UC Irvine

UC Irvine Electronic Theses and Dissertations

Title

Finding a place for chatbots in genetic counseling: Practitioners' experiences, views, and ideas for future applications

Permalink

https://escholarship.org/uc/item/0b2181vw

Author

Wallis, Jordann

Publication Date

2020

Copyright Information

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,
IRVINE

Finding a place for chatbots in genetic counseling: Practitioners' experiences, views, and ideas for future applications

THESIS

submitted in partial satisfaction of the requirements
for the degree of

MASTER OF SCIENCE

in Genetic Counseling

by

Jordann Wallis

Dissertation Committee:
Professor Maureen Bocian, Chair
Assistant Clinical Professor Katherine Hall
Assistant Clinical Professor Rebecca LeShay

2020

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to express the deepest appreciation for my committee members, Dr. Maureen Bocian, Katherine Hall, and Rebecca LeShay. From its beginnings as a continuing education presentation to the form it is in today, this thesis would not have been possible without all of your continued support, encouragement, and guidance. Thank you for helping turn a topic I am passionate about into a thesis that I am proud to have completed.

Kathy, in addition to being on my thesis committee, you have been the most outstanding faculty mentor, and I could not have asked for better. Thank you for every phone call, happy hour, and "quick" office meeting to keep me on track and calm my nerves.

I would also like to thank Pamela Flodman and Dr. Katherine Osann for their invaluable statistics support and encouragement through every stage of my thesis. My data analysis would not be what it is without your expert assistance.

Pam, you have also been a constant source of support for me since I arrived in Orange in the Fall of 2018. Thank you for being an unending fountain of wisdom, guidance, and cake recipes, and helping me find my voice as a genetic counselor.

To Aneesa Masters, thank you for reminding me that "you can do anything for two years." I made it through, and now I know I can handle anything that life throws at me. You gave me the idea that sparked this entire thesis, and I am so happy to be able to call you a friend and now a colleague.

Finally, to my friends and family, who have cheered me on since long before I was accepted to UCI, thank you for every phone call, note, letter, present, and baked good that you have shared with me on this two-year journey. I cherish each and every one of you. Justene, for the late-night check-ins and Facetime calls. Kyle, for empathizing with the graduate school experience. And Ryan, for always knowing how to make me smile and reminding me why I did this, even while we were 1000 miles apart.

ABSTRACT OF THE THESIS

Finding a place for chatbots in genetic counseling: Practitioners' experiences, views, and ideas for future applications

by

Jordann Wallis

Master of Science in Genetic Counseling

University of California, Irvine, 2020

Professor Maureen Bocian, Chair

Genetic counseling chatbots have recently been developed, with several currently in use. This raises two important questions: if genetic counselors are interested in using chatbots in their practices, and what applications and information genetic counselors want included in these chatbots. To date, these questions have not been explored, and there has been no published research on genetic counselors' opinions on the usage of chatbots. The aim of this thesis is to investigate the current perspectives of genetic counselors and genetic counseling graduate students regarding the use of chatbots in the genetic counseling field. A survey was developed to explore genetic counselors' and genetic counseling graduate students' familiarity with, usage of, and opinions regarding chatbots, both in general and specifically in the genetic counseling field. This includes their thoughts on what information genetic counseling chatbots should provide and potential barriers to their use. It was hypothesized that counselors and students who are younger, see a larger number of patients per week, use alternative counseling methods, and are already familiar with chatbots in general will be more interested in offering a genetic counseling chatbot.

While overall, participants were only slightly interested in offering a chatbot to their patients, the variables that predicted greater interest were different than those hypothesized. The data showed that counselors who work in a laboratory or non-patient-facing setting and do not have administrative and/or support staff are more interested. In addition, both counselors and students who are familiar with genetic counseling chatbots and would consider using a chatbot for their personal health are more interested. Participants' main concern was that counselors would be unable to assess whether patients understood the information included in the chatbot. While participants' preferences for what is included in a genetic counseling chatbot is in line with what is currently being offered, the results of this thesis still offer some important insights into the future development and refinement of genetic counseling chatbots.

I. INTRODUCTION

1.1 Genetic Counseling

Genetic counselors are healthcare professionals who are trained in both medical genetics and counseling to help guide individuals through what is known about genetic disorders, how they are inherited, and what impact this information can have on them and their families. They use personal, family, and medical history to assess the risks for genetic conditions and determine if genetic testing is appropriate. Genetic counselors then assist patients in interpreting their results and understanding the potential impact on their medical management, the recurrence risk, and the implications for other family members ("Who Are Genetic Counselors?" 2020). There are currently over 5,000 certified genetic counselors and 51 accredited genetic counseling graduate programs in North America ("ABGC Fall Digest" 2019) (Professional Status Survey 2020: Executive Summary, 2020). Since 2010, the genetic counseling profession has grown by more than 100% (Professional Status Survey 2020: Executive Summary, 2020). From the traditional areas of prenatal, pediatric, and adult/general genetics, over the years we have seen genetic counseling expand to include a variety of other specialties. The area with the most growth has been cancer genetic counseling, which became the second most common specialty behind prenatal in 2002 (1980-2002 Professional Status Survey Trends Report, 2004). Currently, cancer is the most common specialty reported by genetic counselors in direct patient care, accounting for 52% of the total workforce (Professional Status Survey 2020: Executive Summary, 2020). Since 2002, genetic counseling has seen expansion into even more specialized niches, such as infertility, psychiatry, cardiology, and neurology. Genetic

counselors have also moved into a variety of positions in industry settings, especially clinical testing laboratories. These roles include variant curation, scientific writing, and customer liaisons, to name only a few (Christian, Lilley, Hume, Scott, & Somerville 2011) (McWalter, et al. 2018). There also has been expansion into other "non-traditional" areas of genetic counseling, many of which, like in industry, do not involve direct patient care. These include research, public health, education, and insurance. While each of these areas individually accounts for a small amount of the workforce, they cumulatively account for 30% of all genetic counselors (Professional Status Survey 2020: Work Environment, 2020), indicating that the range and scope of practice of genetic counseling professionals has greatly expanded beyond where it started.

