforms. The first iteration of the database was the screening of literature based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-compliant standards. This essentially filtered out articles from the total literature collection process that would not be used in the thematic and reference analyses. Once the list of PRISMA articles was finalized, there were multiple computer programs that were utilized.

CiteSpace was utilized to provide cluster-based illustrations of all the PRISMA articles based on similarity. NVivo was used for both the thematic and reference analyses, where the program scanned for thematic codes for advantages and disadvantages and the reference sections of the articles to determine Pearson correlation coefficients based on likeness. Similarly, Microsoft Excel was used to scan the reference sections of the PRISMA articles to find reference matches between them. The Pearson correlation data was transferred to JMP, which used statistical tests to identify descriptive and inferential statistics for each of the categories. Once the thematic and reference analyses were completed, the two results were compared by plotting the results on the same graph, identifying possible trends, and creating observations for each of the touchless technology categories.

Assumptions & Limitations

Since the topic of touchless technologies is relatively new, there were several assumptions made and limitations found when conducting the research. Regardless of the category of touchless technology, each article was collected independently from one another, and all of the thematic and reference data within the sample were assumed to demonstrate independence. While this assumption applies throughout the research, it played a significant role during the statistical testing phase of the reference analysis, where the assumption of independence is required. It was also assumed that the collected literature is an accurate representation of how the scientific community at large views touchless technologies. This assumption ensures that the sample of data reflects the population of data on the topic, so the results will serve as accurate models. The last primary assumption, which will be further elaborated on in the methodology chapter, is that the filtered and selected articles used for analysis were indeed PRISMA-compliant. The PRISMA certification process is an extremely articulate and time-consuming task. To compile a sample of articles that officially “checks all of the boxes” is extremely difficult, so rather than going through each individual item, articles were filtered out if they were clear and obvious in not following the desired format. Therefore, it is assumed that the remaining articles did meet compliance because they met the requirements from a simple surface-level perspective.

There were also several limitations that impacted the research. For one, there is not a lot of literature available on touchless technologies, meaning that the literature review’s ability to provide multiple sources for a singular subject matter is lower than desired. Additionally, touchless technologies are constantly changing, meaning that

introducing future literature may impact the outcomes of this study if the research is repeated. Perhaps the biggest limitation lies within the methodology of collecting themes for the thematic analysis. Simply put, inserting text from the articles into a software can check for word similarity, but it will not read and interpret what is actually being communicated. Where the reference analysis can be completed through a program, the thematic analysis requires the researcher to read and interpret the papers. This introduces an element of user error and bias into the results of the study, which could potentially impact the replicability of results if repeated by another researcher.

Significance of Study

As previously mentioned, the negative effects of the COVID-19 pandemic were felt by organizations across the globe, which provided further evidence that organizations must consider adapting their work environments to be safer to maintain their economic productivity. This is where touchless technologies could come into play; it could be an effective way to reduce the spread of germs while allowing employees to come to work and be productive. With that said, it would be financially irresponsible for organizations to completely shift their business models around touchless technologies since a fully adapted workplace may not be practical. There may be types of touchless technologies that are worth considering, and there may be others that are not. This all depends on the advantages and disadvantages of touchless technologies themselves and the subjective needs of the organization. By understanding the different uses of touchless technologies and evaluating their advantages and disadvantages, organizations can responsibly make calculated decisions on implementing them around their business models.

Remaining Chapters

Chapter II is the literature review for this research. It includes the information that is relevant to thoroughly describing the different touchless technology types and their capabilities. Chapter III describes the methodology used during this research. It elaborates in greater detail on the executive-level style summary discussed in the methodology section of this chapter. Chapter IV presents the results of this research. It follows a similar pattern to that of the methodology chapter, displaying each of the results found from following the methodology. Chapter V provides the conclusions reached during this research. It addresses the investigative questions, applications to the United States Air Force, and future research needed to continue the goal of exploring the capabilities, conveniences, and drawbacks of touchless technologies.

II. Literature Review

The purpose of this chapter is to provide the reader the foundational knowledge required to understand the topic at large. This chapter will begin with an introduction to touchless technologies in general. This topic will allow the reader to understand what they are and the reasoning behind why organizations are considering them more heavily. The chapter will then introduce each of the five categories of touchless technologies, where each type will be broken down into more detail. Following the breakdown of each category, the key themes identified across the contributing literature will be discussed. The chapter will then conclude by summarizing the importance of touchless technologies and by transitioning towards the upcoming methodology chapter.

Introduction to Touchless Technology

Simply put, touchless technologies are devices that do not require the physical touch of the operator to achieve its function (Stein, 2020). They do not have to look similar in size, shape, or even perform the same tasks; the aspect that connects touchless technologies to each other is the elimination of physical contact from the user to the device (Vinson, 2020).

Touchless technologies in general were created for many different applications. Some were made to reduce the amount of energy and resources being used within facilities; examples of this include automatic faucets that conserve water (Lozier, 2016). Some have been created to increase the level of safety in terms of public health; for instance, there are light fixtures which emit different frequencies of light that are

activated periodically within hospitals to sterilize rooms from transmissible disease (Landgrebe, 2011). Some have been designed to reinforce levels of security within infrastructure; this includes biometric scanning for entering both physical spaces and cyberspace (Ramanathan, 2021; Lin et al., 2018). Some have been made to proactively monitor the health of infrastructure systems and automatically report data to engineers and facility managers, thereby informing them on the current state of the building (Meyer et al., 2014). No matter which application though, these technologies share the trait of not requiring physical touch to control.

Functional Categories

To understand touchless technologies in greater detail, a more in-depth breakdown of their different categories needs to be discussed. All of the touchless technology literature can be organized into five groups based on their general functionality: (1) facial/biometric recognition technologies, (2) gesture recognition technologies, (3) touchless sensing technologies, (4) personal devices which prevent public touch, and (5) voice recognition technologies (Stein, 2020). This remainder of this section will further explain each category of touchless technology.

Facial/Biometric Recognition

The first category that will be discussed are technologies that are designed to identify and track the biometrics of the user. The crucial element that separates this type of technology from the rest is the role of the user (Ratha & Govindaraju, 2007). Unlike the other categories, biometric analysis distinguishes users from non-users, thus allowing

only specific people to utilize the device (Ratha and Govindaraju, 2007). Biorecognition technologies are used to compare data collected from a particular individual to a database; this is done to identify positive or negative matches between the user and the system (Ratha and Govindaraju, 2007). The most common uses of this category are for security purposes, and the means by which these technologies collect biometric data include contactless fingerprinting, facial recognition, and eye/iris recognition (Ratha and Govindaraju, 2007). For all the means by which these technologies gather data, it is important that the equipment is as accurate as possible so that security breaches are avoided. A visual explaining facial/biometric recognition's capabilities can be found in Figure 2.

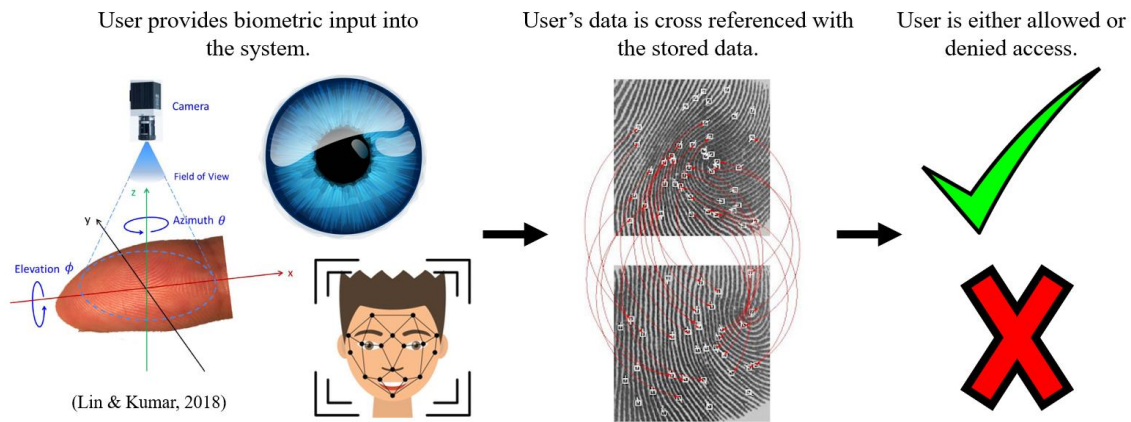


Figure 2. Visual of Facial/Biometric Recognition

Fingerprinting technologies are considered to be the most common of all biometric technologies, as each appendage's unique ridge pattern can serve as a key for the user in question (Parziale, 2008). Traditionally, fingerprints were captured within

two-dimensional space through the scanning of the print on a transparent surface, but there have been issues with this method. The biggest issue is the potential distortion of the print when “smushed” onto the flat surface. An analogy that captures this problem is like the stretching of continents on maps compared to the globe of the earth; the naturally convex surfaces of the fingertip are distorted when placed onto a pad, thus causing the data to be a less accurate representation of the user (Parziale, 2008). The issue that arises is that the areas of stretching are always inconsistent. Because each fingerprinting action warps the skin in a different way, there is a variance of results between the user’s immediate fingerprint and the saved data on file (Parziale, 2008). The most recent advancement to correct this distortion problem is through touchless scanners that capture three-dimensional information (Parziale, 2008). This type of fingerprint scans the finger using lasers, and the finger does not come in contact with a traditional transparent pad (Parziale, 2008). By keeping the biometric data in the form of a round fingertip rather than a stretched two-dimensional image, the user’s immediate scan would in theory better match the data that is associated with the account (Parziale, 2008). However, this is so far only theoretical. The reality is that accuracy of the lasers and the consistency of the environment (contrast, lighting, different finger positions, and illumination) have yet to provide consistent results (Parziale, 2008). Higher consistency and accuracy will likely improve as the capability continues to advance.

Facial recognition technology uses similar scanning capabilities to that of the three-dimensional fingerprint, but it aims to recognize the user’s face (Sinha, 2019). Because it is possible for the angle of the user’s face to vary during scanning, only taking one sample of data would not be sufficient (Sinha, 2019). This also holds true if the face

is displaying different expressions; different emotions will provide different data for the system. Because of this, multiple images need to be taken instantaneously for the purpose of maximizing the possibility of outcomes (Sinha, 2019). The different angles and lighting settings of all the separate pieces of data can combine to create and archive an “eigenface,” which often consists of up to 150 eigen images (Sinha, 2019). It is crucial for the eigenmatrix of facial recognition data to be extremely diverse to improve its ability to recognize the user’s face and thus reduce the threat of security breaches (Sinha, 2019). This method of cross validating the eigenmatrix’s data with the current user is extremely effective at allowing access for the correct people and yields extremely high success rates (Sinha, 2019). Similar to the fingerprint, the ability to render three-dimensional images provides more data for the system, which makes the security protocol more accurate and harder to obtain false positives. With that said, the complexity of the system continues to experience similar errors with respect to camera and sensing (Sinha, 2019). These inaccuracies will likely improve as the technology continues to evolve.

Following a similar trend of the previous examples, another form of biorecognition is through iris scanning. The iris, which is the portion of the human eye that distinguishes eye color, is unique to the human body and hardly changes as one ages, which makes it completely distinguishable from other people (Latman & Herb, 2013). The iris can be individually identified on a person whether or not the user is a contact/glasses wearer, blind, and/or if they experienced eye surgeries (Latman & Herb, 2013). To begin, the system first collects the user’s data by scanning the iris using both visible and infrared light waves (Latman & Herb, 2013). For the technology to be able to

scan the iris properly, the user needs to be staring directly into the camera lens at a short to medium distance away (Latman & Herb, 2013). Both of these images combined associate a biometric identity to the user, which gives them a unique “key” consisting of distinct characteristics of their iris (Latman & Herb, 2013). By archiving this image, technologies will be able to compare immediate scans with their archives to either allow or deny the person access. Although the cameras used for iris scanning are considered to be more expensive than the cameras for fingerprints and faces, the technology itself yields more reliable results compared to the other two methods (Sinha, 2019). It is regarded to be the most unforgeable biometric data due to the simplistic camera setup and the truly unique and unchangeable characteristics of the human iris (Latman & Herb, 2013).

Gesture Recognition

The second category consists of technologies that are designed to execute commands based on the motions of the user. The overall concept of these technologies is to read the user’s movements using cameras and sensors, interpret the movement, and perform the necessary actions based on what the user is requesting (Vuletic et al., 2019). This is similar to how a keyboard and mouse operates; if the user is telling the computer to go to the next page of a document, they send the command by scrolling down on their mouse, and the computer interprets that message by shifting the document down on the screen (Vuletic et al., 2019). However, since these are touchable buttons, the interpretation of that request is relatively simple compared to gesture recognition. For these technologies, the system must have accurate cameras and sensors to properly

decipher the commands using their software (Vuletic et al., 2019). A visual explaining gesture recognition's capabilities can be found in Figure 3.

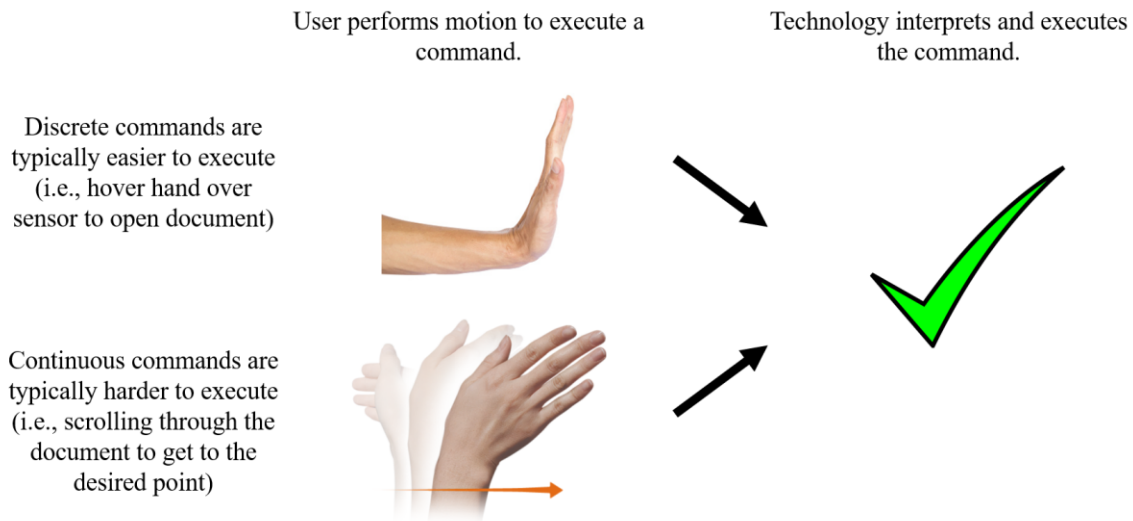


Figure 3. Visual of Gesture Recognition

For the gesture-based command sequence to work, the designers of the system must first understand how humans physically communicate with one another. Throughout human history, people have often used hand gestures to communicate their ideas and feelings (Vuletic et al., 2019). The art of communicating with one's gestures is such a strong method of communication that it is able to overcome language barriers, thereby helping individuals of different nationalities and cultures understand what one is expressing (Vuletic et al., 2019). These commonly understood messages when interpreting gestures can help the programmers/designers create the recognition language for the system (Vuletic et al., 2019). For instance, the act of executing a scrolling command can be done by making an upward swiping motion with your hand. This

upward swipe would then be interpreted by the cameras to execute the command of scrolling (Vuletic et al., 2019). It has been confirmed by studies that this type of communication is quick for a programmer to implement; this is due to the designer's plan to create commands based on instinctual motions that people use every day to communicate messages (Vuletic et al., 2019).

The two main categories of gesture commands are either discrete or continuous commands, and each of these are associated with a wide array of different communicative gestures (Liu et al., 2020; Vuletic et al., 2019). The discrete command, which includes motions such as hovering one's hand in a specific location, is primarily used for computing actions that are definite in nature (Vuletic et al., 2019). For example, hovering over a specific location would indicate that the user wants to select that item; this would be equivalent to clicking on a document in a computer setting (Vuletic et al., 2019). Interpreting static gestures as discrete commands has been relatively successful compared to continuous commands. As the advancement of gesture-based touchless technology has increased, more advanced camera and sensing equipment has been able to interpret discrete commands at higher and higher success rates (Vuletic et al., 2019). Continuous commands, however, fail to meet the same high success rates primarily due to the complexity that is associated with dynamic motion (Vuletic et al., 2019). Since a continuous command is sequential rather than instantaneous, each continuous command goes through five phases which blend with one another: (1) the user prepares to execute the motion, (2) the user begins to place their hand or body in the location where they want to begin the command, (3) the user executes the command at the location where they placed their hand or body, (4) the user begins to retract their hand or body from the

area in which they are executing their command, and (5) the user fully retracts themselves to end the command sequence (Vuletic et al., 2019). Using the scrolling example from earlier, the user must hover their hand over where they want to scroll, continue scrolling with their hand until they want to stop, and then move their hand out of the camera's scope to officially stop the command. This complex sequence of events, and the range of complexities and possibilities within each of these steps, are naturally more difficult for cameras to track and for programs to interpret (Vuletic et al., 2019). With that said, as gesture recognition technology improves with time, continuous commands have been receiving higher success rates (Vuletic et al., 2019).

The capability of gesture recognition technologies has been advancing, but the premise is still considered to be used in only niche areas (Liu et al., 2020). For instance, gesture-based technologies are extremely useful in locations where the traditional keyboard and mouse cannot be used, such as underground mining locations due to active mines not having standard office equipment (Liu et al., 2020). In addition, the technology is typically being developed for recreational use as opposed to operational. An example of this is Microsoft's Kinect One, where the cameras on the device are accurate enough to play games but not precise enough to execute accurate commands for work settings (Liu et al., 2020). Furthermore, gesture recognition technology's easy-to-learn functionality is offset by the fatigue that is created as a result of use. While gesture recognition technology's capabilities are evident, the greatest issue in this category is properly applying utility within the operational environment (Liu et al., 2020).

Touchless Sensing

The third category consists of touchless technologies that are also designed to execute commands based on motion. However, these technologies are more simplistic than gesture recognition; they are either activated or deactivated by tripping a sensor or utilizing a sense of time through an internal clock and schedule (Das et al., 2021; McMullen, 2020). Both methods of sensing do not require physical touch for its operation. A visual explaining touchless sensing's capabilities can be found in Figure 4.

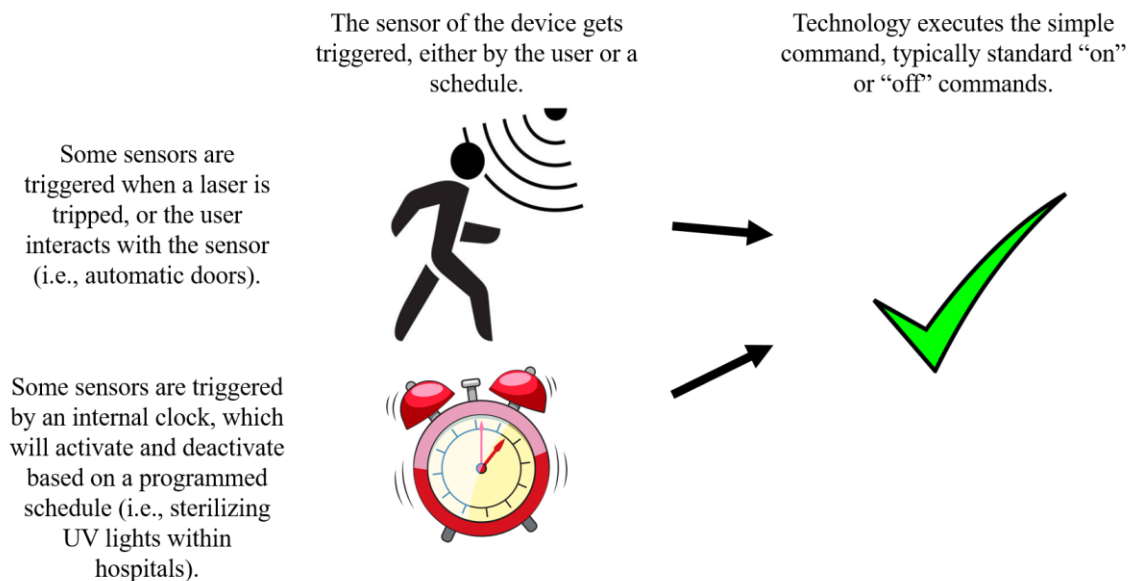


Figure 4. Visual of Touchless Sensing

The most basic form of touchless sensing technologies is where the user interacts with a projected beam of infrared light and/or ultrasonic sensors (Lozier, 2016; Das et al., 2021). As opposed to gesture recognition, the commands that are associated with touchless sensing are much simpler by nature and only require the “tripping” of a sensor

to activate (Lozier, 2016). For a device that uses lasers and sensors, it is initially static when the infrared light and/or ultrasonic sensors are unaffected (Lozier, 2016). The system will continue to remain inactive until the user interferes with the static infrared light and/or ultrasonic sensor of the system (Lozier, 2016). By “getting in the way” of the sensor or infrared beam of light, the action activates the device (Lozier, 2016). A perfect example which illustrates this sequence of events is through touchless sensing faucets; the faucet begins by not running water, and it will continue to not run water until the ultrasonic sensor underneath the nozzle receives interference from the user (Lozier, 2016). Once interfered, the faucet will activate and provide water out of the nozzle (Lozier, 2016). For these types of touchless sensing technologies, the system remains active until the sensor is no longer being interfered with. In other words, once the user is no longer affecting the sensor, the device will return back to its static state (Lozier, 2016). However, some technologies are designed to be inactivated by an automatic timer rather than a second interference event; a common purpose for this is energy conservation (Lozier, 2016). This is so that the device does not have to remain in its active state and waste resources if it is not being properly used (Lozier, 2016). Regardless of how these types of technologies deactivate (re-tripping or timer), the activation of these technologies is executed through the interference of its sensor (Lozier, 2016).

Another common form of touchless sensing is using schedules to activate and deactivate the system. For these types of devices, a sensor or infrared beam is not necessarily required because the system is not reliant on the presence of the user to be activated (Casini et al., 2019). Instead, the system is scheduled to activate and deactivate using a programmed amount of time, meaning that touch is not required for activation

and deactivation (Casini et al., 2019). An example of this type of touchless sensing technology is through ultraviolet light emitting devices; for example, it is imperative that critical rooms, such as operating rooms in hospitals, are disinfected on a consistent basis (McMullen, 2020). An effective method for hospitals to sterilize rooms quickly is to emit specific wavelengths of ultraviolet light throughout the room (McMullen, 2020).

Because this light is extremely effective at killing microorganisms, this device cannot be used with people present because its rays can harm humans (McMullen, 2020).

Therefore, the devices are activated and deactivated based on a timer, particularly during hours that humans are not inhabiting the critical rooms, thus showing that their functionality does not require the physical touch of the user (McMullen, 2020).

Another useful subcategory of timer-based sensing consists of smart-infrastructure systems that automatically track and report data through a system of links and nodes (Morimoto, 2010). These touchless sensors are becoming more prevalent in modern infrastructure planning due to their utility (Morimoto, 2010). The fundamental purpose of this type of sensors is to provide real-time data about the health and operations of a group of facilities (Morimoto, 2010). The type of information that is collected by these technologies includes (but is not limited to) electricity and water usage, room temperatures, and the structural health of a facility (Morimoto, 2010). This type of technology is utilized to track and report facility data for the purpose of gaining an understanding of the building's health. This way, the users who are collecting data can evaluate a situation accurately, make decisions based on the reported data, and execute projects to optimize their infrastructure's utility (Morimoto, 2013).

Personal Devices

The fourth category consists of touchless technologies that are personalized devices that limit the amount of physical interaction with public surfaces and technologies (Kamble et al., 2021). Regarding personal devices, it is possible for the technologies themselves to utilize a sense of touch, particularly in cases where the user is interacting with their own device (Kamble et al., 2021). With that said, the reason this is still considered a touchless technology is because a personal device acts as a buffer to minimize the effects of fomite transmission (Kamble et al., 2021). In other words, someone touching their own device limits interaction with other public devices and spaces. A visual explaining personal devices' capabilities can be found in Figure 5.

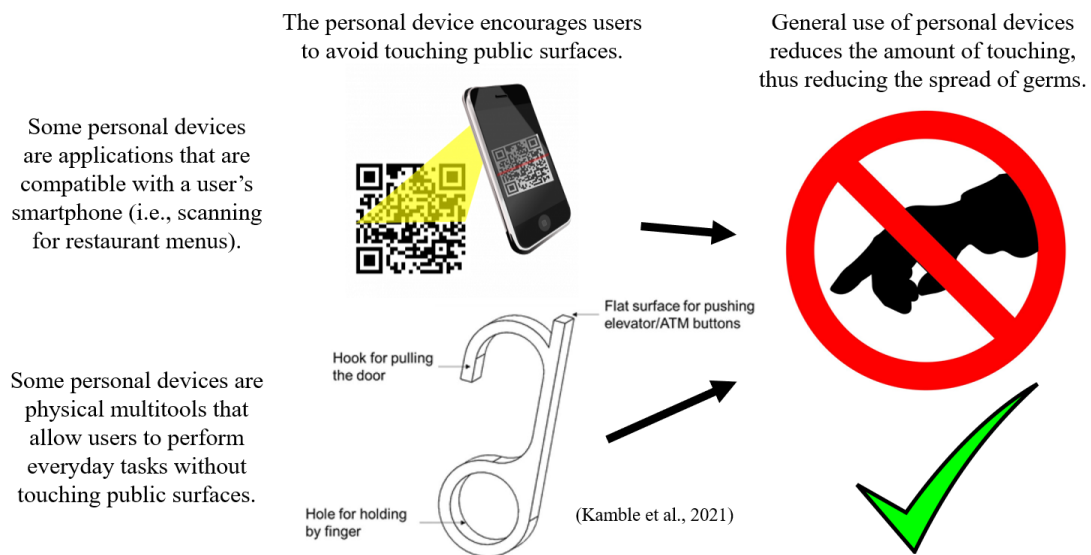


Figure 5. Visual of Personal Devices

An example of a personal device, which illustrates how simple yet effective they can be, is the COVID key; this key is a multifunctional physical tool that can be used to minimize contact from public surfaces (Kamble et al., 2021). Some of the tasks that this device can accomplish include turning doorknobs, pushing/pulling door handles, pushing elevator buttons, gripping rails, grabbing thin surfaces such as dollar bills and credit cards, opening bottles, etc. (Kamble et al., 2021). As many surfaces and objects have been touched by multiple people over an extended period of time, being able to perform these functions through a personal device allows one to avoid touching surfaces (Kamble et al., 2021). Devices such as the COVID key are portable and compact, which encourages users to be equipped with them at all times; however, the key is unable to achieve all necessary goals when it comes to minimizing the spread of germs (Kamble et al., 2021). Where many of the common applications could be accomplished with the key, there will simply be certain functions that a personal device is not built to perform (Kamble et al., 2021).