Genetic counseling has grown rapidly, both in terms of the number of trained counselors and the job opportunities and specialties available to them. In spite of increasing numbers of genetic counselors entering the profession, there still are more job openings in the genetic counseling field than there are current graduates (Hoskovec, et al. 2018). Current estimates indicate there are two to three jobs in the United States for every genetic counseling program graduate; thus, the demand for genetic counselors is still higher than current training capacity (Burns, et al. 2019) (Molteni 2019). Even taking into account experienced genetic counselors who could fill these positions, the U.S. would still need at least 450 more trained individuals to fulfill the demand for genetic counselors in direct patient care in 2020 (Hoskovec, et al. 2018). To attempt to alleviate this gap between supply and demand, genetic counselors have worked to develop a variety of tools, administrative support systems, and alternative counseling methods aimed at reaching more patients and reducing their clinical burden by automating certain tasks.

1.2 Alternative genetic counseling methods

Genetic counselors are no strangers to improvements in their field in terms of efficiency and technology. From simple tools, such as stencils for drawing pedigrees more clearly to more technological advancements (e.g., electronic pedigree construction programs such as Progeny®), genetic counselors have adapted and attempted to make the process of taking complex family histories easier and more efficient (Bennett 2010) (Pritzlaff, et al. 2014). The first electronic pedigree programs were available in 2004, and there are currently almost 30 different programs and/or websites available (Welch, et al. 2018) ("Genomic Data Toolkit - Family History Tools Inventory"). Several of them were created for use specifically in cancer settings (Welch, et al. 2018) (Pritzlaff, et al. 2014). Many clinics send questionnaires to patients before their appointments to collect relevant personal, family, and medical history information, reducing the time spent on these activities during their appointments. In some cases, these forms are even available online so that patients can have immediate access and do not have to wait for a mailed copy (Gordon, Babu, & Laney 2018). This has resulted in genetic counselors being able to review relevant information more quickly and also in sooner appointment times for patients (Gordon, Babu, & Laney 2018). Other genetic counselors may provide clinical services using telecommunications technologies, otherwise known as telemedicine or telegenetics. Telemedicine has been in use by genetic counselors for over 20 years as a way to increase the availability of services in remote areas (Gordon, Babu, & Laney 2018) (Gray, et al. 2000). In addition to being a service provided by genetic counselors who work in academic medical centers and for some healthcare companies (e.g., Kaiser Permanente and Geisinger Medical Group), there is an increasing number of private companies that are employing

counselors specifically to provide telemedicine (Gordon, Babu, & Laney 2018) (Du & Becher 2018). Some genetics clinics have adopted group counseling sessions for patients with similar indications to review pre-test information, followed by shorter individual sessions to discuss other recommendations or testing options tailored towards patients' specific personal and/or family histories (Calzone, et al. 2005) (McCuaig, et al. 2018) (Cloutier, et al. 2017). All of these advances have served to help genetic counselors see more patients, spend less time on the repetitive portions of appointments, and improve access to genetic counseling. Furthermore, studies have shown that overall, both patients and providers are satisfied with the level of information and care they receive through the use of these alternative counseling methods and see them as acceptable alternatives to the traditional in-person approach (Buchanan, Rahm, & Williams 2016) (Cohen et al 2016) (Cloutier, et al. 2017) (Calzone, et al. 2005) (McCuaig, et al. 2018). Clearly, genetic counselors are committed to finding new and more efficient ways to counsel and educate their patients. These methods have not diminished the genetic counseling profession, since counselors have adapted them to serve both their needs and the needs of their patients. In this way, both genetic counselors and patients are still able to provide and receive the same level of care, regardless of the counseling method.

1.3 Chatbots

The newest technological advancement in the field of genetic counseling is chatbots. A chatbot is a computer program that uses artificial intelligence and natural language processing to simulate conversation with human users (Shawar & Atwell 2007). Other names for chatbots include conversational agent, chatterbox, and virtual agent (Shawar &

Atwell 2007) (Io & Lee 2017). The first chatbot, ELIZA, was created in 1966 to mimic a

psychotherapist (Weizenbaum 1966). Users could interact with the chatbot by entering

text commands, and the chatbot would respond in kind. This is still the case today, with

many chatbots utilizing text messages or instant messaging to interact with users

(Brandtzæg & Følstad 2017). As technology has advanced, however, voice commands and

responses are also possible modes of interaction (Io & Lee 2017). The majority of chatbots

are very simple, which means that they are pre-programmed to answer a specific set of

questions. Users interacting with these chatbots can choose from predetermined options

but cannot ask their own questions. There are more complex chatbots that are able to

respond both to user-generated questions and to options that have been predetermined for

users (Io & Lee 2017). While we may not always think of them as such, personal assistants

like Siri, Amazon Alexa, and Google Assistant are all chatbots that many of us may interact

with every day. Finally, there are many websites and mobile applications that use chatbots

as well. The most common of these are used in retail customer service and internet

banking, but chatbots can also be found for news, weather, and food delivery services

(Følstad & Brandtzæg 2017).

Mobile applications (apps) are very small computer programs that have been

designed to perform specific functions on an individual's cell phone or tablet, such as

personal banking, online shopping, or communicating via text messages. Many companies

and retailers have their own apps that are available to download so that a user does not

have to navigate to their website to use their services. Examples of such companies include

Nordstrom, Facebook, and Wells Fargo. While these apps require Internet access, they are

not Internet browsers, since users can only access the services provided by that specific

company. Not all apps are chatbots, although many of them may utilize a chatbot for certain functions, such as customer service (Brandtzæg & Følstad 2017). Thus, when users try to contact customer service via the app they are using, instead of reaching a human representative, they communicate with a chatbot. Many users may not realize that they are interacting with a chatbot instead of a human for most of these exchanges (Radziwill & Benton 2017). These chatbots are programmed with answers to many of the most frequently asked questions identified by the company that created the app. This allows the customer service representatives to spend their time on more complicated problems, while users can still get their simpler questions answered.

Chatbots that are incorporated into online websites work exactly the same way as in mobile apps. Instead of being accessed through an app, however, they are accessed through the company's website. This is usually through a pop-up, or separate window, that allows the user to interact with the chatbot while still navigating the website. Some websites even have these boxes appear unprompted, with the option to minimize them until the user needs or wants to interact with them. As the use of mobile phones has increased, however, users are more commonly encountering and interacting with chatbots on their mobile devices (Io & Lee 2017). It is predicted that over 83% of the population in the United States will use their mobile phones to access the internet in 2020, compared to just under 78% in 2017 (Clement 2019). However, on average, people spend 90% of their mobile phone usage on mobile apps instead of an Internet browser (Wurmser 2019). So, while chatbots are still available on the web, the majority of individuals, especially in the United States, encounter them on their cellphones within mobile apps.

1.4 Chatbots in medicine

As chatbots have become more sophisticated, their use has expanded into other areas, including the field of medicine. Chatbots have been piloted and used for patients with a wide variety of health concerns and medical conditions. Examples of more general health applications include mental and physical wellness (e.g., healthy habits, positive psychology), addictions (e.g., alcoholism, smoking), and sexually transmitted diseases (e.g., AIDS/HIV, syphilis) (Pereira & Díaz 2019). In some cases, the chatbot is designed to function as an advisor or mentor, such as for users struggling with addictions or diagnosed with sexually transmitted diseases. For others, the chatbot can track eating habits or physical activities in addition to functioning like a health coach to encourage users to stay on track with their goals (Pereira & Díaz 2019). Chatbots have also been developed for more specific diagnoses, including neurological disorders (e.g., dementia, Alzheimer disease) and nutritional metabolic disorders (e.g., diabetes, obesity), among others (e.g., aphasia, diagnosing rare diseases, detecting heart conditions/cardiovascular diseases) (Pereira & Díaz 2019). Examples of chatbot functions in these settings include recurrent interviews with patients who have a rare disease diagnosis, providing Alzheimer patients with quizzes designed to slow progression of symptoms, and providing illness-specific advice (Pereira & Díaz 2019).

Many of the studies about chatbots in the medical field at large focus on patient experiences or on patients' thoughts about using chatbots in general (Nadarzynski, Miles, Cowie, & Ridge 2019) (Pereira & Díaz 2019) (Laranjo, et al. 2018). Overall, patients feel that chatbots can be helpful, although there is a small percentage who prefer using them

only for logistical applications (such as making appointments) and would prefer to see a doctor in person to discuss their health concerns (Nadarzynski, Miles, Cowie, & Ridge 2019). There are some studies that have tried to assess physicians'/clinicians' thoughts about using chatbots in their practices (Palanica, Flaschner, Thommandram, Li, & Fossat 2019) (Laranjo, et al. 2018). Of the physicians surveyed in one study, over 70% had never heard of or used any of the chatbots currently available in the medical field (Palanica, Flaschner, Thommandram, Li, & Fossat 2019). However, over half of the physicians recognized the utility of chatbots for distributing general health information, logistical tasks, and helping with patient compliance (Palanica, Flaschner, Thommandram, Li, & Fossat 2019). So, even though most physicians are not using chatbots themselves, they can still see many potential uses for them that would be beneficial for both patients and providers.

1.5 Chatbots in genetic counseling and their functions

There are currently several chatbots that have been developed and are in use by genetic counselors. The most well-known is the chatbot called GIA, which stands for Genetic Information Assistant, developed by Clear Genetics. This chatbot was created in partnership with Geisinger Health Systems and GeneMatters, a company that provides telehealth genetic counseling services. In November 2019, GIA was bought by Invitae, a genetic testing company that was using the chatbot as part of their patient-initiated testing portal (Invitae Corporation 2019). GIA was developed with input from genetic counselors and has three different interfaces, each of which has a separate function that can be used independently. These include interfaces designed to, for example, consent patients to

research studies, follow up with patients after their genetic test results return, and be shared with family members to disclose positive test results and discuss their options for genetic testing and counseling.

All three of these chatbot interfaces are being used at Geisinger locations in Pennsylvania and New Jersey as part of the MyCode Community Health Initiative. Participants in this study provide samples, including blood, for use in research on cardiovascular, cancer, and other health conditions, such as cystic fibrosis and familial hypercholesterolemia. As part of the research study, participants' DNA is tested for variants, or changes, that may predispose them to develop or may even cause one of these conditions. If one of these variants is identified, the patient is notified and is offered an opportunity to speak to a genetics provider who is part of the Geisinger team or to their own medical provider about the result in more detail ("What is MyCode?"). All three interfaces of the GIA chatbot are being used by the MyCode participants. For example, one interface is being used to consent them to the research study. If a variant is identified in their DNA, after their result is disclosed, they are offered the option of using the follow-up chatbot interface to remind them of recommendations made by their health care team. Examples include meeting with a specialist provider or initiating relevant screening or risk-reducing actions that were recommended at the time that they received their results. These individuals can also send their family members a GIA chatbot interface that will explain the patients' test results and what implications these results can have for their relatives.

The GIA chatbot is scripted, meaning that all of the responses that it gives to user

questions have been pre-written, in this case by a team of genetic counselors. In the event

that there is a question that does not have a pre-programmed response, the query is

forwarded to the care team, who then create an answer for the chatbot to use in future

interactions (Schmidlen, Schwartz, Diloreto, Kirchner, & Sturm 2019). The responses

provided by GIA can also be edited or expanded based on user response, which helps the

library of responses to improve and to be able to address a wider variety of inquiries. This

allows the health care team at Geisinger to be in control of what information is being

provided to their patients through the chatbot and to update it as necessary.