Where the COVID key serves as a personal device for physical tasks, an individual's smartphone can also be used as a touchless technology (Wanga et al., 2020). Through the use of downloadable applications, people are able to accomplish a wide array of tasks, and this includes both professional and personal/recreational tasks (Wanga et al., 2020). Professionally, during the COVID-19 pandemic, many tasks such as scheduling and conducting meetings, transferring documents, and notifying others of important information, were easily conducted through cyberspace, which allows economic productivity to survive during the shutting down of offices (Wanga et al., 2020). Personally, people were able to discuss medical issues with their doctors,

purchase groceries, order meals for their families, wirelessly book travel information, and complete other errands without having to touch the public domain and thus ensuring safety from infectious germs (Wanga et al., 2020). Recreationally, people were able to stream their favorite content without having to go to public theatres, video chat with their friends and family, and take care of their health by attending exercise classes all without the risk of infecting others (Wanga et al., 2020). For many aspects of everyday life, the COVID-19 pandemic did not stop people from being able to conduct their daily routines while remaining safe due to personal devices.

However, in instances where social interaction is inevitable, people adapted their personal devices to facilitate these interactions (Wanga et al., 2020). The development of applications allowed even the most trivial person-to-person interactions to be minimized, which in turn minimized the spread of fomite-transmitting diseases (Wanga et al., 2020). An example of this application of touchless technology exists in the restaurant business. Normally, the restaurant would distribute their menus to their customers to inform them of what they are serving, but the threat of spreading COVID-19 through the passing and exchanging of menus caused restaurants to adapt (Wanga et al., 2020). Rather than exposing their customers to danger, restaurants created downloadable menus for customers to scan and view through their smartphones (Wanga et al., 2020). Since the users are touching their own devices, they are minimizing the spreading of disease because it is only their personal device they are touching (Wanga et al., 2020).

Not only were smartphone apps helpful in conducting personal business during the pandemic, but personal devices also helped fight the spread of COVID-19 more directly (Utz et al., 2021). Smart phone application developers utilized this philosophy to

achieve the following objectives. It collected COVID-19 infection history from a network of users. Once the data was safely secured, it tracked those users' locations so that other people could identify how and where the disease was spreading (Utz et al., 2021). It also automatically sent the data to research institutions for the purpose of studying the patterns of the disease (Utz et al., 2021). For the purposes of protecting others from potential infection, citizens have generally accepted apps such as these as long as their privacy is protected (Utz et al., 2021). This category of personal devices clearly has a wide application of uses to not only encourage users to limit the touching of public surfaces, but it also helps fight the spread of fomite diseases (Utz et al., 2021).

Voice Recognition

The last of the five categories consists of touchless technologies in which the user's voice gives the device commands to execute. Touchless, hands-free technologies have allowed users to multitask; however, in examples like gesture recognition, the user may be in the middle of a task and cannot make a gesture, meaning they would be unable to multitask (Prathima & Shimi, 2017). Voice recognition technology allows users to be completely engaged in their activities while also giving commands orally, thus serving as a technology with lots of potential (Prathima & Shimi, 2017; Cronin & Doherty, 2019). A visual explaining voice recognition's capabilities can be found in Figure 6.

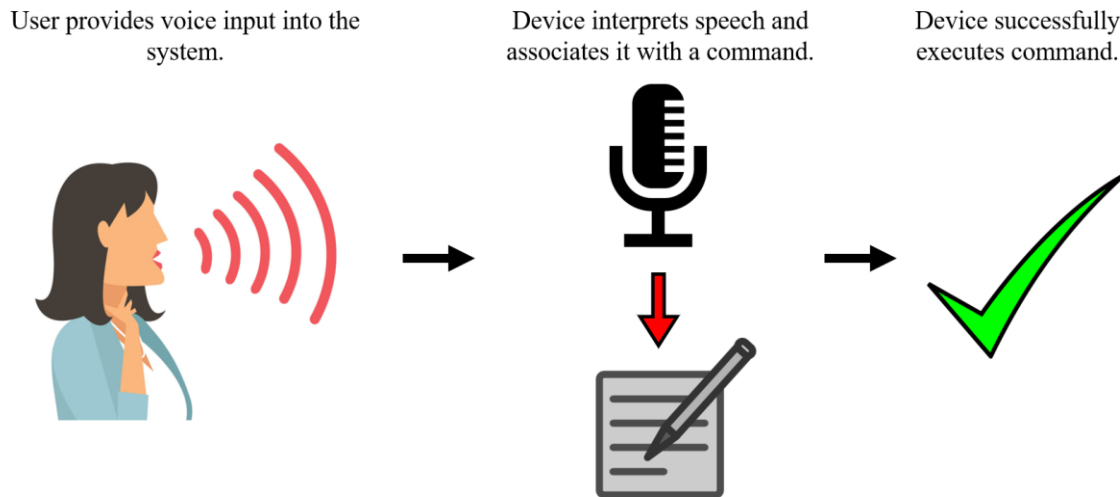


Figure 6. Visual of Voice Recognition

The overall operation of voice recognition technology consists of the user providing a command through the device's microphone, the computer within the device recognizing the speech and interpreting its meaning, and the controller of the device executing the command (Prathima & Shimi, 2017). The key step of this process, which is the interpretation of speech, is conducted through an Arduino platform/microcontroller (Prathima & Shimi, 2017). This piece of technology consists of both the physical hardware and integrated software responsible for dissecting the user's speech through the use of coding languages that transfer human speech to executable code (Prathima & Shimi, 2017). For the voice recognition module to become effective at translating speech, the system needs to be trained in both understanding the user's voice and executing commands (Prathima & Shimi, 2017). Some of the simple household commands that can be executed through this technology include, but are not limited to, switching on and off lights, controlling the television by speaking into a remote, and text-

to-speech capability that will read and send text messages through audio (Prathima & Shimi, 2017).

As previously mentioned, voice recognition technologies allow users to easily multitask, thereby letting them execute commands while simultaneously focusing on their objective at hand (Simmons et al., 2017). An example that demonstrates this is operating an automobile's console and dashboard controls (Simmons et al., 2017). Distractions while driving, particularly from cell phones and extra features built into the car, have been growing in number and causing car accidents to increase (Simmons et al., 2017). While legislation has played a role in reducing the number of people using their cell phones while driving, the demand for connectivity while on the road still remains high (Simmons et al., 2017). Whether the user desires to send a text message, enter a location to navigate to, or update their music selection, the temptation for the driver to operate their phone while driving remains extremely high (Simmons et al., 2017). While hands-free devices, such as buttons on the steering wheel, have allowed users to perform tasks such as switching songs, the growing complexity of what a personal device can accomplish requires more hands-free operability for drivers (Simmons et al., 2017). Many of those tasks can be completed now using voice recognition technology that is built into the automobile; this allows users to completely focus on their driving (Simmons et al., 2017).

This hands-free multitasking approach is not only used with cell phones, but it has been used in professional settings as well (Cronin & Doherty, 2019). In hospitals, surgeons require both of their hands and full attention to perform their work; this is where voice recognition capabilities can aid those doctors (Cronin & Doherty, 2019). It is

crucial for a doctor to remain sterile before and during the entire life of the operation, so in order to execute different commands, they cannot compromise themselves to potential germs (Cronin & Doherty, 2019). Voice-activated commands during surgery not only allows surgeons to fully focus on their tasks, but they keep surgeons from being compromised by surrounding germs (Cronin & Doherty, 2019). In hospital settings, voice recognition technologies are used to achieve multiple types of tasks (Cronin & Doherty, 2019). For example, commands for the purpose of inputting text allow a doctor to simultaneously write a report of the surgery while performing it; this is extremely beneficial because surgeons can record their experiences while the events are fresh in their mind (Cronin & Doherty, 2019). Discrete commands, such as activating lights and machinery, also allow a doctor to utilize technologies to aid them during surgery (Cronin & Doherty, 2019). While vocal fatigue is a possible outcome when constantly speaking to these technologies, utilizing vocal commands proved to be less taxing than using keyboards because the doctor did not have to spend time typing after an exhausting surgery (Cronin & Doherty, 2019).

There have been efforts to integrate facilities with voice recognition technologies in efforts to create touchless facilities (Alexakis et al., 2019). Some smart facilities contain the hardware to execute vocal commands and the proper internet connections to interpret the speech of the user (Alexakis et al., 2019). Infrastructure and built-in appliances that are connected to the internet utilize natural language processing, which is a type of artificial intelligence used to interpret speech (Alexakis et al., 2019). With this capability, users are able to identify and control aspects of the facility such as the temperature, humidity, and which lights are activated throughout the facility (Alexakis et

al., 2019). As appliances' abilities to connect to the internet continues to skyrocket, additional capabilities can be added to a smart building's overall functionality (Alexakis et al., 2019). However, this connectivity has its drawbacks. As this kind of smart facility requires an internet connection, cybersecurity threats remain a concern since the facility could be hacked by outside users (Alexakis et al., 2019). Nevertheless, voice recognition can serve to transform a facility into one that is integrated with touchless technologies, thereby providing convenience to the user (Alexakis et al., 2019).

Key Themes from Review

The entire literature review, which covered content in each of the five categories, shared common themes with one another in terms of the overarching thematic and reference analyses. Regardless of the current states of each of the touchless technology categories, a major commonality that they all share is the growing need for these technologies to improve. Vinson (2020) explains the necessity for touchless technologies: "According to market reports, the demand for touchless technology is growing at the rate of 17.4% and will reach \$15.3 billion in 2025 from \$6.8 billion in 2020. This growth is certainly a reflection of how touchless technology is considered an asset in our collective efforts to mitigate the COVID-19 outbreak." A thorough review of the collected literature confirms that while touchless technologies are evolving, their potential advantages and disadvantages are being evaluated by organizations worldwide to determine if their utility would improve their operations (Vinson, 2020).

Not only is there an evident demand present, but the desire for further exploration and study was present for each of the five categories as well. There is clearly an interest

within the scientific community to further investigate the potential that touchless technologies has to offer. Both the high demand and growing need for research illustrated the following concepts on the topic. As the push towards touchless technologies is still relatively new, progress and development of the different categories differs greatly from one another. The high variability of themes demonstrates that there is little to no universal objectivity of a technology's worth, as the analysis in the literature shows high degrees of subjectivity. Through examples of case study analyses, in-depth literature reviews, and other types of academic works, the literature identified the subjectivity in utility that touchless technologies can provide.

Conclusions from Review

The literature shows that touchless technologies serve the purpose of satisfying a specific objective, while also completing the desired goal of eliminating or minimizing touch. Determining the worth of these technologies is a difficult task because (1) each technology is different from one another and (2) each resulting outcome that can be accomplished by using them is valued subjectively amongst various organizations. Nevertheless, the information found in the literature review helps inform the research being addressed. This chapter also helps provide necessary context to the reader regarding touchless technologies.

III. Methodology

The objective of this chapter is to describe the methodology that was used to address the overarching goal of the research. The topics that will be covered in this chapter are the selection and observation of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)-compliant literature, the thematic analysis, the multiple components comprising the reference analysis, and the comparison between the two analyses. Figure 7 describes a macro level approach to the entire methodology of the research.

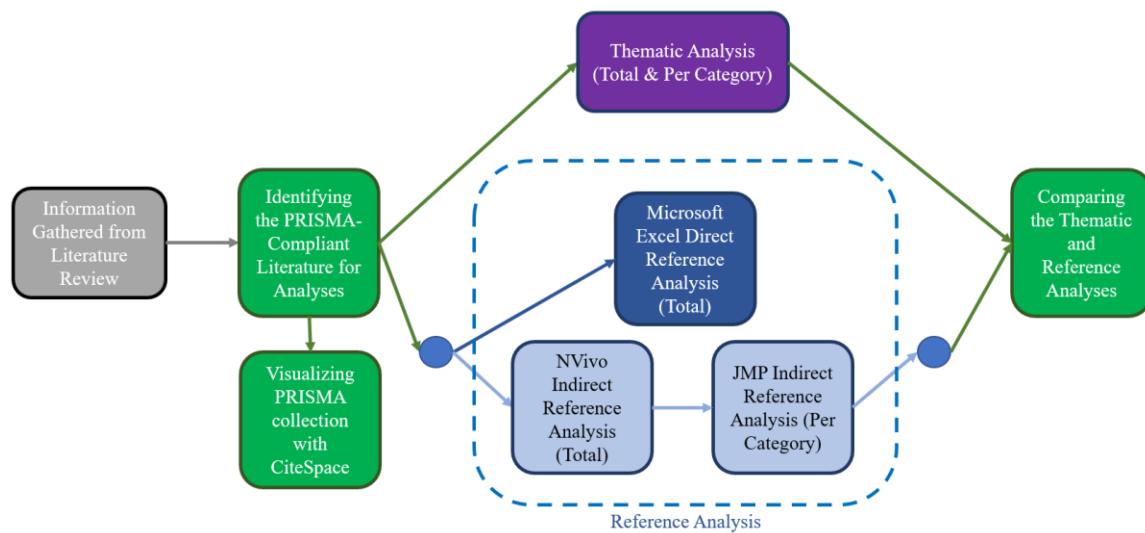


Figure 7. Methodology Flowchart

Collecting PRISMA Literature

This section will include the methodologies for identifying PRISMA literature and modeling PRISMA literature. The purpose of identifying PRISMA literature is to establish a list of collected articles that will be used to continue the research. The purpose of modeling PRISMA literature is to gain a better understanding of the selected literature before analyses begin.

Identifying PRISMA Literature

During the literature collection process, it is possible for diverse types of literature to be collected. With that said, accumulating the literature serves to be one of the biggest potential problems to preserve the replicability of the entire methodology. For a process to be repeatable, the method in which those papers are obtained needs to be systematic. If the researcher does not follow a disciplined set of procedures, and instead simply searches for literature freely, there are multiple problems that could arise. For one, the researcher may not be searching for literature in the most unbiased method possible; freely searching for articles may unintentionally insert bias and reader subjectivity into the search engine. Additionally, it is possible for the search engine itself to contain some sort of bias while searching based on the user's keywords. This variability in how a researcher can obtain literature could lead to varied thematic results because of the user's bias and/or the search engine(s)'s bias. A visual representation of identifying PRISMA literature is shown in Figure 8.

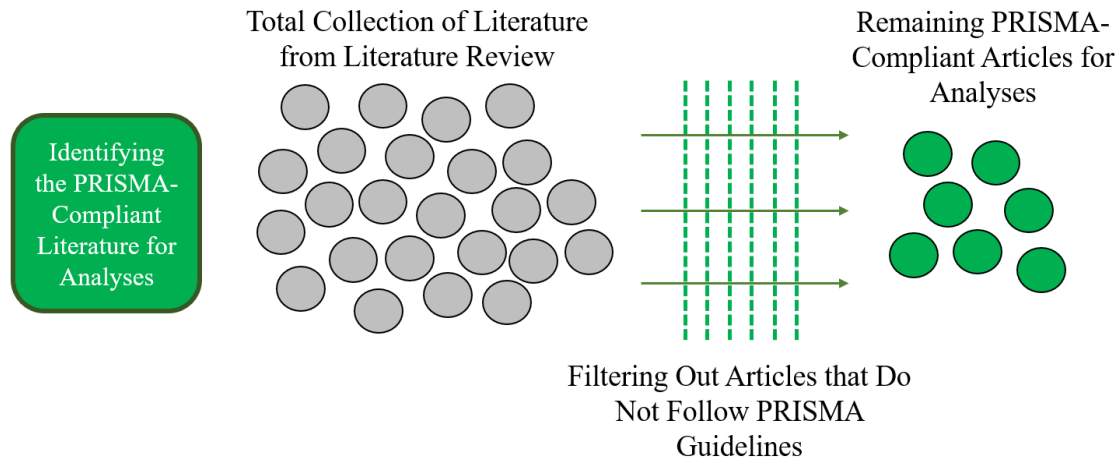


Figure 8. Visual of Identifying PRISMA Literature

An effective method of finding standardized literature is through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Rethlefsen et al., 2021). Essentially, PRISMA stipulates that articles contain the following: a clear title, abstract section, introduction, methods, results, and discussion. The titles of each of these sections may not match exactly, but the article is accepted if the format is still relatively clear. Therefore, to keep the process as repeatable as possible for future iterations, articles that did not follow this standardized structure (i.e., were not PRISMA-compliant) were removed from further analysis. However, the total collection initially provided utility because it was used to help inform the research in the literature review chapter.

In total, 76 articles were collected as a result of conducting the literature review. To determine which of these articles were considered PRISMA-compliant, each article was opened side-by-side with the PRISMA 2020 Item Checklist found from Page (2021). The process consisted of following this checklist and verifying whether or not the 76

articles contained these attributes. An article that was considered PRISMA-compliant contained elements of this checklist. If an article was missing elements of this standardization, it was removed from the collection that would be used to conduct the analyses. The reduction in overall data introduced a potential constraint in that it would be possible that not enough data could be used for analysis. It is imperative that a large enough sample size be collected to account for the potential shrinking of useable data.

The selected articles were classified as either a systematic review of a touchless technology category or a case study that provided key information on a specific touchless technology category. The following observations were made with the articles that were considered to be PRISMA-compliant.

- Each of the abstract sections covered a touchless technology category for the reader to easily identify.
- Each of the introductions provided an articulate rationale and listed their objectives to foreshadow their methodologies and results.
- Each of the methods sections contained eligible criteria regarding the quality of their information sources, data and data collection processes, effective measures regarding analysis outcomes, synthesis methods, and the assessments of those results.
- Each of the results sections contained proper diagrams and/or approaches to presenting their findings, the referenced studies were properly cited, and the results of the syntheses were effectively captured.

- Each of the discussion sections interpreted the analyses effectively, the limitations of the evidence and/or review processes were thoroughly explained, and the future implications of the results were discussed in great detail.

Each PRISMA-compliant article was found using the academic search engine Science Direct Open Access Journals found on the Air Force Institute of Technology (AFIT) online library. Articles and literature that were not found through the AFIT online library were found using Google Scholar. With the PRISMA-compliant articles selected, the methodology section could continue with both the thematic and reference analyses.

Modeling PRISMA Literature

To gain a greater understanding of the articles selected, the articles themselves were visualized according to their contents. In bibliometric analysis, a common practice of identifying the similarity of articles is the use of knowledge mapping (Zuo et al., 2021). The program CiteSpace can compare a collection of literature by identifying the mutual relationships found within patterns in the article (Zuo et al., 2021). Essentially, the higher the similarity, the closer that CiteSpace will plot the articles together (Zuo et al., 2021). Before conducting the specific thematic and reference analyses, the benefit of visualizing the PRISMA articles together is to gain a broader understanding of the collection of articles in general.

By converting the PRISMA iteration of the database into research information systems documents (RISD), they can be plugged into CiteSpace, which would produce a result relatively automatically. Two images will be visualized and examined, one being the authors and one being the contents of the articles. Conducting both will help initially

“tell the story” of the PRISMA articles before the thematic and reference analyses. To create the visualization for authors, the box for “author” was checked prior to running the program. To create the visualization for content, the box for “key words” was checked prior to running the program.

Guo et al. (2021) perfectly describes the utility of using CiteSpace as a tool for painting broader pictures: “CiteSpace usually works as an effective tool for researchers to extract network relations, research emphases, as well as research trends.” Since the focus of this methodology is not through the use of bibliometric software, CiteSpace serves as an excellent tool for “scratching the surface.” There are more advanced bibliometric programs that “present detailed information on the literature,” but since the detailed portion of this analysis would be covered within the thematic and reference analyses, CiteSpace would serve to be a more appropriate application of bibliometric modeling software (Guo et al., 2021).

Thematic Analysis

The purpose of this section of the chapter is to explain the methodology used to conduct the thematic analysis. Quoting Zhou (2022): “Thematic analysis is defined as a method to identify, analyze, and discover the patterns of themes for a set of documents. After selecting the data relevant to the objective of the project, it requires encoding the data to uncover the meaningful themes and concepts of one area.” Essentially, the overall objective of the thematic analysis portion was to understand the current state of touchless technologies by counting the number of advantages and disadvantages attributed to each technology within the articles. To answer the research questions, qualitative thematic

data needed to be collected for each of the five categories. The results of that data can help illustrate the overall advantages and disadvantages for each of the categories and for touchless technology as a whole. This process consisted of several steps that, when chronologically applied, helped identify the current state of touchless technologies. A visual representation of the thematic analysis is shown in Figure 9.

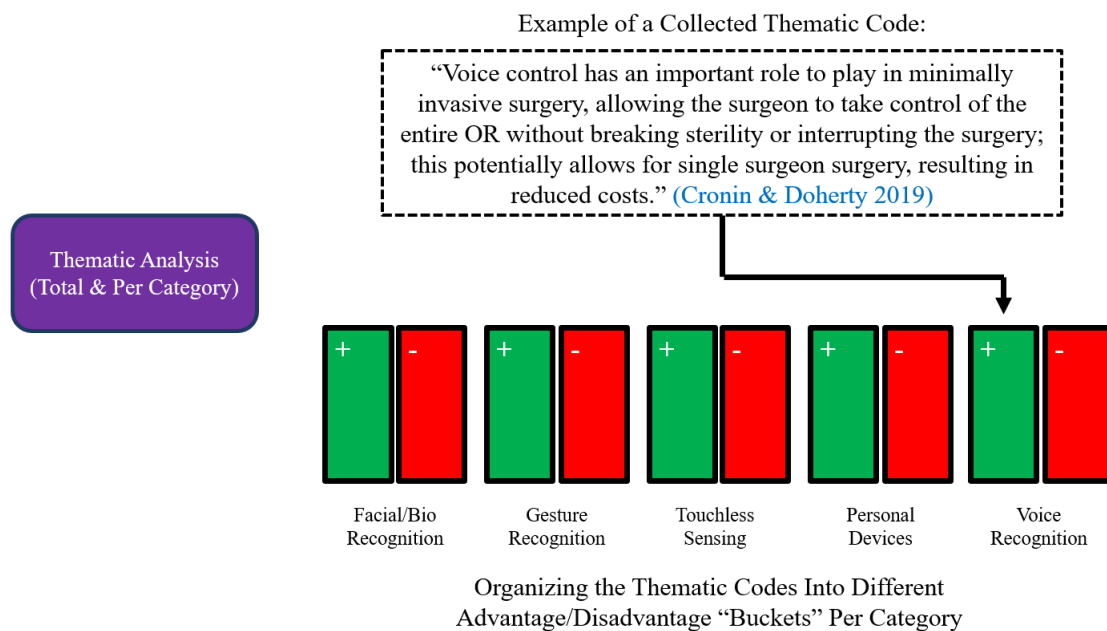


Figure 9. Visual of Thematic Analysis

The first step was gathering the PRISMA-compliant literature that elaborated on the themes of the touchless technology categories through case studies and independent literature reviews. The second step was to categorize the data collected from the literature. Since the overall objective of the thematic analysis is to weigh the advantages and disadvantages for each of the categories, there were multiple types of codes, or excerpts from the literature, that were extracted. For each of the categories, there was a

code “bucket” that collected themes expressing advantages and there was a “bucket” that collected themes talking about disadvantages. With that said, the following list includes each of the code categories: advantages for facial/biometric recognition technologies, disadvantages for facial/biometric recognition, advantages for gesture recognition technologies, disadvantages for gesture recognition technologies, advantages for touchless sensing technologies, disadvantages for touchless sensing technologies, advantages for personal devices, disadvantages for personal devices, advantages for voice recognition technologies, and disadvantages for voice recognition technologies. These code categories served as the foundation for the thematic analysis.

The third step was to read and interpret the collected data for the purposes of loading information within each of the ten code “buckets.” This process consisted of identifying when the author was expressing an advantage or disadvantage within a category. An example of this type of thought process can be found in Cronin and Doherty (2019). The following excerpt clearly expresses an advantage of voice recognition technologies within the medical field: “Voice control has an important role to play in minimally invasive surgery, allowing the surgeon to take control of the entire OR without breaking sterility or interrupting the surgery; this potentially allows for single surgeon surgery, resulting in reduced costs” (Cronin & Doherty, 2019). The authors are communicating the convenience of voice recognition technologies during surgery. Because of this, this excerpt was saved as a code, and that code was then placed into the advantages of voice recognition technologies “bucket.”