In October 2019, Geisinger published the first study specifically about genetic

counseling chatbots that looked at patient perspectives of the three different interfaces of

their chatbot (Schmidlen, Schwartz, Diloreto, Kirchner, & Sturm 2019). The patients were

generally in favor of using the various interfaces but had some concerns about privacy and

usability (Schmidlen, Schwartz, Diloreto, Kirchner, & Sturm 2019). The GIA chatbot was

updated to address these issues and incorporate the patients' suggestions, which speaks to

the importance of collaboration between patients and clinicians to develop tools that help

both parties.

There is also another chatbot that is currently available for use called GeneFAX. It

was developed by a software company named OptraHEALTH and was officially launched in

February, 2018. The goal behind the development of the app was to provide a platform for

individuals to ask questions relevant to genetic testing. This includes understanding the

meaning of a genetic test, or what to expect from genetic testing, as well as information

about genetic disorders or conditions. There is also an option in the app to connect to a genetic counselor through live chat or by scheduling an appointment through an online portal if the user has more specific questions that cannot be answered by the chatbot; as of November 2019, users are connected to board-certified genetic counselors provided by InformedDNA, a private, laboratory-independent genetic counseling company ("The Digital Revolution in Genomics: OptraHEALTH® Launches GeneFAX™, Free to Use Conversational AI Powered App for Consumers" 2018) (Bio-IT World Staff 2019). Unlike GIA, GeneFAX is publicly available and can be downloaded on a variety of platforms, including mobile phones and personal assistant devices such as Amazon Alexa.

In comparison to the GIA chatbot, which has a more limited scope, the GeneFAX chatbot covers a much wider range of topics, from prenatal to cancer to general genetics, including some specific genetic conditions. It will discuss genetic testing in general and also specific genetic tests, such as noninvasive prenatal screening (NIPS). GeneFAX also has an option for users to input their own genetic test results, which the chatbot will then discuss. In contrast to the GIA chatbot, which is entirely scripted by genetic counselors, GeneFAX draws on a database to answer questions from people while they are using the app. This database is curated by OptraHEALTH and also contains a dictionary with over 450,000 genetic terms. Both are continually updated (Versel 2019). According to OptraHEALTH, the database is also validated by board-certified genetic counselors, but they are otherwise uninvolved in the creation of responses provided by the chatbot (Versel 2019).

It is important to note that at this time, no chatbot developed for genetic counseling has been utilized to return genetic test results. Any chatbot that is being used in

conjunction with genetic testing is being offered to patients either before testing has occurred or after the results have been given. This is the case for the GIA chatbot, in which all genetic test results are given to patients by genetic counselors before involving either the follow-up interface or the family cascade interface, or both, depending on patient preference. Since the GeneFAX chatbot is accessible by the general public, if users are entering their own genetic test results, it is unclear what laboratory the genetic test results came from and who disclosed the results to them. Presumably the chatbot is merely explaining results that the individuals have already received in some other form, though there is no way to confirm this. Regardless, the chatbot is not the intended delivery method for the initial return of genetic test results.

1.6 Aim of this study

The aim of this study is to determine if genetic counselors are interested in using chatbots designed specifically for their profession and, if so, what information these chatbots should include. To assess this, a survey was designed to ask genetic counselors about their use of chatbots in general, their familiarity with genetic counseling chatbots specifically, and their thoughts on what information should be included in genetic counseling chatbots. This included options for disclosing positive and negative test results in a variety of clinical settings and scenarios.

The hypothesis of this study is that genetic counselors who are younger, see a large number of patients per week, are using some alternative counseling methods, and are already familiar with chatbots in general are predicted to be more likely to be interested in offering genetic counseling chatbots to their patients. By gaining a better understanding of

the perspectives of genetic counselors, we can determine whether the currently available applications are meeting expectations and, if not, how they can be improved.

As a part of this research, genetic counseling graduate students were also included in the study population. Genetic counseling students are soon to be genetic counselors, and as such, their perspectives about chatbots can provide an important contribution to the field. Furthermore, as a population who may be more familiar with chatbots in general, genetic counseling students may be more open to utilizing them as part of their future careers. Students were included in our research population to compare with genetic counselors in order to see what differences in perspective, if any, there are between these two groups on the use of genetic counseling chatbots.

To date, there have been no studies assessing genetic counselors' attitudes regarding existing genetic counseling chatbots, only on patient perspectives. While it is important to study the population for which the tool is intended, investigating those who would be implementing the tool is also necessary. Since chatbots are being designed to help genetic counselors, they should have the opportunity and ability to decide what information and uses these chatbots have. Chatbots have the potential to be a very helpful tool for genetic counselors, increasing both efficiency and the ability to see more patients. They also have the potential to help genetic counselors spend more time with their patients focusing on the counseling process itself. As such, fully exploring all the possibilities and opportunities that chatbots may offer to the genetic counseling profession is necessary to help determine how best to implement this new technology.

II. METHODS

2.1 IRB Protocol

This research protocol was determined to be exempt using the Institutional Review Board of University of California, Irvine Exempt Self-Determination form. A copy is available from the authors upon request.

2.2 Participant eligibility and inclusion

Individuals were eligible to participate in this study if they were currently practicing board-certified genetic counselors or genetic counseling students currently enrolled in an accredited genetic counseling Master's program. They were only eligible if they were practicing or attending school in the United States of America and were 18 years of age or older. The survey was provided in English, which required participants to read and understand English. The survey was administered online only, which required internet access to participate.

There were 262 total respondents, of whom 47 were removed because they did not complete the survey. An additional 11 respondents were removed because they did not live in the United States and so were disqualified from completing the rest of the survey.

2.3 Recruitment

Participants were recruited through various methods:

1. An advertisement for the survey, including a brief description of the survey and the study link, was distributed through the National Society of Genetic Counselors (NSGC) Student

Research Survey listserv on January 23rd, 2020 , followed by a reminder on February 5th, 2020.

2. E-mail correspondence from the program director of the University of California, Irvine Genetic Counseling Graduate program to the directors of the other currently active genetic counseling Master's programs in the United States was sent in January, 2020, with a reminder sent in March, 2020.

3. An email was distributed among members of the Portland, Oregon practicing genetic counselor listserv.

4. A flyer advertising the survey was posted at the 2019 National Society of Genetic Counselors conference in Salt Lake City, Utah prior to the survey being available online. The flyer was placed on communal tables outside of the main conference room on the first and second days of the conference. Interested participants could send an email to the lead researcher asking to be notified when the survey was available online.

5. Once the survey was available, an electronic flyer including the link was posted online on the lead researcher's LinkedIn page and shared on Twitter by a genetic counselor who is involved in using genetic counseling chatbots. The flyer was also posted online in a Facebook group for genetic counseling graduate students who are enrolled in genetic counseling Master's programs and are expecting to graduate in the summer of 2020.

See Appendix B for examples of survey distribution advertisements, including emails and flyers.

2.4 Protection of participant privacy

Participants were asked to complete an anonymous web-based survey generated through UCI REDCap, a secure web application for building and managing online surveys and databases. Participants accessed the online survey link using their own devices in their own locations. The privacy of participants was protected throughout the entire data collection process. No personal identifiers were obtained in this study. If interested participants had emailed the lead researcher earlier asking to be notified when the survey was available, those email addresses were deleted upon completion of the data collection period. This research study did not cause any harm to participants. All research data was stored securely and confidentially.

2.5 Consent

Implied informed consent was obtained from respondents prior to their participating in the study. On the first page of the online survey, a study information sheet was included that contained the contact information for both the lead researcher and the faculty sponsor, the purpose of the study, the eligibility requirements, and the contact information of the UCI Institutional Review Board. By clicking 'START,' respondents indicated that they consented to be research participants.

2.6 Survey

The survey was written by the lead researcher with input from the thesis committee members. It was separated into three sections, the first of which included demographic information modeled on the NSGC Professional Status Survey demographic questions. The second section was written to explore participants' real or hypothetical usage of chatbots

in their daily lives. The third section was designed to explore participants' opinions on the usage of chatbots in genetic counseling settings, including returning genetic test results. The survey instrument was generated using UCI REDCap and was accessed through the website link: https://is.gd/chatbotGC. In the event that participants were unable to use that link to access the survey, the unabbreviated version was provided: https://ci-redcap.hs.uci.edu/surveys/?s=Y9CETNDXKH.

The survey consisted of a total of 35 questions, including 6 Likert scale-based questions, 20 multiple-choice questions, 10 multiple-answer questions, and one short-answer question. There were 16 questions about demographics, 8 questions designed to assess usage of general chatbots, 10 questions about genetic counseling chatbots, and two questions about barriers to chatbots in genetic counseling. Branching logic was used so that participants only saw questions that were applicable to them in the survey. As such, no participant answered all 35 possible questions. Branching logic was also used to populate a text field for questions where there was an "Other" option so that participants could write in their responses.

In the first section of the survey, branching logic was used to separate genetic counseling graduate students and practicing genetic counselors. Students were asked how long they had been enrolled in a Master's program, and genetic counselors were asked how many years they had been practicing and their primary specialty. In addition, genetic counselors were asked about how they return genetic test results to their patients and whether they have any support staff. If they had support staff, they were to select all the types of staff that applied from the options given.

In the second section, branching logic was used to separate those who had used general chatbots in their personal lives from those who had not. Those who had were asked how often they used chatbots and for what purpose. Participants who had not were asked to predict how often they thought they might use a chatbot for different purposes. Both groups were given the same categories of chatbots to choose from and the same frequency of use options, except for the category "General Questions." This category was only shown to the participants who said that they had used chatbots in their personal lives; it was intended to be shown both to individuals who had used a chatbot previously and to those who had not, but during survey development it was mistakenly not included for the latter group of participants.

Finally, in the third section, branching logic was used to ask additional questions of participants who had indicated that they used a genetic counseling chatbot in their own practice. Specifically, they were asked what they used the genetic counseling chatbot for. Participants were also given 8 different scenarios in which a genetic counseling chatbot would be delivering either positive or negative genetic test results. The 8 scenarios were divided into 4 categories (prenatal, cancer, pediatric, and adult) and included one "low-risk" scenario and one "high-risk" scenario for each category. They were asked to rate on a Likert scale how likely they would be to use a chatbot to deliver the genetic test results in each scenario.

The complete survey for this study is available in Appendix A.

2.6.1 Survey data analysis

Data analysis was conducted using the statistical software IBM Statistical Package for Social Sciences (formerly named SPSS) Statistics v26.0. Demographic information is presented using descriptive statistics (mean, minimum, maximum and standard deviation for continuous variables, frequency and percent for categorical variables). Univariate analysis of the difference between subgroups as well as comparison between independent and dependent variables was performed using Pearson Chi-square tests or Fisher's Exact tests for significance for categorical variables. In particular, responses to the survey question, "How interested are you in offering a chatbot to your patients?" was compared to most other survey questions and analyzed for significance.

Logistic regression was used to investigate the importance of the independent variables—including genetic counseling clinical specialty, administrative/support staff, and consideration of a chatbot for personal health—for predicting responses to the question, "How interested are you in offering a chatbot to your patients?" as the dependent variable. Two separate analyses were performed because clinical specialty and administrative/support staff responses were only obtained from participants who were genetic counselors. Familiarity with genetic counseling chatbots and consideration of using a chatbot for personal health were asked of all participants and were included in a separate analysis. For the first analysis, after adjusting for clinical specialty, administrative/support staff was added as a covariate to investigate which factors, if any, impacted participants' interest in offering a chatbot for their patients. For the second analysis, after adjusting for familiarity with genetic counseling chatbots, consideration of using a chatbot for personal

health was added as a covariate to investigate which factors, if any, affected participants'
interest in offering a chatbot for their patients. Additional analysis was performed using
genetic counseling clinical specialty to predict responses to the question, "How interested
are you in offering a chatbot to your patients?" as the dependent variable. Clinical specialty
was divided into three categories: "cancer," "other clinical," and "laboratory/non-patient-
facing." These three categories were compared to investigate which specialties, if any,
impacted participants' interest in offering a chatbot for their patients.