To complete the thematic analysis, it was important to quantify the qualitative information in the most objective and fair manner possible. In other words, it was not the

objective to interpret the collected codes and apply weighted values to them, for that would introduce a new level of bias into the methodology. Therefore, each of the thematic codes in a touchless technology category were weighted equally. To determine the number of advantages and disadvantages a category contained, the number of collected codes for each category's respective "bucket" were simply counted. On top of that, all of the five categories were also combined together, where all of the data that made up those five categories was used to create a composite ratio of advantages to disadvantages for touchless technologies as a whole.

The primary concern with this approach is the potential for bias and human error. Traditional keyword analysis software finds similarities within the text by matching characters and words based on word similarity. The primary problem with this traditional approach is that keywords and character/word recognition do not properly interpret the themes that are being discussed within the literature. To demonstrate an example of this limitation, Cronin and Doherty (2019) will again be referenced: "Voice control has an important role to play in minimally invasive surgery, allowing the surgeon to take control of the entire OR without breaking sterility or interrupting the surgery; this potentially allows for single surgeon surgery, resulting in reduced costs." Within this segment, the traditional keywords expressing an advantage such as "benefit," "value," or "asset" are not found, which means that an automatic keyword detector would not consider this an advantage for voice recognition technologies. In fact, the word "cost" is found within the excerpt, so even though the segment is discussing an advantage within the technology type, a traditional keyword analysis software would mark this segment as a disadvantage due to the word "cost" appearing. When conducting a thematic analysis, it is important

for the researcher to properly interpret the literature because the technology is simply incapable of doing so. Unfortunately, this leads to the reality that researchers may inject their own biases and make mistakes. Nevertheless, for a truly qualitative data analysis, it is imperative for the researcher to be diligent and impartial when deciphering both the advantages and disadvantages for any given topic.

Reference Analysis

The purpose of this section is to explain the methodology used to conduct the overall reference analysis. Bornmann and Marx (2013) discuss cited reference analysis by elaborating their take on a traditional analysis: “In contrast, we change the perspective and start by selecting all papers dealing with a specific research topic or field... Then we extract all cited references from this field-specific publication set and analyze which papers, scientists, and journals have been cited most often.” Rather than using a traditional citation analysis, which counts the individual citations within the article, the goal behind this reference analysis is to validate the results of the thematic analysis by demonstrating that the contents of the PRISMA-compliant literature are correlated with one another via their reference sections. Two different approaches were used for the reference analyses. The first approach consisted of direct reference analysis using Microsoft Excel, and the second approach consisted of indirect reference analysis using both NVivo and JMP software.

Direct Reference Analysis

Direct reference analysis treats every reference as a specific data point, and those specific data points are then cross-referenced across all the literature to find matches. As such, all of the PRISMA-compliant literature was reviewed to identify all exact matches found within their reference sections. However, the main problem that occurred when combing through the reference sections was that not all of the articles used the same bibliometric style. Two other issues that were found were that (1) not all of the references across all the articles were cited correctly and (2) not every saved PDF contained “copy-able and paste-able” reference data. It was clear that the data needed to be standardized, organized properly, and saved into a “copy-able and paste-able” format. A visual representation of direct reference analysis is shown in Figure 10.

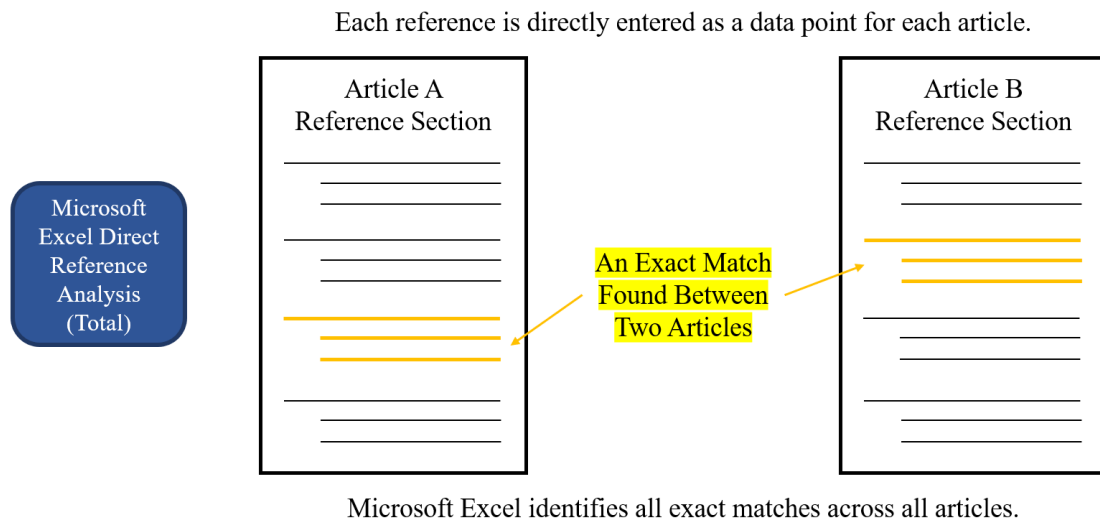


Figure 10. Visual of Direct Reference Analysis

Therefore, a Microsoft Word document was created that corresponds with every respective PRISMA-compliant article used during the analysis, sharing the same numeric label system. The numbers in the documents' titles also corresponded with each article's abbreviated author and year. For example, the Word document for the article named "COVID Key: A Multifunctional Device to Avoid Touch" by Kamble, Pushkar, Mittal, Hodgir, and Karunakaran was named "(Kamble et al., 2021)". Both the article and the Word document shared the number title "64:" within their titles for easy identification. Next, each article was opened alongside a tab of Google Scholar. To ensure that each of the article's references were standardized and precise, each reference was copied and pasted from the article directly into the Google Scholar search bar. From there, the reference was standardized by Google Scholar and available in three different formats: MLA, APA, and Chicago. The Chicago format was chosen because it uses full names rather than abbreviations. It was inferred that this format would provide more accurate data for the indirect reference analysis to be conducted next. The standardized Chicago format for each reference was then copied and pasted into each of the article's associated Word documents. These references would be considered data points for a data set, where the data set represents the collection of PRISMA-compliant articles.

From there, a Microsoft Excel data table was developed with the columns corresponding with the articles and the rows for each column corresponding to the references in each article. To transfer the contents from each Microsoft Word document into the Excel data sheet, each reference was copied and pasted into each respective cell of the data sheet. This process fully populated the data sheet with every reference of every article. On a separate worksheet, a matrix was created, where the dimensions of

each side of the matrix equaled the number of articles used for analysis. The idea was that each combination of row and column on the matrix would provide the reader a number of exact matches between the two article's references. To accomplish this, a series of commands were utilized on the previous data sheet. These series of commands not only identified whether or not there were exact matches between two specified columns, but it also counted how many exact matches existed between those two columns. These commands applied for every combination of articles, and whenever a successful cross-reference was found between two articles, that cell was highlighted to make it easier for the researcher.

Indirect Reference Analysis (Total)

To contrast the direct reference analysis, the indirect reference analysis finds similarities using a different method. Rather than finding exact matches across distinct data points, the NVivo software reads all the data as one generalized data set for each of the PRISMA-compliant articles. The software is able to find similarities between different article's relationships based on word patterns. These similarities are measured through Pearson correlation coefficients, which track the similarity that is found between different combinations of articles. A visual representation of indirect reference analysis is shown in Figure 11.

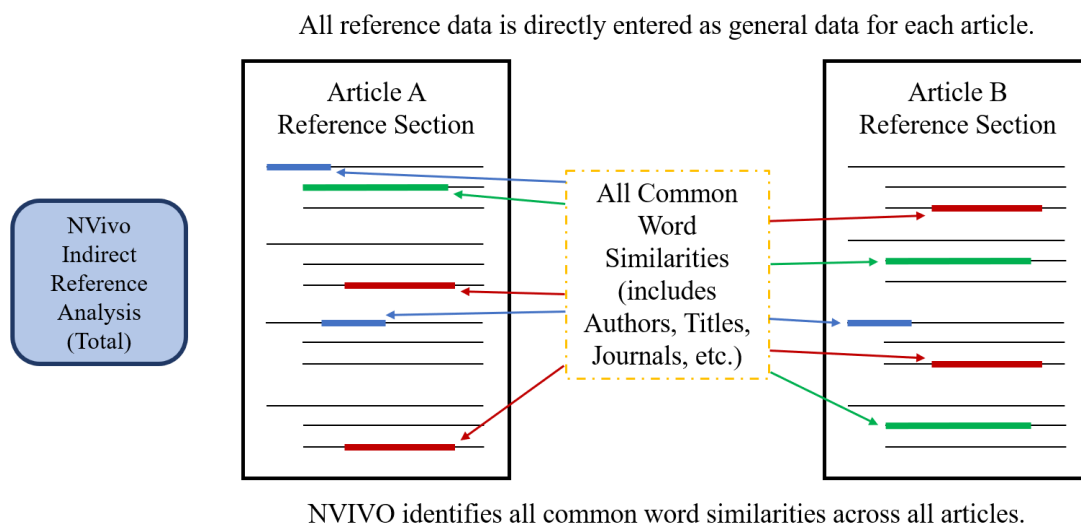


Figure 11. Visual of Indirect Reference Analysis (Total)

Referring to the previous section, all of the Chicago-style references for the PRISMA-compliant articles were saved in separate Microsoft Word documents. Using the already compiled documents, each of them were transferred into the NVivo software, where each article's reference data was a file containing all of the references for that article. To run a correlation analysis for each of the files, each of the article's reference data needed to be entered into the system. This was accomplished by highlighting each of the references and saving them as data within each file. Once that was completed, the correlating process within the software could begin. Similar to that of the direct reference analysis, the NVivo software also evaluates two PRISMA-compliant articles at a time, where the measured correlation between the two selected articles was identified through word similarity. This showed that selecting the Chicago reference was indeed advantageous. The fact that this reference style compared full names and titles, rather than abbreviated ones, meant that a more accurate correlation between two article's

reference sections could be found. From there, the NVivo software produced a data set of Pearson correlation values between different combinations of articles. It also produced a visual representation of the strongest relationships of articles based on Pearson correlation.

When all of the Pearson correlation data was obtained for each of the article relationships, the data was exported to Microsoft Excel, where a histogram was built. The bin sizes were selected to be small enough to show detail, but large enough to be easy for the researcher to interpret. Along with the histogram, descriptive statistics were also calculated and recorded. These descriptive statistics were the mean, median, standard deviation, skewness, and kurtosis of all the Pearson correlation data.

Indirect Reference Analysis (Per Category)

The purpose of this subsection is to take all of the Pearson correlation values of the article's relationships, sort those relationships into the five touchless technology categories, and run a one-way analysis of variance (ANOVA) statistical test on them. Along with the one-way ANOVA, the three basic assumptions of independently collected samples, equal variance, and normality need to be examined for the purpose of validating the results of the one-way ANOVA. All of the data was obtained from NVivo, transferred into JMP, and then analyzed. A visual representation of indirect reference analysis for each category is shown in Figure 12.

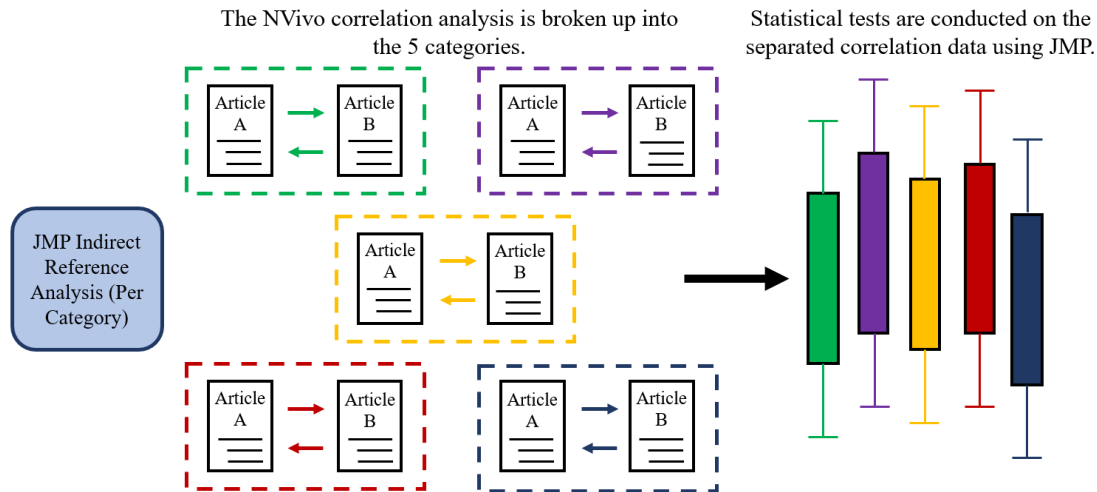


Figure 12. Visual of Indirect Reference Analysis (Per Category)

The initial step in conducting this transition from NVivo to JMP was to first separate the total reference data into the five touchless technology categories. This was accomplished by keeping track of which articles contained thematic data within each of the five touchless technology categories. Within NVivo, five new and separate projects were created, where each of the uploaded Microsoft Word files were re-uploaded into each of those five projects. If there was an article that contained thematic data for multiple touchless technology categories, then that same Word document would be uploaded to each of the projects separately. Similar to the total indirect reference analysis, after the reference data was entered for each of the five categories, five separate data sets were then created. Each of these data sets contained Pearson correlation data for the article relationships only within that touchless technology category. The five separate data sets were exported into the same Microsoft Excel spreadsheet, the data was then “cleaned up” and organized to be all in one data set, and then that data was transferred

over to JMP, where the statistical testing could take place. The statistical tests included the main ANOVA test and the additional O'Brien, Brown-Forsythe, Levene, Bartlett, Shapiro-Wilk, and Kruskal-Wallis tests. To conduct each of the necessary statistical tests, the commands were simply searched within JMP's interface and then performed.

Comparing Analyses

The purpose of this section is to compare the results from the thematic analysis and the reference analysis. Both analyses produced valuable results for each of the five categories, as well as touchless technologies as a whole. It is important to take the time to conglomerate all of the collected results into one figure for the purpose of creating observations from the overall results. A visual representation of comparing analysis is shown in Figure 13.

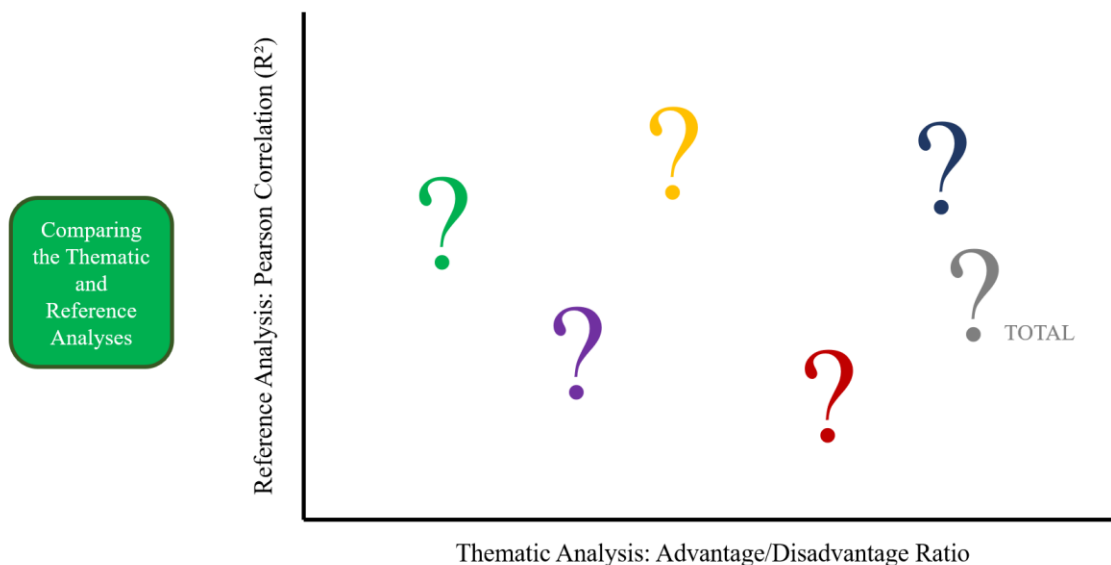


Figure 13. Visual of Comparing Analyses

The metric that was used to record the thematic analysis data was the advantage to disadvantage ratio, so this metric's data was listed for each of the categories on a column of a Microsoft Excel spreadsheet. The metric that was used to record the reference analysis data was the Pearson correlation coefficient, so this metrics data was also listed for each category on an adjacent column of the spreadsheet. The compared metrics were applied to produce a single scatter plot, where each of the categories would be represented by a separate point on the plot. A regression line was then added to provide some context on the relationship that was occurring between the results of the two analyses. Finally, when interpreting the graph, conceptual clusters were illustrated, which signals to the reader the potential relationship that technology categories within the clusters share.

IV. Results

The purpose of this chapter is to display and explain the results that were produced from the methodology outlined in the previous chapter. Both the thematic analysis and the reference analysis generated valuable results. Throughout the entire analysis process, multiple sets of results were generated, which will be illustrated in the same format as they were explained in the methodology section. Brief interpretations of the results will also be included for the benefit of the reader.

Collecting PRISMA Literature

This section will include results both for identifying PRISMA literature and modeling PRISMA literature. The results of identifying PRISMA literature establishes a list of collected articles that were used to continue the research. The results of modeling PRISMA literature helped to gain a better understanding of the selected literature.

Identifying PRISMA Literature

Of the 76 articles that were used to gain high-level knowledge regarding touchless technologies, 31 were used for the overall bibliometric (both thematic and reference) analyses, as shown in Table 1. These 31 articles followed basic PRISMA standards by containing a proper title, abstract, introduction, methods, results, and discussion. The table also indicates whether the specific article contained thematic data from each of the five touchless technology categories. If the article contained thematic data from a category, the cell is shaded green. If not, the cell is shaded in red.

	Does the Piece of Literature Contain Themes in this Category? (GREEN = YES) (RED = NO)					
	Facial/Bio Recognition	Gesture Recognition	Personal Devices	Touchless Sensing	Voice Recognition	
Alexakis et al., 2019	Green	Red	Red	Red	Red	Green
Casini, 2019	Red	Red	Red	Green	Red	Red
Chenhao & Kimar, 2018	Green	Red	Red	Red	Red	Red
Cronin & Doherty, 2019	Red	Green	Red	Red	Red	Green
Das, 2021	Red	Red	Red	Green	Red	Red
Doll and Bearman, 2018	Red	Red	Red	Green	Red	Red
Gerba, 2015	Red	Red	Red	Green	Red	Red
Grover & Sabherwal, 2020	Red	Red	Green	Red	Red	Red
Habibi & Chattopadhyay, 2021	Red	Green	Red	Red	Red	Red
Iqbal & Campbell, 2020	Green	Green	Red	Green	Red	Red
Kamble et al., 2021	Red	Red	Green	Red	Red	Red
Kumar and Shimi, 2015	Red	Red	Red	Red	Red	Green
Landgrebe, 2011	Red	Red	Red	Green	Red	Red
Latman and Herb, 2013	Green	Red	Red	Red	Red	Red
Li et al., 2021	Red	Red	Red	Green	Red	Red
Liu et al., 2020	Red	Green	Red	Red	Red	Red
Lozier, 2016	Red	Red	Red	Green	Red	Red
Mata and Milner, 2021	Red	Red	Red	Red	Red	Red
McMullen et al., 2021	Red	Red	Red	Green	Red	Red
Meyer et al., 2014	Red	Green	Red	Red	Red	Red
Minagawa et al., 2014	Red	Green	Red	Red	Red	Red
Morimoto, 2010	Red	Red	Red	Green	Red	Red
Morimoto, 2013	Red	Red	Red	Green	Red	Red
Nicol, 2020	Red	Red	Red	Green	Red	Red
Pei-Lee et al., 2015	Red	Green	Red	Red	Red	Red
Ramanathan et al., 2021	Green	Red	Red	Red	Red	Red
Simmons et al., 2017	Red	Red	Red	Red	Red	Green
Tokazhanov et al., 2021	Red	Red	Red	Green	Red	Red
Utz et al., 2021	Red	Red	Green	Red	Red	Red
Vuletic et al., 2019	Red	Green	Red	Red	Red	Red
Wanga et al., 2021	Red	Red	Green	Red	Red	Red

Table 1. Table of PRISMA-Compliant Literature

In Table 1, there are multiple occurrences of an article containing multiple themes. For example, the article labeled “Iqbal & Campbell, 2020” contains thematic advantages and/or disadvantages for the facial/bio recognition, gesture recognition, and touchless sensing categories. Elaborating further on this example, it is possible for an article to contain one or more of these themes per category. Therefore, when counting the number of papers that support each functional category, the total number of green cells per column (35) does not add up to the 31 articles used for the overall bibliometric analysis. To be expected, there are more green cells than articles. Rather than using the word “article,” the terminology for these green cells will be called “files” for the thematic analysis, which will be further explained and shown in the following section.

Modeling PRISMA Literature

Figures 14 and 15 illustrate the relationship between PRISMA articles through clustering. Figure 14 examines the contributing authors of the PRISMA collection, and Figure 15 examines the contents discussed within the articles. Visualizing the relationships between the different articles helps the researcher gain an understanding of the categories’ potential similarities before the official thematic and reference analyses are presented. Note that for both Figures 14 and 15, the rainbow color pattern of each cluster represents the strength of similarity within each cluster (i.e., red represents the most similarity, yellow represents medium similarity, purple represents the least similarity). The lines themselves indicate that a connection exists between authors/content, showing how multiple lines webbed together creates a cluster of information.

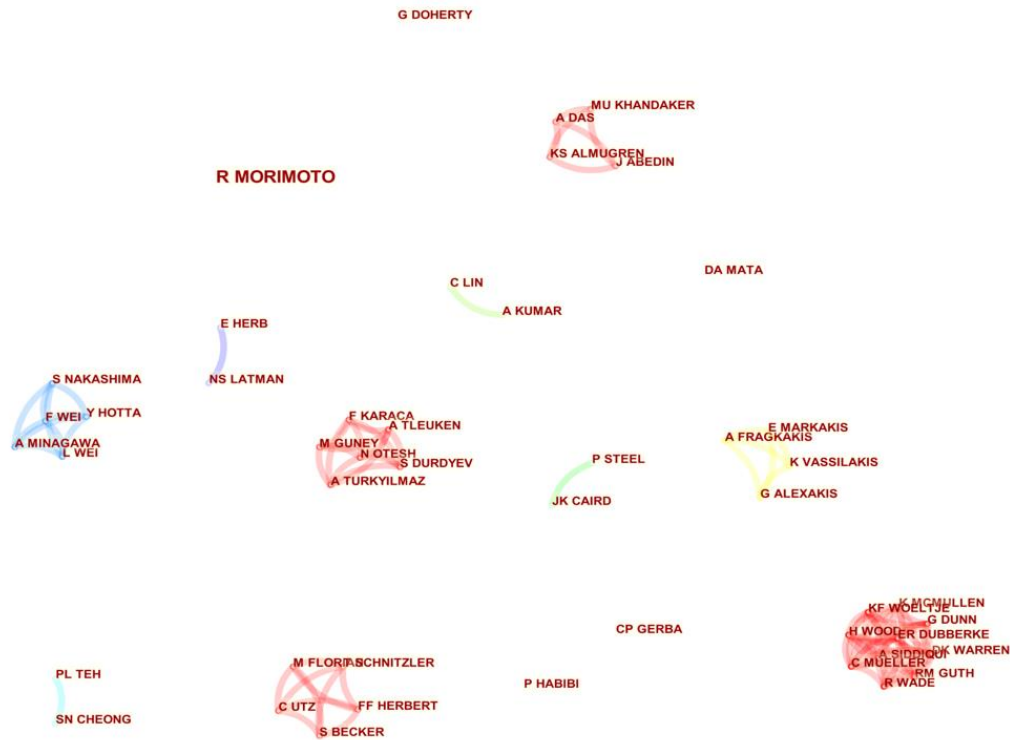


Figure 14. Model of PRISMA Literature (Authors)

Figure 14 communicates several key points. The clusters of authors indicate that certain authors contribute literature within their respective fields. Naturally there are certain fields of expertise that contain more authors, and these are mainly for topics that have a longer history and more literature available. Despite the separation of clusters, the clusters seem relatively equidistant to each other. Although cited authors remain consistent within their areas of expertise, the homogenous distancing of the clusters indicates that authors are cited relatively evenly throughout the collection of literature. When examining the contributing authors across the entire PRISMA collection, it is important that the collection of authors utilizes subject matter experts within their field while also properly diversifying sources. It is clear that Figure 14 supports this concept.

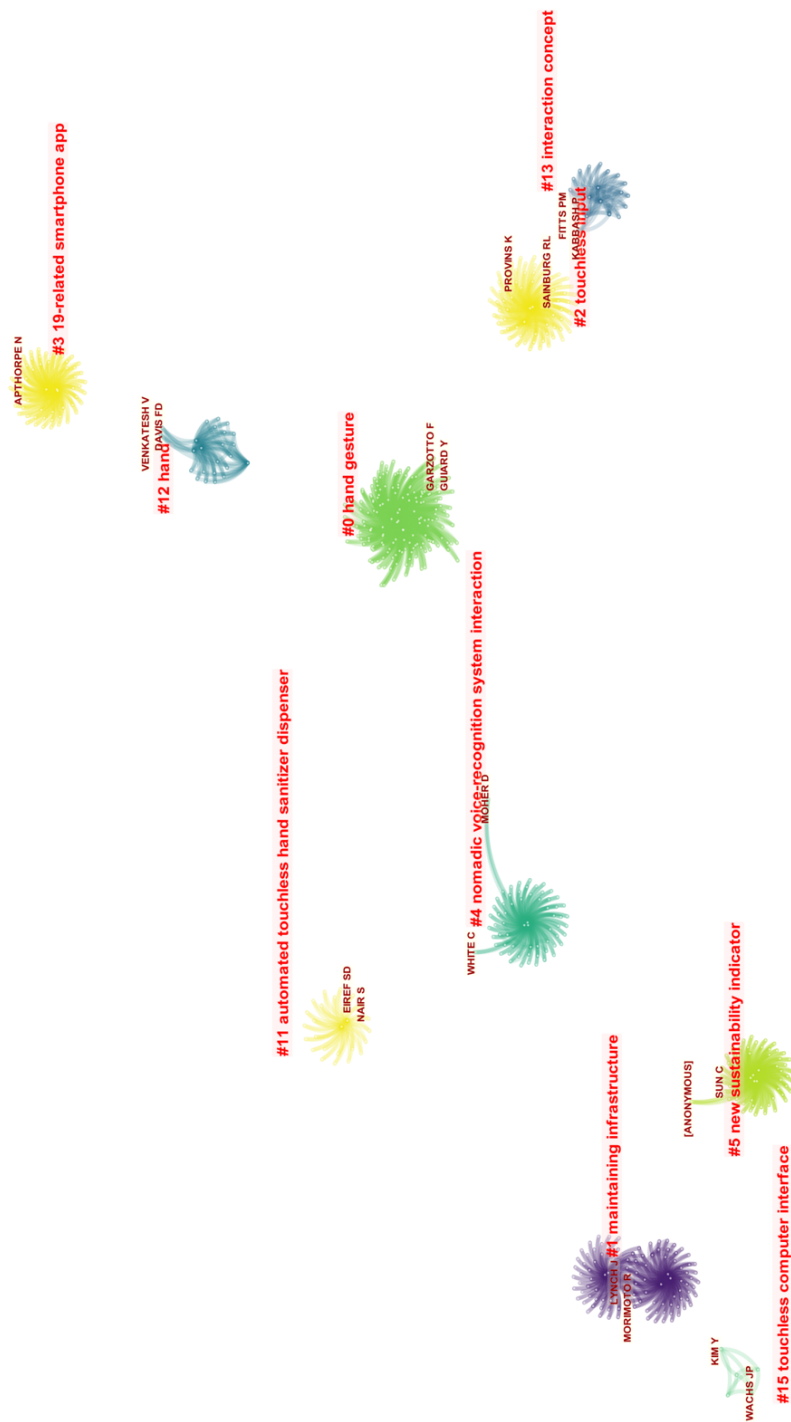


Figure 15. Model of PRISMA Literature (Content)

As expected, based on the shapes of the clusters and the locations of the nodes, the contents within the articles shown in Figure 15 are not equal. There are articles that contain more similarities with one another, and as expected, the similarities correlate with the information presented in Table 1. It is evident that articles that discuss similar touchless technology categories will be closer together and clustered in groups. One of the reasons that five separate and neat clusters based on category do not appear is because there are several articles that discuss more than one topic, thus complicating the visualization. There are also certain subtopics that appear relatively close to one another, such as “new sustainability indicator,” “maintaining infrastructure,” and “touchless computer interface” in the bottom left corner of Figure 15 (i.e., for touchless sensing). These nearby clusters are discussing similar topics within the category, but not necessarily talking about the same technologies, thereby resulting in separate yet nearby clusters. The contents within the articles are not clearly assigned a specific topic, yet they discuss relatively similar subject matter based on the general type of touchless technology. It is clear that Figure 15 supports this concept.

Thematic Analysis

The purpose of this section is to display the results of the thematic analysis. As discussed in the methodology section, the purpose of this was to discover the current state of touchless technologies by counting the number of advantages and disadvantages and calculating ratios. Figure 16 represents the overall diagram showing the results of the thematic analysis.

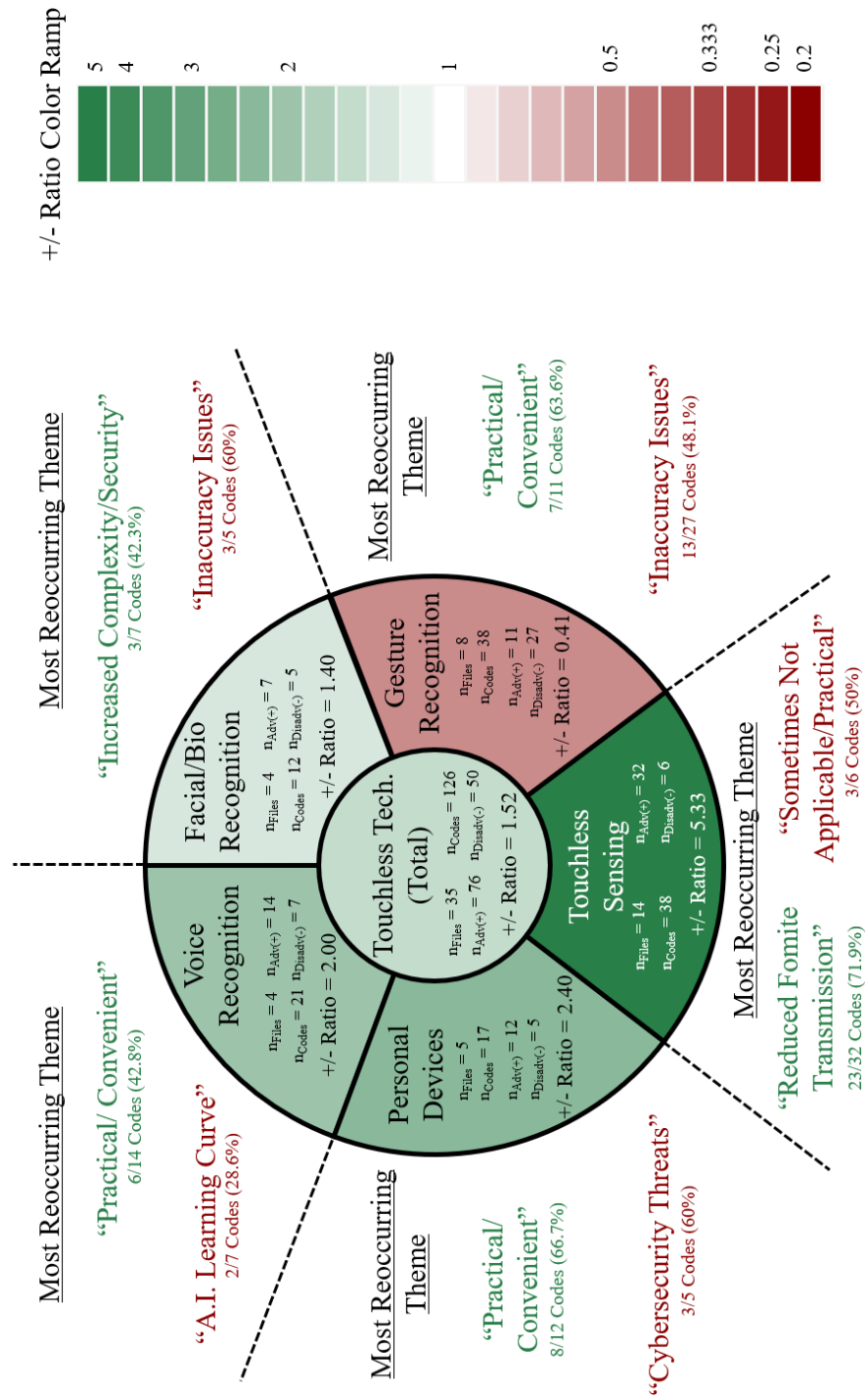


Figure 16. Results of Thematic Analysis

In Figure 16, six cells (the five categories plus touchless technologies as a whole) are displayed to illustrate the results of the analysis. To properly illustrate the results of the thematic analysis, a commonly recognized color ramp is utilized to communicate each category's advantage to disadvantage ratio. The color ramp initially spans from darker greens (high ratios) to lighter greens (lower ratios, but still a ratio above 1). These colors indicate that within the section, there were more advantages that were counted compared to disadvantages. From there, the color ramp turns white, which indicates that a category's number of advantages and disadvantages is the same, which results in a ratio equal to 1. The color ramp then turns into lighter reds (higher ratios that are below a ratio of 1) and darker reds (low ratios), which signals that the results of the analysis contained more counted disadvantages than advantages. The benefit to using the color pattern of dark greens → light greens → white → light reds → dark reds is that these colors are a universally accepted method of communicating whether something is net positive or negative and by how much.

Not only does the color provide valuable information, but the calculated advantage to disadvantage ratio, the number of files, and the number of collected codes are also available for each category to provide more data on the subject. Because the data here are the collected thematic codes, the figure also provides the most prevalent advantages and disadvantages theme found for each category. The most common themes are also color coded to express whether they are illustrating an advantage or disadvantage; a quantifiable percentage of how prevalent this theme was across all of the codes for that category is also included. Observing all of the aspects of the figure

provides an accurate snapshot of the current state of touchless technologies from the viewpoint of the thematic analysis.

The results of the thematic analysis showed that the different types of touchless technologies are currently experiencing a variety of advantages and disadvantages. More information regarding each thematic code and its categorization as either an advantage or disadvantage can be found in Appendix A. When looking at the facial/biometric recognition category in Figure 16, there were 7 counted advantages and 5 counted disadvantages, which means that the advantage to disadvantage ratio for the category is 1.40. The number of files that were used for the analysis was 4, and the number of codes within the articles for this category was 20. The color of the section in the diagram is a light green color, signaling that its advantage to disadvantage ratio contains a slightly higher count of advantages compared to disadvantages. The most reoccurring theme found for advantages discussed the increased amount of security due to the complexity and non-replicability of biorecognition, and this theme occurred in 42.3% of the category's positive codes. Contrasting this point, the most reoccurring theme for facial/bio recognition's disadvantages, which occurred in 60% of the collected negative codes, was the inaccuracy issues regarding identifying the user.

Moving on to the gesture recognition category, 11 counted advantages and 27 counted disadvantages were found within the articles, leading to an advantage to disadvantage ratio of 0.41. The number of files that were used for this section's analysis was 8, while the number of codes for this category was 38. The color of the section in the diagram displays a medium to medium-dark red color, signaling that its advantage to disadvantage ratio contains a heavier concentration of disadvantages compared to

advantages. The most common theme found for advantages elaborated on how basic gestures are such a natural way that humans already communicate, meaning that it is relatively practical and convenient for users to communicate through gestures. This positive theme occurred in 63.6% of the category's advantage codes. The most common theme found for disadvantages was how there are currently inaccuracy issues with the technology, which means that commands are not properly registered within the technology type. This theme made up 48.1% of the technology type's disadvantage codes.

The touchless sensing category had the greatest advantage to disadvantage ratio of all the touchless technology categories. There were 32 counted advantages and 6 counted disadvantages found within its articles, resulting in an advantage to disadvantage ratio of 5.33. Fourteen files were used for this section's analysis, where 38 codes were found across the section's literature. Unlike the two previous categories, the color shown for touchless sensing is dark green, indicating that there is a substantially higher number of counted advantages compared to disadvantages. The highest reoccurring theme found for advantages explained how this type of technology was highly effective in mitigating the effects of fomite transmission. This theme was found in 71.9% of the category's advantage codes. The most common theme found for disadvantages was that there were instances where installing this type of touchless technology may not have been the most practical. This theme appeared in 50% of the technology type's disadvantage codes.

Similar to the positive results for the touchless sensing category but to a lesser degree, the personal devices category had 12 counted advantages and 5 counted disadvantages, resulting in an advantage to disadvantage ratio of 2.40. To complete this

portion of the analysis, 5 files were utilized, and 17 codes were found within its articles to complete the analysis. The color found in this section within the diagram displayed a medium shade of green, indicating that the number of advantages was not as high as the touchless sensing category, but high enough compared to its disadvantages to give it a solid green color. The most common theme found for personal devices was how practical and convenient users felt this type of technology was, and this theme was found in 66.7% of the advantage codes. The biggest theme against personal devices discussed how integrating personal technology increases the level of cybersecurity risks, and 60% of codes expressed this idea.

Voice recognition technologies followed a similar trend to that of personal devices, where 14 advantages were counted and 7 disadvantages were counted, leading to an advantage to disadvantage ratio of 2.00. This type of touchless technology's analysis was based on 7 files, where the number of codes found within its literature was 21. The color closely followed that of the previously discussed category of a medium green, being that the advantages moderately outweighed the disadvantages. The most reoccurring theme of this portion of the analysis, which was similar to that of the personal devices category, was on the convenience of voice commands and the practicality of simply giving a command orally. This theme was found in 42.8% of the advantage codes. The biggest thematic flaw of voice recognition technologies, which occurred in 28.6% of negative codes, was how the artificial intelligence within the technology takes time to learn the user's voice and understand commands, thus leading to inaccuracies in the beginning.

Combining the advantage and disadvantage counts across all five categories, the current state of touchless technologies can be analyzed to provide a broad snapshot. In total, 84 advantages were counted and 50 disadvantages were counted, thus leading to a total advantage to disadvantage ratio of 1.68. The total number of files for the overarching thematic analysis was 35 (i.e., the total number of green cells from Table 1), and the total number of codes was 134. The color that was shown as a result of combining the count data was a lighter green, which means that there was a slightly higher number of advantages across the board compared to the disadvantages. Thematically, the most common themes were not collected at this level because of the differences in the five major touchless technology types. It would not serve the analysis to find commonalities in themes when the technologies themselves are extremely uncommon/unrelated to each other.

Reference Analysis

The purpose of this portion of the chapter is to display the results of the reference analysis. As discussed in the methodology section, the purpose for conducting the reference analysis was to validate the results of the thematic analysis by demonstrating that the respective references used within the 31 articles were correlated with one another. To reiterate from the methodology chapter, this subsection contains the results of two different analyses: the direct reference analysis using Microsoft Excel and the indirect reference analysis using NVivo and JMP (Bornmann & Marx, 2013).

Direct Reference Analysis

Figure 17 compares the number of shared references between any 2 of the 31 PRISMA articles. Both the vertical and horizontal axes contain the same list of the 31 articles in alphabetical order. To identify the number of exact matches that two articles share, the researcher would have to find the cell that corresponds to the papers in the vertical and horizontal axes. For convenience, any positive match between two article's references is shown by highlighting the cell in yellow. Within the yellow cell, the number of exact matches in their respective reference section is shown.

Across all 465 combinations of different articles, there were 11 instances where two papers shared at least one reference (i.e., the count of yellow boxes above or below the black line). This means that approximately 2.37% of the cells were yellow, indicating at least one reference match. Across the entire sample of 1,112 references, there were 29 references that were shared (i.e., the number total within the yellow boxes). This means that approximately 2.61% of all references are shared between two or more articles. In total, 29 matches were found across the 11 yellow boxes, leading to the average number of shared references per relationship to be about 2.63. Of the 11 yellow boxes, 8 of them only share one reference and 3 of them contained multiple shared references. The yellow boxes with multiple shared references were 2, 3, and 16, respectively.

It is reasonably inferred that the explanation for 16 shared references between two papers is that the papers were written by the same author(s). In this instance, both articles were written by one sole author (Risako Morimoto), which means that the methods to locate and obtain references were probably similar for both papers. By simply looking at the titles of the two articles, “Estimating the benefits of effectively and proactively maintaining infrastructure with the innovative Smart Infrastructure sensor system” and “A socio-economic analysis of Smart Infrastructure sensor technology,” it is likely that they discuss the same type of topic and are built with the same type of contributing information. By removing this outlier, 13 of the 1,096 references were shared across 29 articles, which leads to a percentage of about 1.19% shared references.

As a whole, an observation of the direct reference analysis is that it appears to have a trustworthy degree of validity. On one hand, it would likely be unhelpful if none of the articles had any matches within their reference sections. Since an article’s references represent the source of their contributing information, it would be reasonable to conclude that no shared references means that the information is completely disconnected. This could potentially be a problem because information that has zero overlap in sources could result in a disjointed thematic analysis. On the other hand, it would also likely be unfavorable if the articles shared too many matches within their references. Too many matches would symbolize that the collected sample is not diverse enough and likely gathered from the same places, which means that the information and themes extracted from these papers would not be reliable either. Incorporating these two ideas to the collected sample, the fact that 2.61% of the references are shared likely illustrates that there is an ideal balance between referential reinforcement and broadening.

In general, it is reasonable to assume that more matches would be found in a sample if touchless technology research groups existed. The status quo of touchless technologies seems to be that they are only investigated when necessary or needed. In other words, the application drives researching touchless technologies. Theoretically, if touchless technologies drove the research for investigating applications, it is possible to identify more pairings in this type of direct reference analysis. The effort for specifically addressing a technology type could imply that more technology-centric literature would be cited, meaning more references could be shared. While this concept does not apply to this research, investigating this theory as touchless technologies evolve would be interesting and deserves to be mentioned.

Indirect Reference Analysis (Total)

Figure 18 compares the indirect similarities of references across the 31 PRISMA-compliant articles. In summary, each of the references within each article was identified as a collection of data, where they contained a list of attributes including the contributing authors, title, journal issue, and date. The NVivo software reads this information to find similarities based on word patterns. These similarities between articles are measured by utilizing Pearson correlation coefficients.

NVivo calculated Pearson correlation values for every relationship of two articles' similarities of references to include authors, dates of publication, titles of works, and publication data. Figure 18 and Table 2 show a visual and tabular depiction of the results. Note that only the top 25 Pearson correlation values are shown in Table 2; the complete list of Pearson correlations can be found in Appendix B. The purpose of

showing both versions of the results is to illustrate the journal article combinations with the strongest correlated relationships.

In total, there were 465 combinations of papers identified for NVivo's indirect reference analysis. The measurement metric that was used to track the correlation between two pieces of literature was the Pearson coefficient value. For easier readability, the results for the visual representation were organized into four different line thicknesses as shown in Figure 18. In summary, there were 2 article pairings that had a Pearson correlation between 1.0 and 0.7, 7 article pairings that contained a Pearson correlation between 0.7 and 0.5, 63 article pairings that contained a Pearson correlation between 0.5 and 0.3, and 393 article pairings that contained a Pearson correlation between 0.3 and 0. The heavy concentration of Pearson correlations between 0.3 and 0 is demonstrated better in Figure 18.

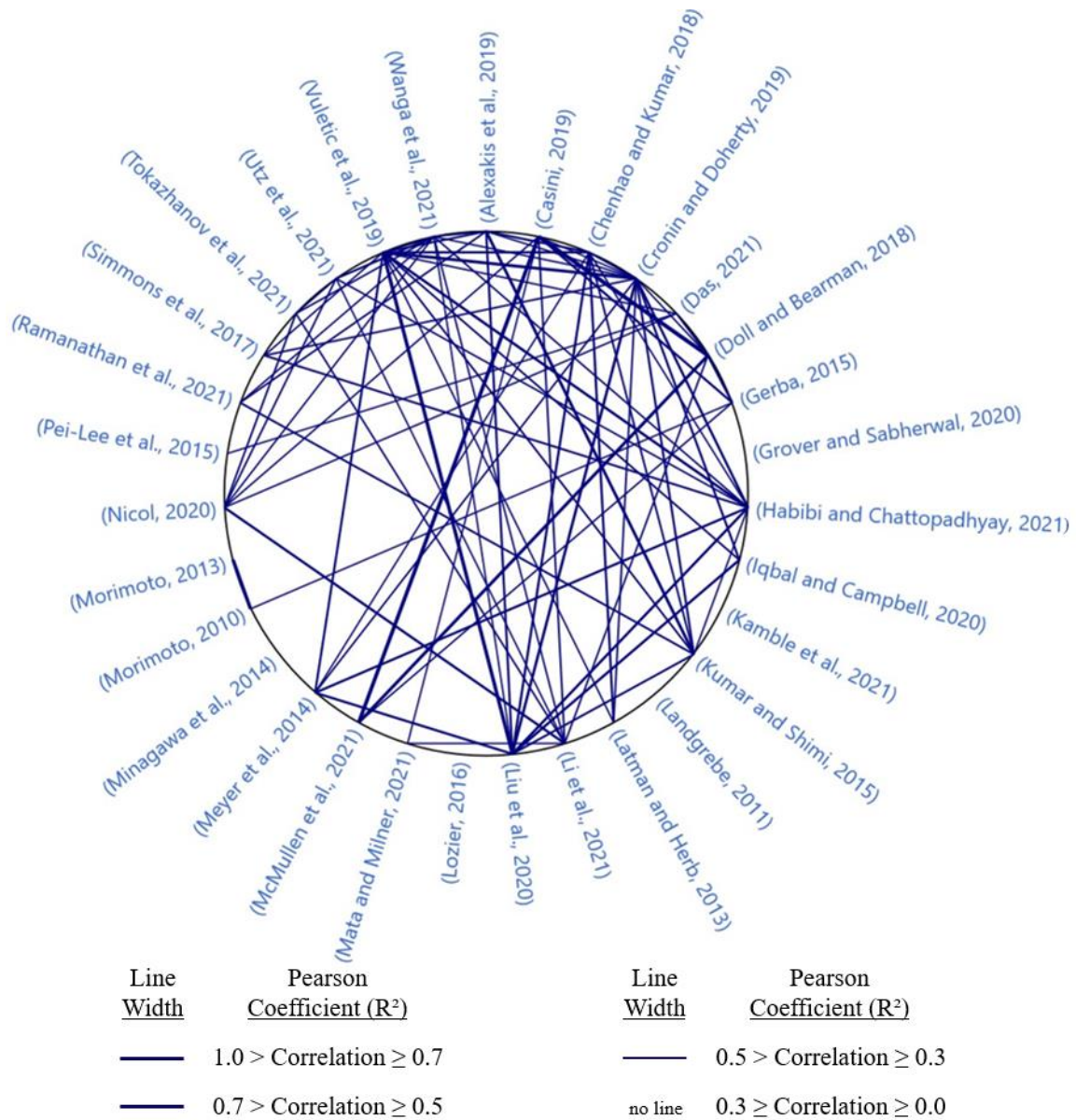


Figure 18. Model of Indirect Reference Analysis (Total)

Items Clustered By Word Similarity - Correlation Table (Top 25 Listed)			
Rank	Literature File #1	Literature File #2	Pearson correlation coefficient (R^2)
1	Doll and Bearman, 2018	Casini, 2019	0.759098
2	McMullen et al., 2021	Casini, 2019	0.710524
3	Vuletic et al., 2019	Liu et al., 2020	0.669154
4	Morimoto, 2013	Morimoto, 2010	0.669087
5	McMullen et al., 2021	Doll and Bearman, 2018	0.59741
6	Vuletic et al., 2019	Cronin and Doherty, 2019	0.573518
7	Kumar and Shimi, 2015	Alexakis et al., 2019	0.551421
8	Liu et al., 2020	Cronin and Doherty, 2019	0.520423
9	Vuletic et al., 2019	Habibi and Chattopadhyay, 2021	0.509417
10	Liu et al., 2020	Habibi and Chattopadhyay, 2021	0.498219
11	Liu et al., 2020	Iqbal and Campbell, 2020	0.484127
12	Nicol, 2020	Li et al., 2021	0.473147
13	Habibi and Chattopadhyay, 2021	Cronin and Doherty, 2019	0.468543
14	Meyer et al., 2014	Habibi and Chattopadhyay, 2021	0.458949
15	Liu et al., 2020	Chenhao and Kumar, 2018	0.454986
16	Meyer et al., 2014	Liu et al., 2020	0.453413
17	Gerba, 2015	Doll and Bearman, 2018	0.44571
18	Vuletic et al., 2019	Chenhao and Kumar, 2018	0.444826
19	Gerba, 2015	Casini, 2019	0.444738
20	Latman and Herb, 2013	Chenhao and Kumar, 2018	0.433807
21	Chenhao and Kumar, 2018	Alexakis et al., 2019	0.43004
22	Iqbal and Campbell, 2020	Cronin and Doherty, 2019	0.42612
23	Vuletic et al., 2019	Meyer et al., 2014	0.423779
24	Liu et al., 2020	Alexakis et al., 2019	0.420611
25	Wanga et al., 2021	Utz et al., 2021	0.420417

Table 2. Table of Indirect Reference Analysis (Total)

Figure 19 visually shows all 465 article combinations by comparing the Pearson correlation values with the frequency of how often those values occurred. When analyzing the histogram, the descriptive statistics help numerically illustrate the results of the correlations. The mean of the histogram is 0.19 and the median is 0.18; because the histogram's mean and median values are not equal, the histogram's distribution does not take on a Gaussian shape, meaning that the distribution is not symmetrical. The shape and direction of the histogram's non-symmetry can also be identified through the skewness value of 1.16, which signifies that the distribution is right leaning and that the concentration of outliers exist within the right tail of the histogram. The concentration of

correlation data around the mean correspond to the standard deviation of 0.12 and the kurtosis of 2.44. The relatively high standard deviation indicates that the data is more spread out around the mean rather than concentrated centrally, and the relatively low kurtosis value implies that there are more data points located within the tails of the distribution compared to a standard Gaussian distribution.