Logistic regression was also used to investigate the importance of the independent
variables—including usage of a general chatbot, considering using a chatbot for personal
health, and interest in offering a genetic counseling chatbot—for predicting responses to
the question, "What features would you like to see in a chatbot for genetic counseling
patients?" as the dependent variable. After adjusting for usage of a general chatbot,
considering using a chatbot for personal health and interest in offering a genetic counseling
chatbot were added as covariates to investigate which factors, if any, impacted what
features participants wanted in a genetic counseling chatbot. All variables were
represented as two dichotomous indicator variables in each regression.

McNemar-Bowker test of symmetry was used to compare distribution among Likert
scale responses to the low-risk negative genetic testing scenarios as part of the question,
"How likely would you be to offer a chatbot to return NEGATIVE/NORMAL results in the
following scenarios?" All p-values are reported without alteration. P-values less than 0.05
were considered statistically significant.

III. RESULTS

3.1 Demographics of all participants

There were 212 eligible participants who responded to the survey (Table 1). Of these, 199 (94%) were women and 13 (6%) were men. All 212 participants provided their age range. Of the 212 participants, 131 (61.8%) were between 20-29 years old, 58 (27.4%) were 30-39 years old, 18 (8.5%) were 40-49 years old, 4 (1.9%) were 50-59 years old, and 1 (0.5%) was 60+ years old. This cohort was predominantly white, with 187 (85.8%) of the participants reporting their race as white/Caucasian. Six (2.8%) individuals reported being of more than one race/ethnicity. Participants were offered a free-text response box if they selected "other" as their race. A complete list of the free-text responses can be found in Appendix C, Table C-1. All 212 participants provided the region of the United States where they live. Regions with the greatest number of respondents included Region 6, encompassing AK, CA, HI, ID, NV, OR, and WA (n=56), Region 4, encompassing AR, IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, and WI (n=48), and Region 2, encompassing DC, DE, MD, NJ, NY, PA, VA, WV, PR, and VI (n=43). Of the 212 eligible participants, the majority reported that the highest degree or level of school they had completed was a Master's Degree (n=119, 56.1%). The next largest proportion reported they had only completed a Bachelor's Degree (n=90, 42.5%), and three had completed a higher degree (1 Professional Degree and 2 Doctoral Degrees, 0.5% and 0.9%, respectively).

Table 1. Gender, age, race/ethnicity, residence, education, and counselor or student classification of survey participants

		Frequency	Percent
Gender	Female	199	93.9
	Male	13	6.1
	Total	**212**	**100**
Age in years	20-29	131	61.8
	30-39	58	27.4
	40-49	18	8.5
	50-59	4	1.9
	60+	1	0.5
	Total	**212**	**100**
Race/Ethnicity	Asian	8	3.8
	Asian Indian	5	2.4
	Black	2	0.9
	White/Caucasian	182	85.8
	Other	8	3.8
	More than one race/ethnicity	6	2.8
	Prefer Not To Respond	1	0.5
	Total	**212**	**100**
Region of residence in the United States	Region 1 (CT, MA, ME, NH, RI, VT)	15	7.1
	Region 2 (DC, DE, MD, NJ, NY, PA, VA, WV, PR, VI)	43	20.3
	Region 3 (AL, FL, GA, KY, LA, MS, MC, SC, TN)	27	12.7
	Region 4 (AR, IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, WI)	48	22.6
	Region 5 (AZ, CO, MT, NM, TX, UT, WY)	23	10.8
	Region 6 (AK, CA, HI, ID, NV, OR, WA)	56	26.4
	Total	**212**	**100**
Highest Level of Education	Bachelor's Degree	90	42.5
	Master's Degree	119	56.1
	Professional Degree (MD, DO, PsyD, EdD, JD, etc.)	1	0.5
	Doctoral Degree (PhD, DPhil, etc.)	2	0.9
	Total	**212**	**100**
Genetic Counselor or Genetic Counseling Student	Genetic Counselor	108	50.9
	Genetic Counseling Student	104	49.1
	Total	**212**	**100**

3.1.1 Demographics of genetic counseling students

A total of 104 genetic counseling students responded to the survey (49.1%). Of these, 45 (21.2%) were in their first year of graduate school, and 58 (27.4%) were in their second year of graduate school (Table 2). One genetic counseling student reported being enrolled in his or her third year of graduate school (0.5%). The majority of students who responded were between the ages of 20-29 (n=91, 87.5%), with 10 being 30-39 years old (9.6%) and two being between ages 40-49 (1.9%). A single student was between 50-59 years of age (1%). This cohort was predominantly white, with 91 (87.5%) reporting their race as white/Caucasian. Four (3.8%) students reported being of more than one race/ethnicity. All 104 genetic counseling student participants provided the region of the United States where they live. Regions with the greatest number of respondents included Region 2 (n=27, 26%), Region 6 (n=27, 26%), and Region 4 (n=22, 21.2%). Of the 104 genetic counseling students, 90 reported that the highest degree they had completed was a Bachelor's Degree (86.5%), 12 reported having completed a Master's Degree (11.5%), one reported having completed a Professional Degree (1%), and one had completed a Doctoral Degree (1%). Participants were offered a free-text response box if they selected "other" as their race. A complete list of these free-text responses can be found in Appendix C, Table C-1.