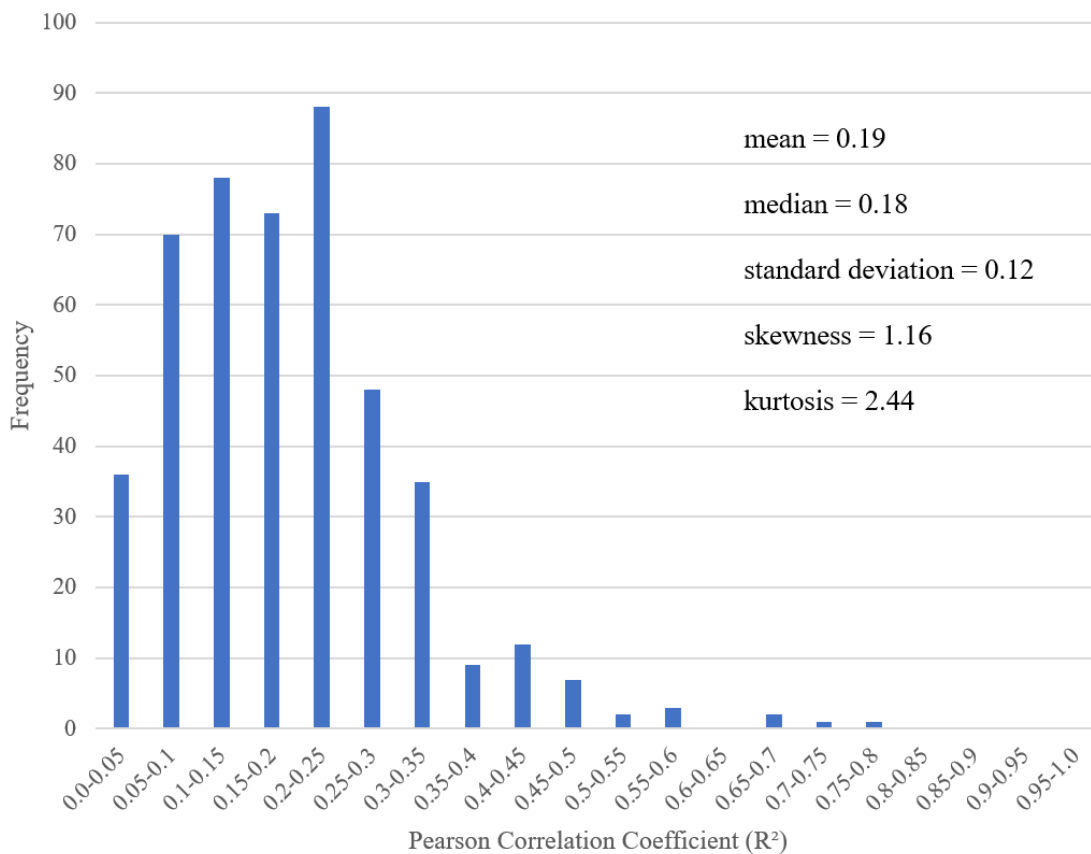


Figure 19. Histogram of Pearson Correlations

The results of the indirect reference analysis reflect the results of the direct reference analysis, demonstrating validity in both processes. In the direct reference analysis, the vast majority of article pairings did not share a common reference (i.e., the majority of the cells in the matrix were white in color, not yellow). Additionally, there were a few select pairings that contained more than one direct relationship, thus skewing the overall percentage of shared references. These results mirror that of the indirect reference analysis, where the majority of pairings had a Pearson correlation between 0.3 and 0. The few pairings which had the largest Pearson correlations skewed the overall results of the indirect analysis, causing Figure 19 to have a right tailed distribution. The results of both analyses convey the same message. While there are articles that contain similarities with one another, the majority of articles refer to many different articles. This helps reinforce the validity stated in the results of the direct reference analysis, where there is an ideal balance between referential reinforcement and broadening.

Indirect Reference Analysis (Per Category)

To reiterate, the purpose of this portion of the indirect reference analysis was to take all of the Pearson correlation values of the articles' relationships, isolate those relationships into the five touchless technology categories, and run a one-way analysis of variance (ANOVA) statistical test on the five categories to determine whether the five mean Pearson correlation values were statistically equivalent. Along with the one-way ANOVA, the three basic assumptions of independently collected samples, equal variance, and normality need to be examined for the purpose of validating the results of the one-

way ANOVA. All of the data was obtained from NVivo, transferred into the program JMP, and analyzed from there.

The first of these statistical tests was the one-way ANOVA, for which the results can be found in Figure 20. The null hypothesis of the test was that the mean Pearson correlation of each touchless technology category is the same. The alternative hypothesis was that the five categories do not share the same mean Pearson correlation values. A probability (α) value of 0.05 was assigned to conduct the analysis.

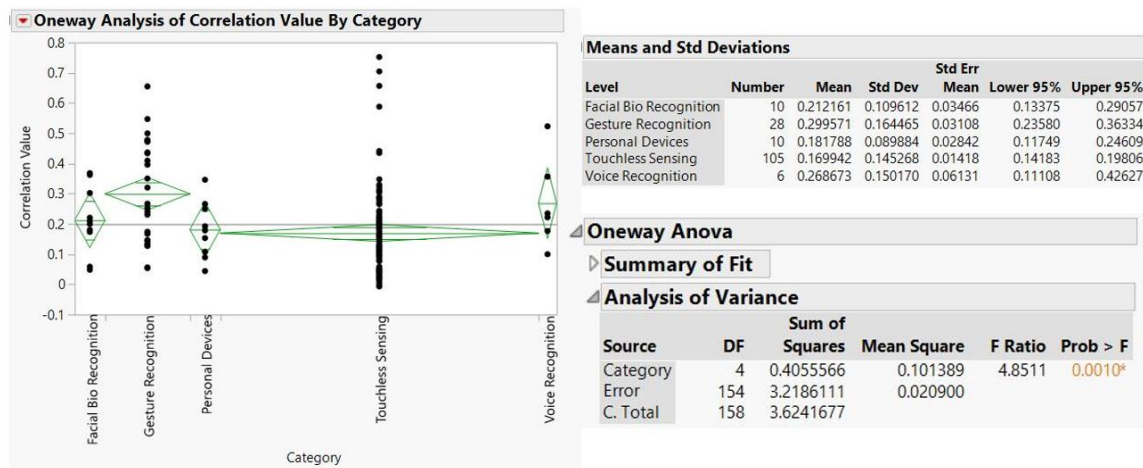


Figure 20. Results of One-Way ANOVA

The results of the one-way ANOVA test was that the probability value was 0.001, which is less than the assigned probability of 0.05, meaning that the null hypothesis was rejected, and the alternate hypothesis was accepted. From a statistical viewpoint, the five touchless technology categories did not share the same mean Pearson correlation values for their article's relationships. The facial/bio recognition category's articles had a mean Pearson correlation of 0.21, the gesture recognition category's articles had a mean

Pearson correlation of 0.30, the personal device category's articles had a mean Pearson correlation of 0.18, the touchless sensing category's articles had a mean Pearson correlation of 0.17, and the voice recognition category's articles had a mean Pearson correlation of 0.27.

To validate the results of the one-way ANOVA, the three assumptions and their respective statistical tests needed to be conducted. The first assumption is that the articles were collected independently. As explained in the methodology section, the approach taken to collect the academic literature demonstrated independence; therefore, the first assumption is met. The second assumption is that the variance of each of the five categories' correlation data are equal. The four statistical tests that were conducted to satisfy this assumption were the O'Brien, Brown-Forsythe, Levene, and Bartlett tests, all of which measure the variance of the Pearson correlation data in different ways. Again, a probability (α) value of 0.05 was assigned to conduct the analyses. The null hypothesis was that the variances of each category were equal, and the alternative hypothesis was that they were not equal. The results of those four tests are found in Figure 21. All four of the tests provided probability values that were greater than the assigned test probability of 0.05 (O'Brien $\rightarrow$ 0.78, Brown-Forsythe $\rightarrow$ 0.20, Levene $\rightarrow$ 0.13, Bartlett $\rightarrow$ 0.29). For these tests, there was not enough evidence to reject the null hypothesis; therefore, the null hypothesis was accepted, and the Pearson correlation's variance was considered equal across the five categories. The results of the four equivalent variance statistical tests further validate the results of the one-way ANOVA.

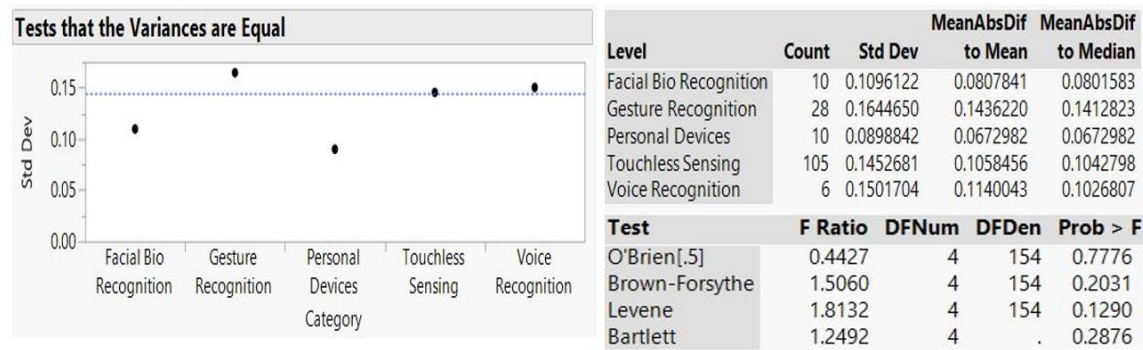


Figure 21. Results of ANOVA Equal Variance

The third assumption required to validate the results of the one-way ANOVA is that each of the five categories' correlation residuals were distributed normally. The initial statistical test that was conducted was the Shapiro-Wilk test, which measures the residuals of the data set. The null hypothesis was that the residuals across all of the Pearson correlation data would be normal, where the alternative hypothesis was that those residuals were not normal. The results of the initial test are shown in Figure 22. As shown in Figure 22, the Shapiro-Wilk test failed, meaning that an alternative test must be conducted to validate the ANOVA results.

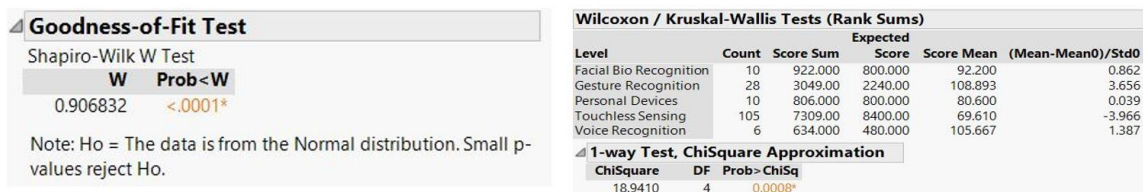


Figure 22. Results of ANOVA Normal Residuals

Therefore, another statistical test can be performed in the case of non-parametric situations (i.e., non-normal distributions). The results of the Kruskal-Wallis test (which can also be found in Figure 22) can help validate the one-way ANOVA in these unique cases. For this test, the null hypothesis would indicate that the mean Pearson correlation values for the five categories are equal, and the alternative hypothesis would suggest that the mean Pearson correlation values are not the same across the five categories. The probability of the Kruskal-Wallis test was 0.0008, which was lower than the assigned probability (α) value of 0.05. This means Pearson correlation values across the five categories are not the same, which agrees with the results of the Shapiro-Wilk test. Therefore, although the third assumption of normality does not apply, the alternative Kruskal-Wallis test for these special circumstances validates the one-way ANOVA results.

The results of the indirect reference analysis per category reflect the initial CiteSpace visualization of data for contents. The cluster diagram vividly showed that the contents of each article differ from one another, where certain clusters form based on similarities that were likely touchless technology categories. The results of the indirect reference analysis reach the same conclusion, showing that the reference sections per category are not equivalent in Pearson correlation value. Both of these results suggest that each of the touchless technology categories differ from one another. This could be explained by the different applications in technologies and how those variations lead to either a broader or more diverse array of research papers on the topic. This idea is further explained in the following section as well as in the conclusion.

Comparing Analyses

The purpose of this subsection is to compare the results from the thematic analysis and the reference analysis. The mean Pearson correlation coefficients found from the JMP analysis were graphed with the results from the thematic analysis, where each of the five categories, and touchless technologies as a whole, were plotted as singular data points. Included with the categorical plot points is a trend line showing the relationship between the two analyses, as shown in Figure 23.

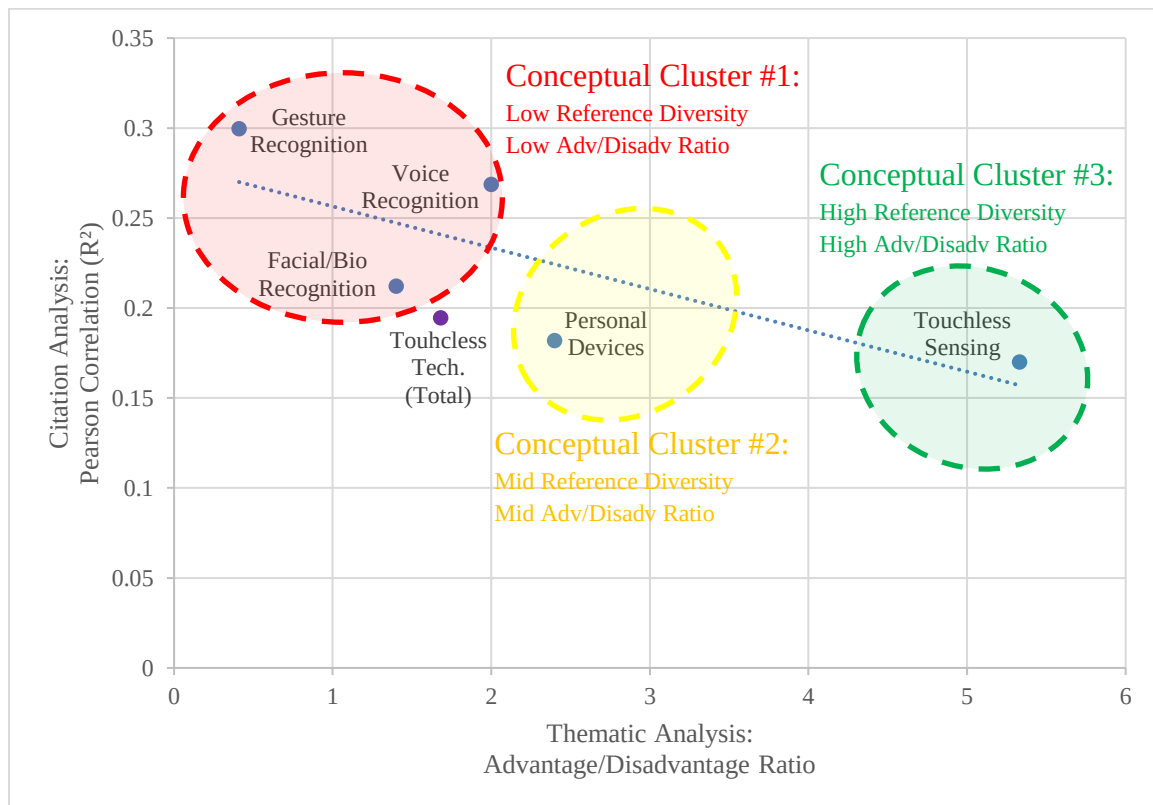


Figure 23. Results of Comparing Analyses

At first glance, it seems as if the results of the thematic analysis and the reference analysis share an inverse relationship; in other words, the category's referential relationship in terms of word similarity appears to increase as the category's advantage to disadvantage ratio decreases. Due to the fact that these two analyses were radically different from one another, and because each analysis was qualitative and quantitative in nature, respectively, it would not be scientifically feasible or realistically possible to use a trend line like this to predict things such as future touchless technology categories that may appear. With that said, the results from this plot provide a lot of valuable insight, which will be discussed in the conclusions chapter.

V. Conclusion

The objective of this chapter is to use the content of the previous chapters to answer the investigative questions posed in the first chapter. The investigative questions were answered as a result of completing the methodology and analyzing the results of the research. The two questions are listed below along with the answers. This chapter also includes a discussion of applications to the U.S. Air Force and recommendations for future research.

Answers to Investigative Questions

This section addresses the two investigative questions. The first investigative question was, “What is the current state of touchless technologies?” The second investigative question was, “How are the results of the thematic and reference analyses related? What can be concluded from evaluating the results of the two analyses together?” The answers to these questions serve as the foundation for exploring the capabilities, conveniences, and drawbacks of touchless technologies.

Answer to Investigative Question 1

From examining all of the information presented in this research, it is clear that touchless technologies are incredibly diverse, contain advantages in many different ways, and are constantly growing in both demand and attention. It is impossible to assign an exact value to a technology’s worth because of the subjective nature that each technology offers to different users. With that said, from a broad viewpoint, the growing capabilities

and investment towards touchless technologies show that they are indeed being subjectively valued by many people. Whether the attention given to touchless technologies was for convenience or necessity, they have certainly offered organizations methods to achieve desired tasks without physical touch.

It is evident through the information presented in the literature review and the results of this research that certain types of touchless technologies provide more benefit and experience fewer problems than other types. Whether the reasoning behind these realities is the difficulty of the task at hand, complexity of the technology, and/or the technology's track record of improving with each iteration, it is clear that not all categories are created equal. All things considered, this does not mean that certain technologies are considered good, average, or bad. Certain groups of people may find more value in investing in simpler, more convenient technologies that have high reliability. For others, their goals may require specific technologies that have the ability to produce higher benefits than other commonly found devices. This is all up to the user, both in the way they decide to maximize the use of touchless technologies and how they decide to invest in them moving forward.

Answer to Investigative Question 2

In general, the relationship between each category's thematic and reference data deals with the possible utility of each category. Categories that are more limited and specific in utility produce more correlated references. These categories also record fewer overall advantages because the amount of broad applicability is low. In contrast, categories that are broader and diverse in utility produce less correlated references.

These categories also contain a larger number of overall advantages because of the high broad applicability being able to produce many different benefits.

Gesture recognition, facial/bio recognition, and voice recognition technologies have all been included in one conceptual cluster. Each of these three categories appear to have strong Pearson correlation values with one another while having a relatively lower advantage to disadvantage ratio. In terms of evaluating the references for each of these categories' articles, the strong Pearson correlations would suggest that there were many similarities in authors, article titles, and journal editions. A reasonable explanation for these similarities is that the relative recency of these new types of technologies means that the number of authors is probably condensed to a smaller, reoccurring few names. Similarly, the applications for these types of technologies are likely to be very few as well, leading to the assumption that the case studies used in the articles were probably similar. When applying this type of thinking to form a conclusion about the similar ratios, the variability of applications for these types of technologies is limited to a small number of specific uses. This, along with the relative recency of these types of technologies, may indicate that there are simply not enough identified advantages for these types of technologies yet. This conceptual cluster signifies that the amount of diversity with these types of technologies is small, leading to stronger connections in references. This also leads to the smaller number of advantages compared to the inevitable disadvantages that will occur.

Personal devices have been included in another conceptual cluster which has a relatively average Pearson correlation coefficient among its articles, and it also has a relatively average advantage to disadvantage ratio compared to the other categories.

Similar to the previous cluster's analysis, this conceptual cluster appears to have more diversity within its utility. In terms of its references, the wider practicality of personal devices means that a broader array of case study topics can be found, which would lead to a greater number of article titles and journal issues. The authors of these different applications would be more diverse as well, leading to the lower Pearson correlation values compared to the previous cluster. When applying the larger amount of possible utility to the cluster's advantage to disadvantage ratio, the wider number of uses serve to provide a greater number of advantages for this category. The more functionality within this cluster has the potential for more advantages compared to the inevitable disadvantage any piece of technology would have.

The final conceptual cluster includes the touchless sensing category. In general, applying the idea of diversification for each of the three conceptual clusters serves to fit the touchless sensing technology category correctly. Touchless sensing technologies have historically been in use the longest out of all of the categories, meaning that the number of applications and uses exceeds the other categories. This leads to a greater number of contributing authors who could produce literature, a higher number of case studies pertaining to the category, and a larger number of journal issues on the topic, which would cause the mean Pearson correlation value to be relatively lower than the other categories. The larger sample size in terms of technological utility means that the number of advantages compared to its disadvantages exceeds that of any other category. It is reasonable to conclude that this conceptual cluster's broad diversity has led to it containing the greatest advantage to disadvantage ratios and the least correlated reference sections amongst its literature.

The primary conclusion to draw is that technologies that have been able to perform a wide array of tasks have been able to produce lots of benefit for users. While there are clearly advantages for the niche categories, their widespread applicability has not matched that of the more general categories of touchless technologies. In time, as more uses are found for these technologies, they will all have greater ratios and less connections reference-wise. This is inevitable in a continuously evolving technological world.

Application to U.S. Air Force

As stated previously, every organization values each piece of technology in a unique manner, and this reality is no different for the U.S. Air Force. It would be impractical for the Air Force to apply touchless technologies universally across all installations and units because not every unit values them in the same way. To contrast that point, it would also be irresponsible to allow every unit commander to customize their own facilities with touchless technologies without sufficient justification. There needs to be a balance achieved between standardization of technologies and interpreting their necessity.

It can be said that some of the touchless technology categories, particularly ones that are simple and diverse in utility, are already found on Air Force installations. Many facilities on Air Force bases take advantage of touchless sensing technology due to the wide array of uses it can offer. Many entrances across the Air Force are automatic, many faucets within restrooms already contain sensors, and many conference rooms contain motion-activated lighting to conserve energy. It is apparent that the Air Force in general

values simplicity, reliability, and conserving resources, so the application of touchless sensing technology remains prevalent within Air Force infrastructure.

On the other hand, certain technology categories are not found to the degree of touchless sensing because of the potential risks they pose. For example, the Air Force greatly values cybersecurity; however, current voice recognition technologies and personal devices contain risks that could expose the Air Force network to potential hacking. Where there are advantages to implementing this technology, the Air Force's subjective stance on protecting their cyberspace shows why they have not integrated these categories within their infrastructure. The Air Force also values being as monetarily efficient as possible, aiming to make responsible decisions with taxpayer dollars while fulfilling its mission needs. Where simple touchless sensing technologies are generally cost effective, there are more complex technologies of each category that are more expensive in comparison. Until the Air Force sees a way in which these high costs are worth the investment, it will continue to execute its missions without these more expensive technologies.

With a constantly advancing technological world, it is likely that touchless technologies will become cheaper to install in the future. On top of that, the initial problems of inaccuracy, cybersecurity threats, and lack of applicability will likely be addressed, thus making them greater potential investments. It will be the Air Force's responsibility to constantly reevaluate their position on touchless technologies. Through the Air Force's subjective lens, where today it may not be advantageous to integrate many different touchless technologies, that conclusion may change in the future.

Through the context of the results, the recommendation of this research is for leadership to identify the needs they have and to explore touchless technologies that address those needs. This does not necessarily mean, however, that the results of this research apply objectively to all situations because value is subjective. For example, it would be irresponsible to recommend “use touchless sensing technologies because they have the most advantages according to this study.” Instead, a more appropriate recommendation for Air Force leaders is to be more aware that certain technologies that have evolved to produce more advantages are more likely to contain the solution to a problem. However, this reality does not make a technology type inherently better because the problem that leadership aims to solve can vary depending on the situation. Where it is imperative that the Air Force equips itself with the most effective technology possible to conduct its warfighting capabilities, it is up to decision-makers to determine if the problem they have can be addressed, and if so, which technological solution effectively addresses that problem.

Future Research

Iterations of this methodology, as well as different approaches altogether, need to continue in order to track the changing number of advantages and disadvantages within touchless technologies. As more technology develops, more case studies and meta-analysis literature will be available that could then be examined for their themes. Additionally, having multiple researchers conduct this methodology in the future would be beneficial because each researcher contains their own natural biases. Although the thematic and reference analyses will likely change due to the development and

improvement of these technologies, finding similar results across multiple researchers would further validate the effectiveness of the study, saying that the researcher's bias is less of a problem than originally anticipated.

In the future, it is likely that quantifiable cost-benefit analysis data would be available for each of the five categories. When there is enough of this data to conduct an official cost-benefit analysis, this should be pursued by future researchers. However, this does not mean that this methodology should be replaced. Although obtaining quantifiable cost-benefit data would illustrate the state of each category, the reality is that the value for many of these technologies are still subjective in nature. In the future, this methodology can be modified to include objective cost-benefit data, but it should not remove its ability to measure and quantify subjective themes.