Table 2. Year in graduate school, age, race/ethnicity, residence, and education of genetic counseling student survey participants

		Frequency	Percent
Year in Graduate School	1st year	45	43.3
	2nd year	58	55.8
	3rd year	1	1
	Total	**104**	**100**
Age (in years)	20-29	91	87.5
	30-39	10	9.6
	40-49	2	1.9
	50-59	1	1
	60+	0	0
	Total	**104**	**100**
Race/Ethnicity	Asian	4	3.8
	Asian Indian	1	1
	Black	0	0
	White/Caucasian	88	84.6
	Other	6	5.8
	More than one race/ethnicity	4	3.8
	Prefer Not To Respond	1	1
	Total	**104**	**100**
Region of residence in the United States	Region 1 (CT, MA, ME, NH, RI, VT)	8	7.7
	Region 2 (DC, DE, MD, NJ, NY, PA, VA, WV, PR, VI)	27	26
	Region 3 (AL, FL, GA, KY, LA, MS, MC, SC, TN)	14	13.5
	Region 4 (AR, IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, WI)	22	21.2
	Region 5 (AZ, CO, MT, NM, TX, UT, WY)	6	5.8
	Region 6 (AK, CA, HI, ID, NV, OR, WA)	27	26
	Total	**104**	**100**
Highest Level of Education	Bachelor's Degree	90	86.5
	Master's Degree	12	11.5
	Professional Degree (MD, DO, PsyD, EdD, JD, etc.)	1	1
	Doctoral Degree (PhD, DPhil, etc.)	1	1
	Total	**104**	**100**

3.1.2 Demographics of genetic counselors

The number of genetic counselors who responded was 108 (50.9%). The largest group of genetic counselors was between the ages of 30-39 (n=48, 44.4%), with 40 between ages 20-29 (37%), 16 between 40-49 (14.8%), 3 between 50-59 (2.8%), and one aged 60 or greater (0.9%) (Table 3). This cohort was also predominantly white/Caucasian, with 96 genetic counselors reporting their race as white/Caucasian (87%). Two (1.9%) genetic counselors reported being of more than one race/ethnicity. Participants were offered a free-text response box if they selected "other" as their race. A complete list of these free-text responses can be found in Appendix C, Table C-1. All 108 genetic counselor participants provided the region of the United States where they live. Regions with the greatest number of respondents included Region 6 (n=29, 26.9%) and Region 4 (n=26, 24.1%). Of the 108 genetic counselors, all but one (n=107, 99.1%) reported that the highest degree they had completed was a Master's Degree. One individual reported having received a Doctoral Degree (0.9%).

Table 3. Age, race/ethnicity, region of residence, and education level for genetic counselor survey participants

		Frequency	Percent
Age (in years)	20-29	40	37
	30-39	48	44.4
	40-49	16	14.8
	50-59	3	2.8
	60+	1	0.9
	Total	**108**	**100**
Race/Ethnicity	Asian	4	3.7
	Asian Indian	4	3.7
	Black	2	1.9
	White/Caucasian	94	87
	Other	2	1.9
	More than one race/ethnicity	2	1.9
	Prefer Not To Respond	0	0
	Total	**108**	**100**
Region of residence in the United States	Region 1 (CT, MA, ME, NH, RI, VT)	7	6.5
	Region 2 (DC, DE, MD, NJ, NY, PA, VA, WV, PR, VI)	16	14.8
	Region 3 (AL, FL, GA, KY, LA, MS, MC, SC, TN)	13	12
	Region 4 (AR, IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, WI)	26	24.1
	Region 5 (AZ, CO, MT, NM, TX, UT, WY)	17	15.7
	Region 6 (AK, CA, HI, ID, NV, OR, WA)	29	26.9
	Total	**108**	**100**
Highest Level of Education	Bachelor's Degree	0	0
	Master's Degree	107	99.1
	Professional Degree (MD, DO, PsyD, EdD, JD, etc.)	0	0
	Doctoral Degree (PhD, DPhil, etc.)	1	0.9
	Total	**108**	**100**

3.1.2.1 Genetic counseling specialties and administrative support

  All 108 genetic counselors reported their current primary specialty (Table 4). Of these, cancer was the most frequently reported clinical specialty (n=36, 33.3%). The next largest group of counselors reported "other" as their primary specialty (n=22, 20.4%), followed by laboratory (n=18, 16.7%). The complete distribution of information regarding the genetic counselor group can be found in Table 4. Participants were offered a free-text response box if they selected "other" as their current primary specialty. A complete list of these free-text responses can be found in Appendix C, Table C-2. The largest proportion of genetic counselors (n=50, 46.3%) had spent 1-4 years practicing in their current primary specialty. All 108 genetic counselors reported the average number of patients that they saw in a week. Of the 108, 25 saw no patients (23.1%), 45 saw between 1-10 patients (41.7%), 33 saw 11-20 patients (30.6%), and 5 saw 21-30 patients (4.6%).

Table 4. Current genetic counseling specialty, years practicing in current specialty, and average number of patients seen by genetic counselor survey participants

		Frequency	Percent
Current, Primary Genetic Counseling Specialty	Cancer	36	33.3
	Other	22	20.4
	Laboratory	18	16.7
	Prenatal	15	13.9
	Pediatric	11	10.2
	General Genetics	4	3.7
	Adult	2	1.9
	Total	**107**	**100**
Time spent practicing in current, primary specialty (in years)	<1	17	15.7
	1-4	50	46.3
	5-9	25	23.1
	10-14	6	5.6
	15-19	6	5.6
	20-24	3	2.8
	25+	1	0.9
	Total	**108**	**100**
Number of patients seen per week (average)	0	25	23.1
	1-10	45	41.7
	11-20	33	30.6
	21-30	5	4.6
	Total	**108**	**100**

Of the 106 genetic counselors who answered regarding administrative or support staff, 93 (87.7%) had some type of additional staff (Table 5). Types of office assistant included administrative or support staff, nurses, genetic counseling assistants, volunteers, and genetic counseling students. Of the 36 genetic counselors who reported having one type of assistant, 30 had administrative or support staff (32.3%), while 6 had genetic counseling assistants (6.5%). Of the 36 genetic counselors who had two types of assistant, the largest proportion had administrative/support staff and either genetic counseling assistants or genetic counseling students (n=13, 14% for both). Of the 16 genetic

counselors with three types of assistant, the largest proportion had administrative/support

staff, nurse(s), and genetic counseling assistants (n=5, 5.4%). Of the 9 genetic counselors

who had four types, the largest proportion had administrative/support staff, nurse(s),

genetic counseling assistants, and genetic counseling students (n=5, 5.4%). Only one

individual (1.1%) had all 5 types of office assistant.