Appendices

Appendix A. Thematic Data

Category	Adv./Disadv.	Article	Thematic Code	Most Reoccurring Theme? (referencing Figure 16)
Facial/Bio Recognition	Advantage	Chenhao & Kumar, 2018	Contactless 3D fingerprint identification has gained significant attentions in recent years as it can offer more hygienic, accurate and ubiquitous personal identification.	X
Facial/Bio Recognition	Advantage	Iqbal & Campbell, 2020	The rapid adoption of biometric systems as official identification to monitor workplace attendance, to control the security of digital devices, and now in the use of ATM machines has created a need for touchless fingerprint detection systems in these areas.	X
Facial/Bio Recognition	Advantage	Latman & Herb, 2013	In this study, the system successfully enrolled all subjects on the first attempt. All 277 subjects were successfully verified and identified on the first day of enrollment. None of the current or prior eye conditions prevented enrollment, verification, or identification. All 35 subjects with alcohol-induced nystagmus were successfully verified and identified. There were no false verifications or false identifications. Two conditions were identified that potentially could circumvent the use of iris recognitions systems in general.	
Facial/Bio Recognition	Advantage	Latman & Herb, 2013	The Mobile-Eyes™ iris recognition system exhibited accurate and reliable enrollment, verification, and identification applications in this study. It may have special applications in subjects with nystagmus.	
Facial/Bio Recognition	Advantage	Latman & Herb, 2013	The lack of basic failures is especially significant given the highly diverse sample demographics, number of attempts and iris comparisons, and varying test conditions. This high success rate is consistent with an International Biometric Group (IBG) study [30] of the Eye Controls SafeMatch™ implementation of the "Eye Controls VectorMatch" algorithms.	
Facial/Bio Recognition	Advantage	Latman & Herb, 2013	In conclusion, this study found the Mobile-Eyes™ iris recognition system to be accurate and reliable under expected indoor applications of enrollment, identity verification, and identification.	X
Facial/Bio Recognition	Advantage	Ramanathan et al., 2021	This technology can be realized real time with low cost and versatile in many aspects.	
Facial/Bio Recognition	Disadvantage	Chenhao & Kumar, 2018	Despite such advantages, contactless 3D imaging often results in partial 3D fingerprints as it requires relatively higher cooperation from users during the contactless 3D imaging. Such contactless 3D fingerprint images significantly degrade matching accuracy due to partial 3D fingerprint imaging.	X

Facial/Bio Recognition	Disadvantage	Chenhao & Kumar, 2018	Contactless partial 3D fingerprint identification is a more challenging problem due to its high degree of freedom during contactless 3D fingerprint acquisition and is also addressed by using proposed model.	X
Facial/Bio Recognition	Disadvantage	Latman & Herb, 2013	One of the weaknesses of most of the previously published evaluations of accuracy of iris biometric instruments has been a deficiency or complete lack of significant demographic information.	X
Facial/Bio Recognition	Disadvantage	Latman & Herb, 2013	However, a potential problem with this is the observation that the color of irises is not a constant over time. For example, about 10 to 20% of children between birth and 6 years of age experience a change in iris color. In addition, Bito et al. found that about 10 to 15% of "white subjects" exhibit a change in iris color throughout adolescence and adulthood. The study by Carino et al. indicated that 10 to 20% of adults exhibit a change in eye-color.	
Facial/Bio Recognition	Disadvantage	Ramanathan et al., 2021	The major challenge faced by the team is maintaining the privacy when the scalability and the data density increase.	
Gesture Recognition	Advantage	Cronin & Doherty, 2019	Overcoming hardware restrictions has been a major theme, but in recent research, technical difficulties have receded.	
Gesture Recognition	Advantage	Cronin & Doherty, 2019	Modern technology can contribute to patient care by allowing healthcare staff rich and immediate access to patient information and imaging.	X
Gesture Recognition	Advantage	Cronin & Doherty, 2019	Rosa and Elizondo state that with a little training of the user, use of their gesture interface is easier and faster than changing sterile gloves or having an assistant outside the sterile environment.	X
Gesture Recognition	Advantage	Habibi & Chattopadhyay, 2021	Both types of touchless inputs produced significantly less degradation between hands than the mouse or stylus.	
Gesture Recognition	Advantage	Habibi & Chattopadhyay, 2021	Touchless inputs are location-independent and require neither a hard flat surface, such as a desk, nor awkward equipment. People can move freely with a head-mounted display (HMD) or interact with a very large display from a distance.	X
Gesture Recognition	Advantage	Habibi & Chattopadhyay, 2021	The last decade has seen an exponential growth of touchless technologies, and consequently, interaction techniques. The use of touchless input is only expected to soar with the maturation of virtual reality (VR) and augmented reality (AR) technologies.	

Gesture Recognition	Advantage	Vuletic et al., 2019	Depth cameras and accelerometers were the most frequently used technologies. However, sensors and cameras are gaining popularity as they provide the ability to implement interfaces requiring no physical contact with the user, which are more intuitive and less invasive. If accuracy and reliability were improved, these could become the primary technology for gesture interfaces in the future.	X
Gesture Recognition	Advantage	Liu et al., 2020	Compared with conventional methods with markers, range-camera-based systems are easier and simpler to use, and a lot cheaper with lower precision.	X
Gesture Recognition	Advantage	Liu et al., 2020	Kinect One is extensively used in many applications for its longer effective detection range and relatively less noisy depth map.	
Gesture Recognition	Advantage	Liu et al., 2020	In many scenarios, where it may be inconvenient or impossible for the user to touch a screen or keyboard, an RGB-D camera will be a fairly useful and powerful interaction tool.	X
Gesture Recognition	Advantage	Iqbal & Campbell, 2020	Today, the average person can certainly appreciate the need for touchless interaction.	X
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	At a practical level, gesture recognition works best at particular distances.	X
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	However, depth segmentation has required an upper and lower threshold, meaning that to use a system the user cannot be too close or too far away.	X
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	Sufficient operational space is one of the factors affecting user comfort. This relates to the question of fatigue, and the need to avoid intense muscle tension over time. Consideration of static ('the effort required to maintain a posture for a fixed amount of time') and dynamic ('the effort required to move a hand through a trajectory') stress is key in promoting user comfort.	
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	As mentioned in 29 papers, and discussed on a practical level in 20 papers, voice control has been found to be slower but more accurate than gesture control, and both were slower than traditional methods.	X
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	However, it is claimed that much existing work from a medical background lacks consideration of practical elements and implementations, remaining experimental and work originating from a technology background often suffers from oversimplification of medical complexity.	
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	There is also a recognised need to minimise unwanted side effects such as accidental gesture recognition.	X

Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	Major themes in their analysis echo the conclusions presented in this article regarding recent improvements in the feasibility of touchless control; the need for improved evaluations; the need to improve usability, including issues surrounding accuracy and unintended gestures; and the potential of multimodal interaction to address some of the practical difficulties in making these systems appropriate for deployment.	
Gesture Recognition	Disadvantage	Cronin & Doherty, 2019	It is clear that while progress has been made in the field, the literature does not support any instance of the technology being mature enough to gain widespread acceptance or adoption.	X
Gesture Recognition	Disadvantage	Habibi & Chattopadhyay, 2021	Regardless of the potential, individuals perform poorly with touchless inputs compared with the mouse, pen, or stylus.	X
Gesture Recognition	Disadvantage	Habibi & Chattopadhyay, 2021	Familiarity or practice alone can not explain these performance differences; studies show that motor learning, induced by distributed practice, does not improve touchless performance to become as good as mouse or touch input.	X
Gesture Recognition	Disadvantage	Habibi & Chattopadhyay, 2021	But in spite of its potential, touchless input is limited by the lack of haptic feedback and forearm fatigue.	
Gesture Recognition	Disadvantage	Pei-Lee et al., 2015	Currently, only limited guidance is provided for designers and manufacturers in their development of consumer somatosensory	
Gesture Recognition	Disadvantage	Pei-Lee et al., 2015	For individuals with small hand-size, they faced incompatibility to technology (i.e., lack of sensitivity or inability of the technology to read the signal) leads frustration to fatigue.	
Gesture Recognition	Disadvantage	Pei-Lee et al., 2015	When people with small hand-size are unable to access the digital appliance using hand gesture, they can break into frustration and fatigue.	X
Gesture Recognition	Disadvantage	Vuletic et al., 2019	From the review, the community seems disparate with little evidence of building upon prior work and a fundamental framework of gesture-based interaction is not evident.	
Gesture Recognition	Disadvantage	Vuletic et al., 2019	Technologies can roughly be divided into visual based sensors and cameras, and physical wearables. The former are unobtrusive, and provide opportunity for natural movement, while the latter are generally more accurate and easier to set up and track, but can encumber the wearer.	
Gesture Recognition	Disadvantage	Liu et al., 2020	However, as an interaction device, Kinect is not precise enough for accurate control, which prevents it from being popular in many real applications.	X

Gesture Recognition	Disadvantage	Liu et al., 2020	Occlusion is another common problem. While the user is interacting with the device, it is inevitable that part of the user is occluded, which imposes a significant effect on gesture recognition and an uncomfortable experience for the user.	
Gesture Recognition	Disadvantage	Liu et al., 2020	Unlike traditional interactive devices, which provide accurate enough control over the cursor, current touchless interactive systems can offer only limited interaction actions.	X
Gesture Recognition	Disadvantage	Liu et al., 2020	Meanwhile, most applications are focused on particular scenarios, which make these systems inconvenient for users to customize according to their own applications and requirements. In addition, these restrictions may bring difficulty to users with different culture backgrounds while they are learning the designed gestures.	
Gesture Recognition	Disadvantage	Liu et al., 2020	Throughout the development of our system, the challenge of low gesture recognition accuracy caused by the limited precision of human body detection emerged. Current RGB-D cameras can capture joint data in real time with acceptable calculation, but the precision is too low for serious applications, such as vehicle control.	X
Gesture Recognition	Disadvantage	Liu et al., 2020	New approaches based on convolutional neural networks (CNN) and RGB cameras can produce more accurate estimations of human pose, but the time cost is too large for real-time interaction applications. It is necessary to work for further achievement to accelerate the calculation while maintaining a relatively high precision.	
Gesture Recognition	Disadvantage	Iqbal & Campbell, 2020	The gesture-based technologies that have been adopted in research have thus far not been popular outside of research labs.	
Gesture Recognition	Disadvantage	Iqbal & Campbell, 2020	There are several issues in the design, development, and adoption of such technologies that should be addressed in the	
Gesture Recognition	Disadvantage	Mingawa et al., 2014	The present prototype allows intuitive operations in two directions including screen scaling, and determines which of the two types of operations is intended according to the shape of the hand held up. However, an increased number of operation commands may require the user to learn the shapes and may generate misjudgement as well. To ensure that the number of operation commands is easy to use for the user, measures are necessary such as assigning small command sets according to situations of use so as to prevent placing an increased burden on the user.	

Gesture Recognition	Disadvantage	Mingawa et al., 2014	With hand gesture detection using a camera, the position and state of the hand were generally made changeable so that the user could make motions in the detection area by presenting the image to the user showing whether the hand was in the detection area. However, images from a near-IR camera as in the present study are different from visible images that can be usually obtained, which makes it difficult to associate an image with the real space even if it is presented.	X
Gesture Recognition	Disadvantage	Mingawa et al., 2014	As a result of an experiment, it has been found out that non-detection may occur depending on the distance between the hand and face. In the future, we intend to verify the feasibility of the prototype mentioned above to work on easier-to-use integration and build an integrated interface with less non-detection by improving the accuracy.	X
Personal Devices	Advantage	Habibi & Chattopadhyay, 2021	As virtual reality (VR) and augmented reality (AR) technologies mature and high-resolution, large displays become affordable, the use of touchless input in interaction techniques, whether via a device in midair, like a smartphone, or device-less, is expected to rise.	X
Personal Devices	Advantage	Grover & Sabherwal, 2020	Digitalization can play a role here, by using touchless menus on smartphones, robotbased services, coordinating touches delivery, etc.	X
Personal Devices	Advantage	Kamble et al., 2021	The user satisfaction score is recorded based on six basic metrics, viz. ease of use, size, strength, appearance, material and ease of carrying. A satisfaction score of 85% is reported, with ABS being the preferred material of choice.	X
Personal Devices	Advantage	Kamble et al., 2021	Different case studies highlighting the multifunctionality of the presented design of the COVID key are reflected in this work. The detailed FEA analysis shows that the present COVID key is fit to be used in domestic and workplace settings. The prime application for the given COVID key is in the hospital buildings with a high number of people living or being treated for COVID. All majority actions such as pushing, pulling, pinching, tightening, measuring and holding can be performed satisfactorily with the present COVID key.	X
Personal Devices	Advantage	Kamble et al., 2021	A novel key design that gives good protection against infectious surfaces by enabling a remote touch.	
Personal Devices	Advantage	Kamble et al., 2021	Multifunctionality of the key enables the user to perform various actions and reduces the need to carry multiple tools to perform a wide range of actions.	X
Personal Devices	Advantage	Kamble et al., 2021	The size of the key is compact; hence it can be stored in the pockets, handbags and purse after proper sanitization.	X

Personal Devices	Advantage	Kamble et al., 2021	The geometry is simplified to make it suitable for 3D printing where the CAD model can be shared with people. It can be printed from the nearby 3D printing facility. It makes the distribution of the key easy and widespread.	X
Personal Devices	Advantage	Wanga et al., 2021	Smartphone installed with relevant app brings people together even when this coronavirus (COVID-19) pandemic forces us apart.	X
Personal Devices	Advantage	Utz et al., 2021	Many "corona apps" require widespread adoption to be effective, which has sparked public debates about the privacy, security, and societal implications of government-backed health applications.	
Personal Devices	Advantage	Utz et al., 2021	In all surveyed countries, aspects regarding pandemic control were among the most frequently mentioned positive aspects of corona apps. Thus, many citizens seem to be generally open to the idea of using mobile apps to help limiting the spread of a virus.	
Personal Devices	Advantage	Utz et al., 2021	Such apps can be further developed to be ready for deployment in potential future pandemics.	
Personal Devices	Disadvantage	Kamble et al., 2021	It could be troublesome to use the key initially due to a lack of experience in using it. Thus, the authors suggest using the key repeatedly to get accustomed to social settings.	
Personal Devices	Disadvantage	Kamble et al., 2021	Key is not suitable for some very specific or extreme applications with size and temperature constraints. However, the design and material can be modified to suit the particular application.	
Personal Devices	Disadvantage	Utz et al., 2021	The use of smartphone applications in the fight against the pandemic has sparked intense public debates about the privacy, security, and societal implications of government-recommended health apps and specific aspects of their implementations.	X
Personal Devices	Disadvantage	Utz et al., 2021	User acceptance and their willingness to use these apps can thus be critical for the overall success of smartphone apps in the efforts to fight the pandemic. Many of the publicly discussed and criticized aspects are well-known elements in the theory of "privacy as contextual integrity", which acknowledges that factors beyond the technical implementation, like social norms and expectations, influence perceptions of privacy violations.	X
Personal Devices	Disadvantage	Utz et al., 2021	First, designers and developers of apps that collect sensitive health data should keep in mind the factor levels that positively influence user acceptance (e. g., avoid technical malfunctions, provide data only to health authorities or research institutions, do not collect data that could be used to uniquely identify the user (US and DE)).	X

Touchless Sensing	Advantage	Grover & Sabherwal, 2020	In doing so, companies that can identify the customer's post-pandemic value points (e.g., touchless service) and then deliver on them – foster customer surplus.	
Touchless Sensing	Advantage	Gerba, 2015	This study evaluated an ultraviolet (UV) light point-of-dispense water treatment system for control of <i>P aeruginosa</i> . No <i>P aeruginosa</i> was detected in 30 different water dispensers in which the UV light device had been operating for 1-34 months. In comparison, <i>P aeruginosa</i> was found in other taps that did not feature this UV light system.	X
Touchless Sensing	Advantage	Landgrebe, 2011	405nm light is known to kill some species of bacteria.	X
Touchless Sensing	Advantage	Landgrebe, 2011	The following organisms were killed at greater than 4 logs using 405nm light at 1 hour exposure time; <i>Acinetobacter baumannii</i> , <i>Klebsiella pneumoniae</i> , <i>Staphylococcus aureus</i> , <i>Staphylococcus epidermidis</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Enterococcus faecalis</i> , and <i>Streptococcus pneumoniae</i> .	X
Touchless Sensing	Advantage	Landgrebe, 2011	Our results suggest that a therapeutic window may exist for treatment of some infections in human tissues using 405 nm light.	X
Touchless Sensing	Advantage	Lozier, 2016	Therefore, touchless, sensor-operated faucets can contribute to a higher level of handwashing hygiene.	X
Touchless Sensing	Advantage	Lozier, 2016	The advantages of sensor-operated faucets extend beyond the public restroom to almost any other type of handwashing station, especially in applications requiring the highest levels of cleanliness.	X
Touchless Sensing	Advantage	Lozier, 2016	Sensing technologies based on electronics are most often used for hands-free activation of plumbing fittings such as faucets to improve user accessibility in compliance with the Americans with Disabilities Act (ADA) and improve overall hygiene and restroom cleanliness.	X
Touchless Sensing	Advantage	Lozier, 2016	More water can be saved when sensor faucets automatically switch off as soon as users remove their hands from the wash area, as opposed to metered and manual faucets that can be left running for extended cycles, sometimes even after users leave the restroom. These energy savings over the faucet's lifetime reduce a facility's water and wastewater bills.	
Touchless Sensing	Advantage	Lozier, 2016	Since these faucets are preset to shut off after a certain amount of time, they save a significant amount of water, and accidental flooding can't occur if a user leaves it running. And, because they are hands-free, they help reduce the spread of germs and keep the vanity area clean.	X

Touchless Sensing	Advantage	Doll & Bearman, 2018	Bypassing the variability in human practices, disinfection devices are now increasingly deployed after manual cleaning to further reduce bioburden in patient rooms.	X
Touchless Sensing	Advantage	Doll & Bearman, 2018	Devices include hydrogen peroxide (HP) or UV-light emitting machines. Manual cleaning remains an important precursor step, as gross organic soil must be removed from surfaces to allow penetration of germicidal vapor/aerosol or radiation.	X
Touchless Sensing	Advantage	Doll & Bearman, 2018	There has been a single large, multi-center, controlled study to assess HAI reduction using a UV device. This study found a significant reduction in HAI acquisition when the UV device was added to quaternary ammonium cleaning. Clostridium difficile acquisitions were not significantly impacted.	X
Touchless Sensing	Advantage	Nicol, 2020	In general, fomite transmission opportunities are fewer when "touch-less" sensor-operated amenities such as sinks, soap and paper towel dispensers are provided.	
Touchless Sensing	Advantage	Nicol, 2020	Touchless or automatic paper towel dispenser, as well as automatic doors or doorless entry ways, are even better choices for reducing contamination during hand drying and to keep hands from re-contamination after washing.	X
Touchless Sensing	Advantage	Iqbal & Campbell, 2020	Replacing this button-based interaction with a gesture or interactive hand controller could handle such cases and move the world forward.	X
Touchless Sensing	Advantage	Morimoto, 2010	A probabilistic cost benefit analysis, which takes into account future uncertainty, is conducted using a Monte Carlo simulation. Our findings suggest that if the Smart Infrastructure sensor system is applied to water pipelines in the British market, there are likely to be significant economic benefits.	
Touchless Sensing	Advantage	Morimoto, 2010	They could be realised by avoiding disruption and damage costs (including water loss) due to water pipe bursts, as well as by reducing annual operating and maintenance costs. The mean cumulative net present value of savings derived from the case scenario for the period through year 2056 was estimated at US\$ 23.7 billion.	
Touchless Sensing	Advantage	Morimoto, 2010	The Smart Infrastructure can speed up the process of improving the current sensor system, generating direct economic benefits, such as reduced O&M costs due to its automated system.	
Touchless Sensing	Advantage	Morimoto, 2010	The Smart Infrastructure sensor system constitutes an economically sound investment, partly due to its relatively low development and harmonisation costs. Based on our findings, the application of this system is highly likely to generate significant economic, environmental, and social benefits.	

Touchless Sensing	Advantage	Morimoto, 2013	The advantages of using these wireless sensors are their reliability, low-cost, low power and fast deployment characteristics.	
Touchless Sensing	Advantage	Morimoto, 2013	However, the benefit of managing both industries simultaneously using the Smart Infrastructure sensor could be significant. Thus, this kind of emerging technology is proved to play a major role in improving and integrating the current infrastructure management practice. Moreover, the findings indicate that the potential socio-economic impacts appear to be realised gradually, therefore early implementation could be recommended.	
Touchless Sensing	Advantage	Das, 2021	This study reveals that the LDR-based automated hand sanitizer dispenser system is a novel concept, and it is cost-effective compared to the conventional ones. The presented device is expected to play a key role in contactless hand disinfection in public places, and reduce the spread of infectious diseases in society.	X
Touchless Sensing	Advantage	Casini, 2019	The implementation of the standard cleaning and disinfection procedure with the integration of the PX-UVC treatment had effective results in both the reduction of hygiene failures and in control environmental contamination by high-concern microorganisms.	X
Touchless Sensing	Advantage	Casini, 2019	Implementation of this "no-touch" technology in various hospitals has documented a sustained reduction in surface microbial contamination, reduced cross contamination, and a reduced spread of multi-drug resistant bacterial infections.	X
Touchless Sensing	Advantage	Casini, 2019	In the last few years, no-touch systems for environmental decontamination are increasingly being considered, such as the UVC no-touch technology that can be done routinely and rapidly in different hospital settings after patient discharge or transfer.	X
Touchless Sensing	Advantage	Casini, 2019	No-touch surface decontamination technologies that use ultraviolet light may be effective in enhancing the results of the effort spent to reduce the microbial burden and potentially achieving lower Healthcare-associated Infections HAI rates, as aimed for in infection control strategies.	X
Touchless Sensing	Advantage	Li et al., 2011	The results and insights derived from the analysis have important implications on adaptive built environment management to prevent infectious disease outbreaks and respond to the on-going pandemic.	X

Touchless Sensing	Advantage	Li et al., 2011	Providing information to end-users is critically important for them to change behaviors. Human behavior plays an important role in the transmission of pathogens such as SARSCoV-2. Changing behaviors is critical to preventing transmission.	X
Touchless Sensing	Advantage	Li et al., 2011	The occupants can access the useful information via webpage to plan their visit and staying time in the facilities, and practice appropriate personal hygiene and cleaning practices based on the information.	X
Touchless Sensing	Advantage	Tokazhanov et al., 2021	The use of touchless technology (PVP2) is the most important indicator in the prevention of virus propagation according to all three groups of experts (Acad: 5.66; Ind: 5.86; Med: 7.19). The fact that the Med experts gave this indicator the highest score indicates the crucial role of touchless technologies in preventing the spread of the virus via direct contact with contaminated surfaces.	X
Touchless Sensing	Advantage	Tokazhanov et al., 2021	As agreed upon by all experts, the use of touchless technologies was found to be the most promising way to prevent the spread of viruses, along with the use of temperature is very low, it is important to keep a normal temperature inside. Additionally, heaters that are hot all the time decrease the humidity of the indoor air.	X
Touchless Sensing	Disadvantage	McMullen et al., 2021	Findings from 3 hospitals in our health system demonstrated no significant effect of UVL room disinfection on CDI rates.	
Touchless Sensing	Disadvantage	McMullen et al., 2021	Compliance with utilization of the devices varied across hospitals, but despite high utilization in some settings, CDI rates remained unchanged.	X
Touchless Sensing	Disadvantage	Landgrebe, 2011	There has been no practical application of this method in clinical practice.	X
Touchless Sensing	Disadvantage	Doll & Bearman, 2018	The HP or UV light is toxic to humans. Thus, these devices are used only in empty patient rooms – for example, after a patient discharge.	
Touchless Sensing	Disadvantage	Doll & Bearman, 2018	UV and HP devices are costly, and cost-effectiveness has not been well established. They also require human resources to deploy.	X
Touchless Sensing	Disadvantage	Das, 2021	The key problem of the conventional ultrasonic and infra-red-based dispensers is their malfunctioning due to the interference of sunlight, vehicle sound, etc. when deployed in busy public places.	
Voice Recognition	Advantage	Cronin & Doherty, 2019	[It is believed] that voice control has an important role to play in minimally invasive surgery, allowing the surgeon to take control of the entire OR without breaking sterility or interrupting the surgery; this potentially allows for single surgeon surgery, resulting in reduced costs.	X

Voice Recognition	Advantage	Cronin & Doherty, 2019	Voice recognition has been described as having accuracy as high as 99 per cent; however, some studies have shown slightly lower accuracy than human transcription.	
Voice Recognition	Advantage	Cronin & Doherty, 2019	Voice control is generally deemed good for discrete commands, though it is not appropriate for continuous parameter adjustment, for which gestures are better suited.	
Voice Recognition	Advantage	Cronin & Doherty, 2019	Use of a voice recognition interface resulted in a significantly higher quality of anaesthesia record as compared to the traditional interface (99% of medications recorded vs 56%), as well as a reduced error rate.	
Voice Recognition	Advantage	Cronin & Doherty, 2019	[They] considered the issue of user fatigue when implementing voice recognition as compared to keyboard input and gathered user feedback regarding both input tools by means of a questionnaire. Their results indicated that users found that voice input caused less fatigue and was easier compared with keyboard operation, despite being inexperienced with voice input.	X
Voice Recognition	Advantage	Kumar & Shimi, 2015	The results show the system can provide great assistant to the physically challenged people without any third person's assistances.	X
Voice Recognition	Advantage	Kumar & Shimi, 2015	Integrating voice recognition technology to home automation systems make the system more user friendly and easy to operate.	X
Voice Recognition	Advantage	Simmons et al., 2017	Driver distraction is a growing and pervasive issue that requires multiple solutions. Voice-recognition (V-R) systems may decrease the visual-manual (V-M) demands of a wide range of in-vehicle system and smartphone interactions.	X
Voice Recognition	Advantage	Simmons et al., 2017	Driving while interacting with a VR system is associated with increases in reaction time and lane positioning, and decreases in detection compared to driving without a system.	
Voice Recognition	Advantage	Simmons et al., 2017	While using a V-R system, reaction time was increased and detection was decreased compared to baseline driving.	
Voice Recognition	Advantage	Alexakis et al., 2019	The microcontroller that is programmed to control the home lights in Figure 3 receives MQTT messages by the IoT Agent to handle their states. It is synchronized with the database the first time it boots and, after that, only uses the received MQTT messages for the whole process. As a result, it is working efficiently and very fast.	

Voice Recognition	Advantage	Alexakis et al., 2020	Firestore synchronizes with the microcontrollers that relate to the DHT11 sensors every 5 s, which keeps the results up to date. Moreover, the microcontrollers compare the present sensor values with the previous ones, so only updated measurements are sent to the database. As a result, the microcontroller does not overload the whole network with unnecessary traffic.	
Voice Recognition	Advantage	Alexakis et al., 2021	The Internet of Things field undoubtedly offers a revolution in the way we interact with everyday objects and devices, still has a lot to offer, and is changing the way we interact with everyday devices. Even though our implementation is still in its early stages, we strongly believe that it can contribute in this direction and offer even more possibilities.	X
Voice Recognition	Advantage	Alexakis et al., 2022	Furthermore, with the use of natural language as an input method, usability is enhanced. People with visual or moving disabilities, or elderly people who are not so accustomed to technology, can be assisted to make every-day actions more easily with the use of our IoT Agent. Furthermore, natural language can also help people with special needs in the matter of safety.	
Voice Recognition	Disadvantage	Cronin & Doherty, 2019	As mentioned in 29 papers, and discussed on a practical level in 20 papers, voice control has been found to be slower but more accurate than gesture control, and both were slower than traditional methods.	
Voice Recognition	Disadvantage	Cronin & Doherty, 2019	Two major issues for voice control are people's accents and ambient noise, with the noise levels of an OR making voice control extremely	X
Voice Recognition	Disadvantage	Kumar & Shimi, 2015	The voice recognition module needs to be trained first before it can be used to recognize commands.	X
Voice Recognition	Disadvantage	Kumar & Shimi, 2015	The Limitation of the system is the use of the computer which makes system more expensive.	
Voice Recognition	Disadvantage	Simmons et al., 2017	However, the degree that V-R systems integrated into vehicles or available in mobile phone applications affect driver distraction is incompletely understood.	
Voice Recognition	Disadvantage	Simmons et al., 2017	Although V-R systems have some driving performance advantages over V-M systems, they have a distraction cost relative to driving without any system at all. The pattern of results indicates that V-R systems impose moderate distraction costs on driving.	
Voice Recognition	Disadvantage	Simmons et al., 2017	Finally, it is important to note that although the current study demonstrates that voice-recognition systems have a distraction cost, it is unclear whether these translate into increased	

Appendix B. Reference Correlation Data

Rank	Literature File #1	Literature File #2	Pearson correlation coefficient (R ²)
1	Doll and Bearman, 2018	Casini, 2019	0.759098
2	McMullen et al., 2021	Casini, 2019	0.710524
3	Vuletic et al., 2019	Liu et al., 2020	0.669154
4	Morimoto, 2013	Morimoto, 2010	0.669087
5	McMullen et al., 2021	Doll and Bearman, 2018	0.59741
6	Vuletic et al., 2019	Cronin and Doherty, 2019	0.573518
7	Kumar and Shimi, 2015	Alexakis et al., 2019	0.551421
8	Liu et al., 2020	Cronin and Doherty, 2019	0.520423
9	Vuletic et al., 2019	Habibi and Chattopadhyay, 2021	0.509417
10	Liu et al., 2020	Habibi and Chattopadhyay, 2021	0.498219
11	Liu et al., 2020	Iqbal and Campbell, 2020	0.484127
12	Nicol, 2020	Li et al., 2021	0.473147
13	Habibi and Chattopadhyay, 2021	Cronin and Doherty, 2019	0.468543
14	Meyer et al., 2014	Habibi and Chattopadhyay, 2021	0.458949
15	Liu et al., 2020	Chenhao and Kumar, 2018	0.454986
16	Meyer et al., 2014	Liu et al., 2020	0.453413
17	Gerba, 2015	Doll and Bearman, 2018	0.44571
18	Vuletic et al., 2019	Chenhao and Kumar, 2018	0.444826
19	Gerba, 2015	Casini, 2019	0.444738
20	Latman and Herb, 2013	Chenhao and Kumar, 2018	0.433807
21	Chenhao and Kumar, 2018	Alexakis et al., 2019	0.43004
22	Iqbal and Campbell, 2020	Cronin and Doherty, 2019	0.42612
23	Vuletic et al., 2019	Meyer et al., 2014	0.423779
24	Liu et al., 2020	Alexakis et al., 2019	0.420611
25	Wanga et al., 2021	Utz et al., 2021	0.420417
26	Kumar and Shimi, 2015	Cronin and Doherty, 2019	0.40852
27	Liu et al., 2020	Kumar and Shimi, 2015	0.405285
28	Simmons et al., 2017	Habibi and Chattopadhyay, 2021	0.400673
29	Ramanathan et al., 2021	Kumar and Shimi, 2015	0.391955
30	Vuletic et al., 2019	Alexakis et al., 2019	0.382032
31	Cronin and Doherty, 2019	Chenhao and Kumar, 2018	0.381335
32	Vuletic et al., 2019	Kumar and Shimi, 2015	0.37747
33	Kumar and Shimi, 2015	Chenhao and Kumar, 2018	0.372395
34	Vuletic et al., 2019	Iqbal and Campbell, 2020	0.369898
35	Doll and Bearman, 2018	Das, 2021	0.369413
36	Ramanathan et al., 2021	Alexakis et al., 2019	0.363844
37	Li et al., 2021	Casini, 2019	0.352288
38	Meyer et al., 2014	Cronin and Doherty, 2019	0.349909
39	Simmons et al., 2017	Cronin and Doherty, 2019	0.349871
40	Tokazhanov et al., 2021	Nicol, 2020	0.349235
41	Latman and Herb, 2013	Cronin and Doherty, 2019	0.345922

42	Utz et al., 2021	Nicol, 2020	0.339511
43	Wanga et al., 2021	Tokazhanov et al., 2021	0.338982
44	Utz et al., 2021	Habibi and Chattopadhyay, 2021	0.338767
45	Tokazhanov et al., 2021	Li et al., 2021	0.337609
46	Wanga et al., 2021	Habibi and Chattopadhyay, 2021	0.336176
47	Wanga et al., 2021	Vuletic et al., 2019	0.330898
48	Li et al., 2021	Doll and Bearman, 2018	0.330285
49	Utz et al., 2021	Tokazhanov et al., 2021	0.3285
50	Wanga et al., 2021	Li et al., 2021	0.323765
51	Wanga et al., 2021	Nicol, 2020	0.322389
52	Wanga et al., 2021	Alexakis et al., 2019	0.321604
53	Vuletic et al., 2019	Das, 2021	0.318533
54	McMullen et al., 2021	Gerba, 2015	0.318045
55	Nicol, 2020	Casini, 2019	0.316774
56	Mata and Milner, 2021	Li et al., 2021	0.316411
57	Wanga et al., 2021	Cronin and Doherty, 2019	0.315184
58	Cronin and Doherty, 2019	Alexakis et al., 2019	0.315126
59	Wanga et al., 2021	Ramanathan et al., 2021	0.314315
60	Vuletic et al., 2019	Simmons et al., 2017	0.313464
61	Doll and Bearman, 2018	Cronin and Doherty, 2019	0.312598
62	Vuletic et al., 2019	Latman and Herb, 2013	0.311333
63	Nicol, 2020	Das, 2021	0.310171
64	Habibi and Chattopadhyay, 2021	Chenhao and Kumar, 2018	0.308707
65	Meyer et al., 2014	Chenhao and Kumar, 2018	0.308703
66	Kumar and Shimi, 2015	Habibi and Chattopadhyay, 2021	0.307113
67	Wanga et al., 2021	Liu et al., 2020	0.306419
68	Utz et al., 2021	Li et al., 2021	0.304472
69	Morimoto, 2010	Gerba, 2015	0.303857
70	Mata and Milner, 2021	Casini, 2019	0.302065
71	Pei-Lee et al., 2015	Das, 2021	0.301649
72	Cronin and Doherty, 2019	Casini, 2019	0.301445
73	Ramanathan et al., 2021	Cronin and Doherty, 2019	0.299359
74	Ramanathan et al., 2021	Chenhao and Kumar, 2018	0.298454
75	Meyer et al., 2014	Alexakis et al., 2019	0.29692
76	Mata and Milner, 2021	Doll and Bearman, 2018	0.296409
77	Das, 2021	Cronin and Doherty, 2019	0.295084
78	Nicol, 2020	Doll and Bearman, 2018	0.294727
79	Simmons et al., 2017	Mata and Milner, 2021	0.293092
80	Mata and Milner, 2021	Cronin and Doherty, 2019	0.289957
81	Wanga et al., 2021	Kumar and Shimi, 2015	0.289937
82	Das, 2021	Casini, 2019	0.289373
83	Iqbal and Campbell, 2020	Habibi and Chattopadhyay, 2021	0.28928
84	Vuletic et al., 2019	Pei-Lee et al., 2015	0.287663
85	Latman and Herb, 2013	Alexakis et al., 2019	0.287352

86	Vuletic et al., 2019	Ramanathan et al., 2021	0.286626
87	Simmons et al., 2017	Morimoto, 2013	0.285974
88	Morimoto, 2013	Latman and Herb, 2013	0.2854
89	Latman and Herb, 2013	Kumar and Shimi, 2015	0.285264
90	Utz et al., 2021	Ramanathan et al., 2021	0.285158
91	Habibi and Chattopadhyay, 2021	Alexakis et al., 2019	0.284441
92	Ramanathan et al., 2021	Das, 2021	0.28174
93	Nicol, 2020	Kamble et al., 2021	0.278822
94	Simmons et al., 2017	Meyer et al., 2014	0.278308
95	Wanga et al., 2021	Kamble et al., 2021	0.276528
96	Pei-Lee et al., 2015	Cronin and Doherty, 2019	0.27378
97	Kumar and Shimi, 2015	Das, 2021	0.272626
98	Simmons et al., 2017	Li et al., 2021	0.270347
99	Landgrebe, 2011	Casini, 2019	0.269459
100	Wanga et al., 2021	Chenhao and Kumar, 2018	0.266233
101	Pei-Lee et al., 2015	Habibi and Chattopadhyay, 2021	0.265249
102	Simmons et al., 2017	Liu et al., 2020	0.265204
103	Ramanathan et al., 2021	Li et al., 2021	0.26423
104	Nicol, 2020	Mata and Milner, 2021	0.263588
105	Wanga et al., 2021	Das, 2021	0.262941
106	Li et al., 2021	Das, 2021	0.261154
107	Latman and Herb, 2013	Habibi and Chattopadhyay, 2021	0.261055
108	Morimoto, 2013	Kumar and Shimi, 2015	0.260749
109	Morimoto, 2010	Latman and Herb, 2013	0.260622
110	Liu et al., 2020	Latman and Herb, 2013	0.260589
111	Iqbal and Campbell, 2020	Alexakis et al., 2019	0.259104
112	Ramanathan et al., 2021	Latman and Herb, 2013	0.256912
113	Utz et al., 2021	Cronin and Doherty, 2019	0.256674
114	Ramanathan et al., 2021	Liu et al., 2020	0.255818
115	Morimoto, 2013	Cronin and Doherty, 2019	0.255752
116	Simmons et al., 2017	Latman and Herb, 2013	0.255049
117	Gerba, 2015	Cronin and Doherty, 2019	0.254895
118	Morimoto, 2013	Alexakis et al., 2019	0.254593
119	Wanga et al., 2021	Simmons et al., 2017	0.252936
120	Utz et al., 2021	Simmons et al., 2017	0.251823
121	Meyer et al., 2014	Iqbal and Campbell, 2020	0.249642
122	Simmons et al., 2017	Kumar and Shimi, 2015	0.249528
123	Iqbal and Campbell, 2020	Chenhao and Kumar, 2018	0.248459
124	Pei-Lee et al., 2015	Morimoto, 2013	0.248237
125	Meyer et al., 2014	Kumar and Shimi, 2015	0.248108
126	Morimoto, 2013	Habibi and Chattopadhyay, 2021	0.247265
127	Utz et al., 2021	Liu et al., 2020	0.245909
128	Simmons et al., 2017	Ramanathan et al., 2021	0.245891
129	Simmons et al., 2017	Casini, 2019	0.244651

130	Landgrebe, 2011	Doll and Bearman, 2018	0.244076
131	Wanga et al., 2021	Mata and Milner, 2021	0.243297
132	Li et al., 2021	Cronin and Doherty, 2019	0.243288
133	Utz et al., 2021	Meyer et al., 2014	0.242277
134	Nicol, 2020	McMullen et al., 2021	0.242242
135	Utz et al., 2021	Das, 2021	0.242065
136	Ramanathan et al., 2021	Habibi and Chattopadhyay, 2021	0.241688
137	Wanga et al., 2021	Pei-Lee et al., 2015	0.241674
138	Tokazhanov et al., 2021	Morimoto, 2010	0.241441
139	Ramanathan et al., 2021	Morimoto, 2013	0.241377
140	Vuletic et al., 2019	Utz et al., 2021	0.240693
141	Gerba, 2015	Das, 2021	0.240159
142	Habibi and Chattopadhyay, 2021	Casini, 2019	0.240009
143	Morimoto, 2010	Cronin and Doherty, 2019	0.239984
144	McMullen et al., 2021	Li et al., 2021	0.239474
145	Pei-Lee et al., 2015	Doll and Bearman, 2018	0.238359
146	Habibi and Chattopadhyay, 2021	Doll and Bearman, 2018	0.237641
147	Li et al., 2021	Kamble et al., 2021	0.236599
148	Pei-Lee et al., 2015	Li et al., 2021	0.236036
149	Pei-Lee et al., 2015	Morimoto, 2010	0.235139
150	Wanga et al., 2021	Casini, 2019	0.235094
151	Simmons et al., 2017	Pei-Lee et al., 2015	0.234582
152	Li et al., 2021	Gerba, 2015	0.234444
153	Morimoto, 2010	Habibi and Chattopadhyay, 2021	0.233541
154	McMullen et al., 2021	Mata and Milner, 2021	0.232266
155	Vuletic et al., 2019	Morimoto, 2013	0.231701
156	Li et al., 2021	Habibi and Chattopadhyay, 2021	0.231566
157	Wanga et al., 2021	Morimoto, 2013	0.231245
158	Mata and Milner, 2021	Habibi and Chattopadhyay, 2021	0.231001
159	Simmons et al., 2017	Morimoto, 2010	0.230323
160	Tokazhanov et al., 2021	Kamble et al., 2021	0.230127
161	Simmons et al., 2017	Doll and Bearman, 2018	0.229708
162	Utz et al., 2021	Kamble et al., 2021	0.229208
163	Morimoto, 2010	Li et al., 2021	0.228815
164	Morimoto, 2010	Mata and Milner, 2021	0.227628
165	Kumar and Shimi, 2015	Iqbal and Campbell, 2020	0.225519
166	Utz et al., 2021	Alexakis et al., 2019	0.22539
167	McMullen et al., 2021	Landgrebe, 2011	0.224986
168	McMullen et al., 2021	Das, 2021	0.224402
169	Kumar and Shimi, 2015	Casini, 2019	0.223653
170	Wanga et al., 2021	Meyer et al., 2014	0.223125
171	Mata and Milner, 2021	Gerba, 2015	0.221405
172	Nicol, 2020	Cronin and Doherty, 2019	0.221389
173	Mata and Milner, 2021	Latman and Herb, 2013	0.221246

174	Morimoto, 2010	Casini, 2019	0.220896
175	Pei-Lee et al., 2015	Casini, 2019	0.220785
176	Latman and Herb, 2013	Casini, 2019	0.219972
177	Morimoto, 2013	Mata and Milner, 2021	0.219729
178	Wanga et al., 2021	Grover and Sabherwal, 2020	0.219652
179	Meyer et al., 2014	Latman and Herb, 2013	0.218711
180	Habibi and Chattopadhyay, 2021	Das, 2021	0.218623
181	Morimoto, 2013	Gerba, 2015	0.218547
182	Tokazhanov et al., 2021	Morimoto, 2013	0.218044
183	Morimoto, 2013	Meyer et al., 2014	0.217958
184	Morimoto, 2013	Li et al., 2021	0.215121
185	Utz et al., 2021	Pei-Lee et al., 2015	0.214821
186	Wanga et al., 2021	Latman and Herb, 2013	0.214747
187	Das, 2021	Alexakis et al., 2019	0.214018
188	Morimoto, 2013	Chenhao and Kumar, 2018	0.213869
189	Utz et al., 2021	Morimoto, 2013	0.213655
190	Morimoto, 2013	Liu et al., 2020	0.213012
191	Pei-Lee et al., 2015	Mata and Milner, 2021	0.212454
192	Utz et al., 2021	Mata and Milner, 2021	0.211968
193	Ramanathan et al., 2021	Pei-Lee et al., 2015	0.209931
194	Liu et al., 2020	Das, 2021	0.208766
195	Simmons et al., 2017	Chenhao and Kumar, 2018	0.208713
196	Wanga et al., 2021	Morimoto, 2010	0.208081
197	Li et al., 2021	Latman and Herb, 2013	0.207175
198	McMullen et al., 2021	Cronin and Doherty, 2019	0.206158
199	Utz et al., 2021	Latman and Herb, 2013	0.205484
200	Utz et al., 2021	Grover and Sabherwal, 2020	0.204278
201	Tokazhanov et al., 2021	Das, 2021	0.204217
202	Nicol, 2020	Habibi and Chattopadhyay, 2021	0.202921
203	Tokazhanov et al., 2021	Ramanathan et al., 2021	0.202607
204	Landgrebe, 2011	Gerba, 2015	0.202061
205	Ramanathan et al., 2021	Mata and Milner, 2021	0.201698
206	Simmons et al., 2017	Das, 2021	0.20141
207	Tokazhanov et al., 2021	Grover and Sabherwal, 2020	0.200422
208	Wanga et al., 2021	Doll and Bearman, 2018	0.200152
209	Utz et al., 2021	Kumar and Shimi, 2015	0.198981
210	Simmons et al., 2017	Alexakis et al., 2019	0.19848
211	Ramanathan et al., 2021	Nicol, 2020	0.198299
212	Pei-Lee et al., 2015	Nicol, 2020	0.197825
213	Kumar and Shimi, 2015	Doll and Bearman, 2018	0.196709
214	Pei-Lee et al., 2015	Kamble et al., 2021	0.196709
215	Mata and Milner, 2021	Kamble et al., 2021	0.195637
216	Mata and Milner, 2021	Das, 2021	0.19265
217	Morimoto, 2013	Casini, 2019	0.192328

218	Pei-Lee et al., 2015	Latman and Herb, 2013	0.191789
219	Nicol, 2020	Grover and Sabherwal, 2020	0.191303
220	Minagawa et al., 2014	Cronin and Doherty, 2019	0.191106
221	Latman and Herb, 2013	Doll and Bearman, 2018	0.189796
222	Ramanathan et al., 2021	Casini, 2019	0.189666
223	Wanga et al., 2021	Iqbal and Campbell, 2020	0.18956
224	Vuletic et al., 2019	Li et al., 2021	0.18925
225	Ramanathan et al., 2021	Kamble et al., 2021	0.188536
226	Li et al., 2021	Kumar and Shimi, 2015	0.188274
227	Morimoto, 2013	Das, 2021	0.188148
228	Pei-Lee et al., 2015	Kumar and Shimi, 2015	0.188139
229	Utz et al., 2021	Chenhao and Kumar, 2018	0.186772
230	Kamble et al., 2021	Das, 2021	0.185883
231	Vuletic et al., 2019	Minagawa et al., 2014	0.185274
232	Nicol, 2020	Morimoto, 2010	0.184623
233	Morimoto, 2010	Doll and Bearman, 2018	0.184517
234	Vuletic et al., 2019	Morimoto, 2010	0.183568
235	Vuletic et al., 2019	Doll and Bearman, 2018	0.183447
236	Wanga et al., 2021	Gerba, 2015	0.180752
237	Morimoto, 2013	Doll and Bearman, 2018	0.179145
238	Morimoto, 2010	Kumar and Shimi, 2015	0.178755
239	Ramanathan et al., 2021	Meyer et al., 2014	0.178678
240	Tokazhanov et al., 2021	Mata and Milner, 2021	0.178677
241	Pei-Lee et al., 2015	Gerba, 2015	0.176882
242	Nicol, 2020	Gerba, 2015	0.176035
243	Tokazhanov et al., 2021	Casini, 2019	0.175688
244	Utz et al., 2021	Morimoto, 2010	0.174982
245	Tokazhanov et al., 2021	Cronin and Doherty, 2019	0.174419
246	Simmons et al., 2017	McMullen et al., 2021	0.174085
247	Pei-Lee et al., 2015	Liu et al., 2020	0.173333
248	Vuletic et al., 2019	Kamble et al., 2021	0.173088
249	Kamble et al., 2021	Habibi and Chattopadhyay, 2021	0.172402
250	McMullen et al., 2021	Habibi and Chattopadhyay, 2021	0.171557
251	Nicol, 2020	Latman and Herb, 2013	0.167393
252	Ramanathan et al., 2021	Morimoto, 2010	0.166767
253	Vuletic et al., 2019	Mata and Milner, 2021	0.166733
254	Latman and Herb, 2013	Das, 2021	0.166615
255	Kumar and Shimi, 2015	Gerba, 2015	0.16599
256	Kamble et al., 2021	Cronin and Doherty, 2019	0.165241
257	Vuletic et al., 2019	Nicol, 2020	0.164182
258	Morimoto, 2010	Meyer et al., 2014	0.163824
259	Habibi and Chattopadhyay, 2021	Gerba, 2015	0.16287
260	Utz et al., 2021	Casini, 2019	0.162406
261	Vuletic et al., 2019	Casini, 2019	0.161541

262	Minagawa et al., 2014	Liu et al., 2020	0.161085
263	Tokazhanov et al., 2021	Habibi and Chattopadhyay, 2021	0.161026
264	Simmons et al., 2017	Nicol, 2020	0.160814
265	Ramanathan et al., 2021	Doll and Bearman, 2018	0.160805
266	Utz et al., 2021	Doll and Bearman, 2018	0.160643
267	Pei-Lee et al., 2015	Meyer et al., 2014	0.158025
268	Simmons et al., 2017	Gerba, 2015	0.157589
269	Wanga et al., 2021	McMullen et al., 2021	0.155588
270	Simmons et al., 2017	Kamble et al., 2021	0.154328
271	Utz et al., 2021	Iqbal and Campbell, 2020	0.154219
272	McMullen et al., 2021	Latman and Herb, 2013	0.154
273	Tokazhanov et al., 2021	Simmons et al., 2017	0.153861
274	Morimoto, 2010	Liu et al., 2020	0.153318
275	Das, 2021	Chenhao and Kumar, 2018	0.153185
276	Morimoto, 2010	Das, 2021	0.152574
277	Kamble et al., 2021	Casini, 2019	0.152518
278	Iqbal and Campbell, 2020	Das, 2021	0.152252
279	Minagawa et al., 2014	Habibi and Chattopadhyay, 2021	0.15164
280	Landgrebe, 2011	Cronin and Doherty, 2019	0.151499
281	Simmons et al., 2017	Iqbal and Campbell, 2020	0.150423
282	Vuletic et al., 2019	Tokazhanov et al., 2021	0.149535
283	Utz et al., 2021	McMullen et al., 2021	0.1495
284	Tokazhanov et al., 2021	Latman and Herb, 2013	0.149069
285	Mata and Milner, 2021	Kumar and Shimi, 2015	0.148805
286	Morimoto, 2013	Kamble et al., 2021	0.147993
287	Pei-Lee et al., 2015	McMullen et al., 2021	0.147569
288	Ramanathan et al., 2021	McMullen et al., 2021	0.147005
289	Meyer et al., 2014	Das, 2021	0.146315
290	Tokazhanov et al., 2021	Doll and Bearman, 2018	0.145994
291	Pei-Lee et al., 2015	Minagawa et al., 2014	0.145882
292	Liu et al., 2020	Li et al., 2021	0.145769
293	Minagawa et al., 2014	Meyer et al., 2014	0.14561
294	Kamble et al., 2021	Doll and Bearman, 2018	0.144779
295	Morimoto, 2010	Alexakis et al., 2019	0.144192
296	Nicol, 2020	Morimoto, 2013	0.142649
297	Casini, 2019	Alexakis et al., 2019	0.142355
298	Landgrebe, 2011	Kumar and Shimi, 2015	0.142007
299	Latman and Herb, 2013	Gerba, 2015	0.141081
300	Meyer et al., 2014	Li et al., 2021	0.141015
301	Tokazhanov et al., 2021	Pei-Lee et al., 2015	0.140841
302	Ramanathan et al., 2021	Gerba, 2015	0.139036
303	McMullen et al., 2021	Kumar and Shimi, 2015	0.138975
304	Morimoto, 2010	Chenhao and Kumar, 2018	0.138957
305	Li et al., 2021	Grover and Sabherwal, 2020	0.138901

306	Kamble et al., 2021	Grover and Sabherwal, 2020	0.135277
307	Morimoto, 2010	Lozier, 2016	0.133973
308	Morimoto, 2010	McMullen et al., 2021	0.133303
309	Tokazhanov et al., 2021	Kumar and Shimi, 2015	0.132721
310	Ramanathan et al., 2021	Grover and Sabherwal, 2020	0.132716
311	Kamble et al., 2021	Chenhao and Kumar, 2018	0.132206
312	Kamble et al., 2021	Alexakis et al., 2019	0.130927
313	Pei-Lee et al., 2015	Landgrebe, 2011	0.130341
314	Liu et al., 2020	Kamble et al., 2021	0.129877
315	Ramanathan et al., 2021	Iqbal and Campbell, 2020	0.129637
316	Morimoto, 2013	Lozier, 2016	0.129451
317	Latman and Herb, 2013	Iqbal and Campbell, 2020	0.128815
318	Mata and Milner, 2021	Liu et al., 2020	0.126577
319	Simmons et al., 2017	Minagawa et al., 2014	0.125372
320	Tokazhanov et al., 2021	Liu et al., 2020	0.125298
321	Tokazhanov et al., 2021	Alexakis et al., 2019	0.125199
322	Nicol, 2020	Kumar and Shimi, 2015	0.124843
323	Tokazhanov et al., 2021	McMullen et al., 2021	0.124099
324	Meyer et al., 2014	Mata and Milner, 2021	0.122573
325	Kumar and Shimi, 2015	Kamble et al., 2021	0.121615
326	Morimoto, 2013	Iqbal and Campbell, 2020	0.120361
327	Doll and Bearman, 2018	Alexakis et al., 2019	0.120337
328	Tokazhanov et al., 2021	Gerba, 2015	0.119625
329	Mata and Milner, 2021	Iqbal and Campbell, 2020	0.11959
330	Morimoto, 2013	McMullen et al., 2021	0.118268
331	Kamble et al., 2021	Gerba, 2015	0.117849
332	Liu et al., 2020	Doll and Bearman, 2018	0.117447
333	Mata and Milner, 2021	Chenhao and Kumar, 2018	0.116773
334	Nicol, 2020	Liu et al., 2020	0.116656
335	Nicol, 2020	Minagawa et al., 2014	0.115876
336	Pei-Lee et al., 2015	Alexakis et al., 2019	0.115002
337	Li et al., 2021	Alexakis et al., 2019	0.114559
338	Landgrebe, 2011	Habibi and Chattopadhyay, 2021	0.114174
339	Liu et al., 2020	Casini, 2019	0.113594
340	Li et al., 2021	Chenhao and Kumar, 2018	0.113389
341	Morimoto, 2010	Kamble et al., 2021	0.113346
342	Meyer et al., 2014	Doll and Bearman, 2018	0.112568
343	Latman and Herb, 2013	Kamble et al., 2021	0.112299
344	Utz et al., 2021	Gerba, 2015	0.111734
345	Lozier, 2016	Das, 2021	0.110209
346	Meyer et al., 2014	Kamble et al., 2021	0.108174
347	Meyer et al., 2014	Casini, 2019	0.108117
348	Pei-Lee et al., 2015	Chenhao and Kumar, 2018	0.107378
349	Minagawa et al., 2014	Casini, 2019	0.107351

350	Vuletic et al., 2019	Gerba, 2015	0.106413
351	Minagawa et al., 2014	Doll and Bearman, 2018	0.106258
352	McMullen et al., 2021	Kamble et al., 2021	0.106196
353	Grover and Sabherwal, 2020	Das, 2021	0.105704
354	McMullen et al., 2021	Alexakis et al., 2019	0.104999
355	Vuletic et al., 2019	McMullen et al., 2021	0.103997
356	Tokazhanov et al., 2021	Iqbal and Campbell, 2020	0.10178
357	Vuletic et al., 2019	Landgrebe, 2011	0.10166
358	Mata and Milner, 2021	Alexakis et al., 2019	0.100966
359	Nicol, 2020	Landgrebe, 2011	0.100217
360	Grover and Sabherwal, 2020	Alexakis et al., 2019	0.099696
361	Tokazhanov et al., 2021	Chenhao and Kumar, 2018	0.099121
362	Minagawa et al., 2014	Li et al., 2021	0.098483
363	Tokazhanov et al., 2021	Meyer et al., 2014	0.096386
364	Landgrebe, 2011	Das, 2021	0.095805
365	Wanga et al., 2021	Minagawa et al., 2014	0.094401
366	Minagawa et al., 2014	Mata and Milner, 2021	0.094329
367	Lozier, 2016	Gerba, 2015	0.092858
368	Wanga et al., 2021	Landgrebe, 2011	0.092815
369	Chenhao and Kumar, 2018	Casini, 2019	0.091173
370	Mata and Milner, 2021	Landgrebe, 2011	0.087892
371	Meyer et al., 2014	Gerba, 2015	0.087106
372	Doll and Bearman, 2018	Chenhao and Kumar, 2018	0.086605
373	Lozier, 2016	Doll and Bearman, 2018	0.086127
374	Pei-Lee et al., 2015	Grover and Sabherwal, 2020	0.085929
375	Li et al., 2021	Landgrebe, 2011	0.085395
376	Kumar and Shimi, 2015	Grover and Sabherwal, 2020	0.085277
377	Ramanathan et al., 2021	Landgrebe, 2011	0.084278
378	Morimoto, 2010	Minagawa et al., 2014	0.08339
379	Pei-Lee et al., 2015	Iqbal and Campbell, 2020	0.077867
380	Nicol, 2020	Iqbal and Campbell, 2020	0.077786
381	Habibi and Chattopadhyay, 2021	Grover and Sabherwal, 2020	0.077777
382	Meyer et al., 2014	McMullen et al., 2021	0.077383
383	Liu et al., 2020	Gerba, 2015	0.077286
384	Minagawa et al., 2014	Latman and Herb, 2013	0.077049
385	Minagawa et al., 2014	Landgrebe, 2011	0.076664
386	Nicol, 2020	Meyer et al., 2014	0.076326
387	Nicol, 2020	Chenhao and Kumar, 2018	0.076259
388	Latman and Herb, 2013	Landgrebe, 2011	0.076257
389	Lozier, 2016	Liu et al., 2020	0.075629
390	Morimoto, 2013	Minagawa et al., 2014	0.074676
391	Liu et al., 2020	Landgrebe, 2011	0.073697
392	Ramanathan et al., 2021	Minagawa et al., 2014	0.072878
393	Simmons et al., 2017	Landgrebe, 2011	0.072655

394	Landgrebe, 2011	Kamble et al., 2021	0.072348
395	Li et al., 2021	Iqbal and Campbell, 2020	0.071001
396	Landgrebe, 2011	Alexakis et al., 2019	0.070854
397	Minagawa et al., 2014	Kumar and Shimi, 2015	0.069814
398	Minagawa et al., 2014	Alexakis et al., 2019	0.069394
399	Minagawa et al., 2014	Iqbal and Campbell, 2020	0.068262
400	Grover and Sabherwal, 2020	Cronin and Doherty, 2019	0.068
401	Utz et al., 2021	Minagawa et al., 2014	0.066477
402	Simmons et al., 2017	Lozier, 2016	0.066415
403	Meyer et al., 2014	Grover and Sabherwal, 2020	0.065901
404	Morimoto, 2013	Grover and Sabherwal, 2020	0.065583
405	Morimoto, 2013	Landgrebe, 2011	0.065497
406	McMullen et al., 2021	Chenhao and Kumar, 2018	0.065488
407	Minagawa et al., 2014	Kamble et al., 2021	0.064631
408	Morimoto, 2010	Iqbal and Campbell, 2020	0.062802
409	Minagawa et al., 2014	McMullen et al., 2021	0.062662
410	Utz et al., 2021	Lozier, 2016	0.062561
411	Kamble et al., 2021	Iqbal and Campbell, 2020	0.062372
412	Iqbal and Campbell, 2020	Casini, 2019	0.061325
413	Morimoto, 2010	Grover and Sabherwal, 2020	0.061177
414	Iqbal and Campbell, 2020	Doll and Bearman, 2018	0.061052
415	Gerba, 2015	Alexakis et al., 2019	0.060101
416	Lozier, 2016	Casini, 2019	0.059182
417	Morimoto, 2010	Landgrebe, 2011	0.058694
418	Liu et al., 2020	Grover and Sabherwal, 2020	0.057643
419	Nicol, 2020	Alexakis et al., 2019	0.05659
420	Tokazhanov et al., 2021	Landgrebe, 2011	0.055864
421	Gerba, 2015	Chenhao and Kumar, 2018	0.055843
422	Vuletic et al., 2019	Grover and Sabherwal, 2020	0.055549
423	Mata and Milner, 2021	Grover and Sabherwal, 2020	0.055152
424	Minagawa et al., 2014	Chenhao and Kumar, 2018	0.05495
425	Wanga et al., 2021	Lozier, 2016	0.054762
426	Lozier, 2016	Cronin and Doherty, 2019	0.054439
427	Lozier, 2016	Li et al., 2021	0.0538
428	Lozier, 2016	Iqbal and Campbell, 2020	0.052097
429	Vuletic et al., 2019	Lozier, 2016	0.050218
430	Meyer et al., 2014	Landgrebe, 2011	0.049999
431	Utz et al., 2021	Landgrebe, 2011	0.049678
432	Minagawa et al., 2014	Gerba, 2015	0.048779
433	Minagawa et al., 2014	Das, 2021	0.04853
434	Lozier, 2016	Alexakis et al., 2019	0.048321
435	Tokazhanov et al., 2021	Minagawa et al., 2014	0.04811
436	Ramanathan et al., 2021	Lozier, 2016	0.047717
437	Lozier, 2016	Latman and Herb, 2013	0.047657

438	Grover and Sabherwal, 2020	Casini, 2019	0.045062
439	Nicol, 2020	Lozier, 2016	0.044942
440	Landgrebe, 2011	Chenhao and Kumar, 2018	0.044938
441	McMullen et al., 2021	Liu et al., 2020	0.044422
442	Mata and Milner, 2021	Lozier, 2016	0.043887
443	Lozier, 2016	Chenhao and Kumar, 2018	0.042195
444	McMullen et al., 2021	Lozier, 2016	0.040662
445	Iqbal and Campbell, 2020	Grover and Sabherwal, 2020	0.039912
446	Pei-Lee et al., 2015	Lozier, 2016	0.037913
447	Lozier, 2016	Habibi and Chattopadhyay, 2021	0.036642
448	Grover and Sabherwal, 2020	Doll and Bearman, 2018	0.036216
449	McMullen et al., 2021	Grover and Sabherwal, 2020	0.035204
450	Simmons et al., 2017	Grover and Sabherwal, 2020	0.034938
451	Tokazhanov et al., 2021	Lozier, 2016	0.032672
452	Grover and Sabherwal, 2020	Gerba, 2015	0.029528
453	McMullen et al., 2021	Iqbal and Campbell, 2020	0.027674
454	Grover and Sabherwal, 2020	Chenhao and Kumar, 2018	0.027393
455	Minagawa et al., 2014	Lozier, 2016	0.025545
456	Landgrebe, 2011	Grover and Sabherwal, 2020	0.02278
457	Latman and Herb, 2013	Grover and Sabherwal, 2020	0.020909
458	Landgrebe, 2011	Iqbal and Campbell, 2020	0.020899
459	Meyer et al., 2014	Lozier, 2016	0.019784
460	Iqbal and Campbell, 2020	Gerba, 2015	0.017904
461	Lozier, 2016	Kumar and Shimi, 2015	0.011922
462	Minagawa et al., 2014	Grover and Sabherwal, 2020	0.008088
463	Lozier, 2016	Kamble et al., 2021	-0.000755
464	Lozier, 2016	Landgrebe, 2011	-0.002081
465	Lozier, 2016	Grover and Sabherwal, 2020	-0.003219

Appendix C. Clip Art Sources

Figure	Image Description	URL
Figure 3	Magnifying Glass	https://www.pngkit.com/bigpic/u2q8r5q8e6i1u2u2/
Figure 4	Green Light Bulb	https://th.bing.com/th/id/R.f95cc682d3b2452cb2125c8f040c489?rik=L%2bFPXEUQTQYqqA&riu=http%3a%2f%2fclipart-library.com%2fnewhp%2f14-149350_energy-conservation-efficient-energy-use-solar-energy-efficient.png&ehk=sKRslYPNPTdHNKdp9G%2b9rMpCQTSEZAWef5VmD%2bY9nFM%3d&risl=&pid=ImgRaw&r=0
Figure 4	Face Scan	https://us.123rf.com/450wm/allismagic/allismagic1702/allismagic170200052/72208489-biometrical-identification-facial-recognition-system-concept-asian-man-vector-illustration.jpg?ver=6
Figure 4	Fingerprint Match	https://2.bp.blogspot.com/_PvIZNwS6Y1o/SbWQNsVAB1I/AAAAAAAaWl/wnflwJHoMU0/s400/MinutiaeMatching.jpg
Figure 4	Iris	https://media.istockphoto.com/vectors/human-eye-iris-isolated-on-white-background-vector-id487674227?k=6&m=487674227&s=612x612&w=0&h=Q5RySsUz578QYiq7hSs8egYtZAQ-h_Ilw5o6phafps=
Figure 5	Static Hand	https://media.istockphoto.com/photos/man-making-stop-gesture-with-hand-isolated-on-white-background-with-picture-id855670474?k=6&m=855670474&s=170667a&w=0&h=jqyWNktt5YdnpxSEiwsQWISH-i_ZdlO991t2OaqDCs=
Figure 5	Swiping Hand	https://th.bing.com/th/id/R.92174562360f15c4671a46003a724ff6?rik=33xtoowAAy4epg&riu=http%3a%2f%2fwww.codeproject.com%2fKB%2ftablets%2f636490%2fswiperight.png&ehk=6IDYmGfszRJE56Abs8cq1YX0ZV6065HdS54pKVt%2fd2k%3d&risl=&pid=ImgRaw&r=0&sres=1&sresct=1
Figure 6	Alarm Clock	https://www.jing.fm/clipimg/full/0-6438_alarm-clock-clipart-png.png
Figure 6	Person Tripping Sensor	https://media.istockphoto.com/vectors/walking-man-symbol-with-motion-sensor-waves-signal-vector-id867747020?k=6&m=867747020&s=612x612&w=0&h=18p2CvoRI23GwWb6XT-WA8FlcbEF6mBOdwf3wHRMeRo=
Figure 7	"Do Not Touch" Sign	https://www.giplastics.co.uk/wp-content/uploads/2020/02/Do-Not-Touch-Web-File-scaled.jpg
Figure 7	Phone Scanning QR Code	https://thumb.xfactorapp.com/tt/360/247/0/100/v3/uploads/_xfactor/cms/56cdc3795d4b84cf5e8b46f3/56cdc3781a354_Coffee.png
Figure 8	Emitting Voice	https://clipground.com/images/voice-clip-art-10.jpg
Figure 8	Gray Syntax Image	https://www.clker.com/cliparts/2/0/4/4/11949945421472684305edit.svg.med.png
Figure 8	Microphone	https://th.bing.com/th/id/R.24b3e4c251638a3ad80c218e93756278?rik=0l1V8KZb2kVwtQ&riu=http%3a%2f%2fimages.clipartpanda.com%2fmicrophone-icon-vector-microfono_microphone_icon-1969px.png&ehk=fRrxPuDIUSP%2bMwHy5BQDJJeWydB0DSFcMbmOQfdkGV8%3d&risl=&pid=ImgRaw&r=0
Multiple Figures	Green Checkmark	https://th.bing.com/th/id/R.52cd1cce5f846879185802cd1fb08f2e?rik=KwkOfHT2DC5n7w&riu=http%3a%2f%2fwww.downloadclipart.net%2flarge%2f44012-small-green-check-mark-clipart.png&ehk=VTW%2bQBZ%2fYp%2f4EmCo0xxuAUOv4GE%2f%2f4ILEMcTeLVmyMo%3d&risl=&pid=ImgRaw&r=0

References

- Alexakis, G., Panagiotakis, S., Fragkakis, A., Markakis, E., and Vassilakis, K. (2019). "Control of smart home operations using natural language processing, voice recognition and IoT technologies in a multi-tier architecture." *Designs* 3.3, 32.
- Bornmann, L., & Marx, W. (2013). The proposal of a broadening of perspective in evaluative bibliometrics by complementing the times cited with a cited reference analysis. *Journal of Informetrics*, 7(1), 84-88.
- Bufquin, D., Park, J.-Y., Back, R. M., de Souza Meira, J. V., and Hight, S. K. (2021). "Employee work status, mental health, substance use, and career turnover intentions: An examination of restaurant employees during covid-19." *International Journal of Hospitality Management*, 93, 102764.
- Casini, B., Tuvo, B., Cristina, M. L., Spagnolo, A. M., Totaro, M., Baggiani, A., Privitera, G. P. (2019). "Evaluation of an ultraviolet C (UVC) light-emitting device for disinfection of high touch surfaces in hospital critical areas." *International journal of environmental research and public health*, 16.19, 3572.
- Centers for Disease Control and Prevention. (2021). How COVID-19 Spreads. Retrieved from [https:// www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html](https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html)
- Coccia, M. (2021). "The relation between length of lockdown, numbers of infected

- people and deaths of covid-19, and economic growth of countries: Lessons learned to cope with future pandemics similar to covid-19.” *Science of The Total Environment*, 145801.
- Cronin, S. and Doherty, G. (2019). “Touchless computer interfaces in hospitals: A review.” *Health informatics journal*, 25(4), 1325–1342.
- Das, A., Barua, A., Mohimin, A. Md., Abedin, J., Khandaker, M. U., Al-mugren, K. S. (2021). "Development of a Novel Design and Subsequent Fabrication of an Automated Touchless Hand Sanitizer Dispenser to Reduce the Spread of Contagious Diseases." *Healthcare*. Vol. 9. No. 4. Multidisciplinary Digital Publishing Institute.
- Diodato, V. (1994). *Dictionary of Bibliometrics*. Binghamton, NY: The Hawthorn Press, Inc.
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., Lim, W. M. (2021). "How to conduct a bibliometric analysis: An overview and guidelines." *Journal of Business Research* 133: 285-296.
- Grover, V. and Sabherwal, R. (2020). “Making sense of the confusing mix of digitalization, pandemics and economics.” *International Journal of Information Management*, 55, 102234.
- Guo, Y. M., Huang, Z. L., Guo, J., Guo, X. R., Li, H., Liu, M. Y., Ezzaddine, S., & Nkeli, M. J. (2021). A bibliometric analysis and visualization of blockchain. *Future Generation Computer Systems*, 116, 316-332.
- Iqbal, M. Z., and Campbell, A. (2020). "The emerging need for touchless interaction technologies." *Interactions* 27.4, 51-52.

- Kamble, P. Mittal, Y. G., Gote, G., Hodgir, R., Karunakaran, K. P. (2021). "COVID Key: A Multifunctional Device to Avoid Touch." *Transactions of the Indian National Academy of Engineering*, 1-20.
- Kumar, M. and Shimi, S. L. (2015) "Voice recognition based home automation system for paralyzed people." *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)* 4.10.
- Kurgat, E. K., Sexton, J. D., Garavito, F., Reynolds, A., Contreras, R. D., Gerba, C. P., Leslie, R. A., Edmonds-Wilson, S. L., and Reynolds, K. A. (2019). "Impact of a hygiene intervention on virus spread in an office building." *International journal of hygiene and environmental health*, 222(3), 479–485.
- Landgrebe, K. D. (2011). "Illumination using 405 nm light kills pathogenic bacteria." *American Journal of Infection Control*, 39(5), E46–E47
- Latman, N. S., and Herb, E. (2013). "A field study of the accuracy and reliability of a biometric iris recognition system." *Science & Justice*, 53(2), 98-102.
- Lin, C. and Kumar, A. (2018). "Contactless and partial 3D fingerprint recognition using multi-view deep representation." *Pattern Recognition*. 83, 314-327.
- Liu, J., Zhang, H., and Li, C. (2020). "Comtis: Customizable touchless interaction system for large screen visualization." *Virtual Reality & Intelligent Hardware*, 2(2), 162–174.
- Lozier, P. (2016). "Electronic sensor faucets improve hygiene and conserve water in commercial restrooms. *Architect*, 105, 74-77.
- Mata, D. A. and Milner Jr, D. A. (2021). "Statistical methods in experimental pathology: A review and primer." *The American Journal of Pathology*.

- McMullen, K., Guth, R. M., Wood, H., Mueller, C., Dunn, G., Wade, R., Siddiqui, A., Dubberke, E. R., Woeltje, K. F., and Warren, D. K. (2020). "Impact of no-touch ultraviolet light room disinfection systems on *clostridioides difficile* infections." *American Journal of Infection Control*.
- Meyer, R., Butzler, J., Dzaack, J., and Schlick, C. (2014) "Development of interaction concepts for touchless human-computer interaction with geographic information systems." *International Conference on Human-Computer Interaction*.
- Morimoto, R. (2010). "Estimating the benefits of effectively and proactively maintaining infrastructure with the innovative Smart Infrastructure sensor system." *Socio-Economic Planning Sciences*, 44.4, 247-257.
- Morimoto, R. (2013). "A socio-economic analysis of Smart Infrastructure sensor technology." *Transportation Research Part C: Emerging Technologies*, 31, 18-29.
- Na, J., Tibebu, H., De Silva, V., Kondoz, A., and Caine, M. (2020). "Probabilistic approximation of effective reproduction number of covid-19 using daily death statistics." *Chaos, Solitons & Fractals*, 140, 110181.
- Nicol, A.-M. (2020). "Covid-19 transmission pathways and relevance to the WC setting." *National collaborating centre for environmental health*.
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tezlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hrobjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco,

- A. C., Welch, V. A., Whiting, P., Moher, D. (2021). "The PRISMA 2020 statement: an updated guideline for reporting systematic reviews." *Bmj* 372.
- Parziale, G. (2008). "Touchless fingerprinting technology." *Advances in biometrics*. 25-48.
- Prathima, N., Shimi, S. L. (2017). "Voice recognition based home automation system for paralyzed people." *International Journal for Modern Trends in Science and Technology* 3.2, 101-106.
- Ramanathan, S. S. K., Basha, R. F. K., and Banu, A. (2021). "A novel face recognition technology to enhance health and safety measures in hospitals using SBC in pandemic prone areas." *Materials Today: Proceedings*.
- Ratha, N. K. and Govindaraju, V. (2007) "Advances in biometrics: sensors, algorithms and Systems". *Springer Science & Business Media*.
- Rethlefsen, M. L., Kirtley, S., Waffenschmidt, S., Ayala, A. P., Moher, D., Page, M. J., Koffel, J.B., and PRISMA-S Group. (2021). "PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews." *Systematic reviews* 10.1: 1-19.
- Simmons, S. M., Jeff K. Caird, J. K., and Steel, P. (2017) "A meta-analysis of in-vehicle and nomadic voice-recognition system interaction and driving performance." *Accident Analysis & Prevention*, 106, 31-43.
- Sinha, G.R., (2019). "Advances in Biometrics: Modern Methods and Implementation Strategies". *Springer Nature*.
- Stein, M. (2020). "5 types of touchless technology to use throughout your workplace." *Envoy*.

- Taylor, Z. (2020). "A study of space bathroom design." *Acta Astronautica*, 174, 55–60.
- Tokazhanov, G., Tleuken, A., Durdyev, S., Otesh, N., Guney, M., Turkyilmaz, A., & Karaca, F. (2021). Stakeholder based weights of new sustainability indicators providing pandemic resilience for residential buildings. *Sustainable Cities and Society*, 75, 103300.
- Utz, C., Becker, S., Schnitzler, T., Farke, F. M., Herbert, F., Schaewitz, L., Degeling, M., Durmuth, M. (2021). "Apps against the spread: Privacy implications and user acceptance of COVID-19-related smartphone apps on three continents." *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*.
- Vinson, D. (2020). "Touchless technologies." *PUPN*.
- Vuletic, T., Duffy, A., Hay, L., McTeague, C., Campbell, G., and Greal, M. (2019). "Systematic literature review of hand gestures used in human computer interaction interfaces". *International Journal of Human-Computer Studies*, 129, 74–94.
- Wanga, H., Thobius, J., and Mauna, B. C. (2020). "Social distancing: Role of smartphone during coronavirus (COVID–19) pandemic era." *International Journal of Computer Science and Mobile Computing*, 9.5, 181-188.
- Zhou, H., Yip, W. S., Ren, J., & To, S. (2022). Thematic analysis of sustainable ultra precision machining by using text mining and unsupervised learning method. *Journal of Manufacturing Systems*, 62, 218-233.
- Zuo, Z., Cheng, J., Guo, H., & Li, Y. (2021). Knowledge mapping of research on

strategic mineral resource security: A visual analysis using CiteSpace. *Resources Policy*, 74, 102372.

REPORT DOCUMENTATION PAGE					<i>Form Approved</i> OMB No. 0704-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.						
1. REPORT DATE (DD-MM-YYYY) 03/14/2022		2. REPORT TYPE Master's Thesis			3. DATES COVERED (From - To) Oct 2020 - Mar 2022	
4. TITLE AND SUBTITLE A Thematic and Reference Analysis on Touchless Technologies				5a. CONTRACT NUMBER		
				5b. GRANT NUMBER		
				5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Curia, Eric, R, Capt				5d. PROJECT NUMBER		
				5e. TASK NUMBER		
				5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way Wright-Patterson AFB OH 45433-77765					8. PERFORMING ORGANIZATION REPORT NUMBER AFIT-ENV-22-M-190	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Civil Engineering Center 2261 Hughes Ave, Ste.155 JBSA Lackland, TX 78236-9853					10. SPONSOR/MONITOR'S ACRONYM(S) AFCEC	
					11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT DISTRIBUTION A. Approved for public release: distribution unlimited.						
13. SUPPLEMENTARY NOTES This work is a declared work of the U.S. Government and is not subject to copyright protection in the United States.						
14. ABSTRACT The purpose of this research is to explore the utility and current state of touchless technologies. Five categories of technologies are identified as a result of collecting and reviewing literature: facial/biometric recognition, gesture recognition, touchless sensing, personal devices, and voice recognition. A thematic analysis was conducted to evaluate the advantages and disadvantages of the five categories. A reference analysis was also conducted to determine the similarities between articles in each category. Touchless sensing showed to have the most advantages and least similar references. Gesture recognition was the opposite. Comparing analyses shows more reliable technology types are more beneficial and diverse.						
15. SUBJECT TERMS Touchless, Sensing, Biometric, Gesture						
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 132	19a. NAME OF RESPONSIBLE PERSON Alfred E. Thal, Jr., PhD	
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include area code) (312) 785-3636 x7401	