Table 5. Availability of administrative staff and reported types by genetic counselor survey participants

		Frequency	Percent
Access to administrative or support staff	No	13	12.3
	Yes	93	87.7
	Total	**106**	**100**
Reported types of administrative or support staff	Administrative/support staff only	30	32.3
	Genetic Counseling Assistants only	6	6.5
Two types:	Administrative/support staff and Genetic Counseling Assistants	13	14
	Administrative/support staff and Genetic Counseling Students	13	14
	Administrative/support staff and Nurses	8	8.6
	Genetic Counseling Assistants and Students	2	2.2
Three types:	Administrative/support staff and Nurses and Genetic Counseling Students	5	5.4
	Administrative/support staff and Genetic Counseling Assistants and Students	5	5.4
	Administrative/support staff and Nurses and Genetic Counseling Assistants	2	2.2
	Administrative/support staff and Genetic Counseling Assistants and Volunteers	2	2.2
	Administrative/support staff and Volunteers and Genetic Counseling Students	2	2.2
Four types:	Administrative/support staff and Nurses and Genetic Counseling Assistants and Students	2	2.2
	Administrative/support staff and Nurses and Volunteers and Genetic Counseling Students	1	1.1
	Administrative/support staff and Genetic Counseling Assistants and Students and Volunteers	1	1.1
	All of the above	1	1.1
	Total	**93**	**100**

3.1.2.2 Calling out genetic test results

Genetic counselors were also asked who calls out both positive/abnormal and negative/normal genetic test results in their practice, regardless of whether they have assistants or not (Table 6). Participants were able to choose multiple responses to these two questions. Options included themselves, other genetic counselors, administrative support, other, and not applicable, with a write-in text box for those individuals who chose "other" as a response. All 108 genetic counselors responded to both questions.

The largest proportion of genetic counselors responded that they themselves call out negative/normal genetic test results (n-33, 30.6%). The second largest proportion reported that both they and other genetic counselors in the office call out negative/normal genetic test results (n=31, 28.7%). These responses were the opposite from those regarding calling out positive/abnormal genetic test results, with the largest proportion being both genetic counselors themselves and other genetic counselors in their offices (n=39, 36.1%) and the second largest proportion being only the genetic counselors themselves (n=37, 34.3%). A total of 22 genetic counselors (20.4%) reported that this question does not apply to them with respect to negative/normal genetic test results, while 21 responded similarly for positive/abnormal genetic test results (19.4%).

Participants were offered a free-text response box if they selected "other" as the individual who calls out negative/normal or positive/abnormal test results. A complete list of these free-text responses can be found in Appendix C, Tables C-3 and C-4.

Table 6. Reported individual(s) who disclose genetic test results (negative/normal and positive/abnormal) by genetic counseling survey participants

		Frequency	Percent
Individual(s) who call out negative/normal genetic testing results	Myself only	33	30.6
	Other genetic counselors in my office only	4	3.7
	Administrative/support staff only	2	1.9
	Other only	1	0.9
Two responses:	Myself and Other genetic counselors in my office	31	28.7
	Myself and Other	3	2.8
	Myself and Administrative/support staff	2	1.9
	Other genetic counselors in my office and Administrative/support staff	1	0.9
Three responses:	Myself and Other genetic counselors in my office and Other	5	4.6
	Myself and Other genetic counselors in my office and Administrative/support staff	4	3.7
	Does not apply	22	20.4
	Total	**108**	**100**
Individual(s) who call out positive/abnormal genetic testing results	Myself only	37	34.3
	Other genetic counselors in my office only	4	3.7
Two responses:	Myself and Other genetic counselors in my office	39	36.1
	Myself and Administrative/support staff	1	0.9
Three responses:	Myself and Other genetic counselors in my office and Other	6	5.6
	Does not apply	21	19.4
	Total	**108**	**100**

3.1.2.3 Genetic counselor use of alternative counseling methods

Genetic counselors were asked if they had used or were currently using alternative counseling methods in their practices (Table 7). All 108 genetic counselors responded, and the results were almost evenly split between yes (n=53, 49.1%) and no (n=55, 50.9%). Of the 53 genetic counselors who responded yes, 35 (67.9%) indicated that they had used or were using telemedicine/telegenetics. The second largest proportion of genetic counselors

responded that they were using both telemedicine/telegenetics and web-based portals (n=10, 18.9%). Only one (1.9%) genetic counselor had used or was using chatbots. Participants were offered a free-text response box if they selected "other" as the alternative counseling method. One individual selected "other" in order to clarify what he/she meant by web-based portal and what it was used for and wrote that, "EPIC EMR is the web-based portal referenced - used for direct patient contact and negative result disclosures". Because this was not a distinct alternative counseling method, it was not counted as a valid response to "other," which is why that option is not reflected in Table 7. Furthermore, it was not counted as a response for any other analysis using this question.

Genetic counselors were also asked specifically if they offered a chatbot as part of their counseling practice (Table 8). The majority (95.4%) responded no, while only 5 (4.6%) responded yes. Those 5 genetic counselors were asked what that chatbot was used for in their counseling practice and were instructed to select all responses that applied from the following options: "Screening tool to identify potential patients," "Follow up with patients after return of genetic test results," "Informing at-risk family members of patient test results," "General information tool for patients," "Other (please specify)." One counselor reported that the chatbot was used as a screening tool to identify potential patients only. Two counselors reported that the chatbot was used as a general information tool for patients only. The other two counselors each chose two responses; both indicated that the chatbot was used to inform at-risk family members of patient test results, while one indicated that it was also used as a screening tool to identify potential patients, and the other indicated that it was used to follow up with patients after the return of genetic test results.

Table 7. Use of alternative counseling methods and reported types of alternative methods by genetic counseling survey participants

		Frequency	Percent
Use of alternative genetic counseling methods	No	55	50.9
	Yes	53	49.1
	Total	**108**	**100**
Reported alternative genetic counseling methods used	Telemedicine/Telegenetics (including web-based video) only	35	66
	Telemedicine/Telegenetics (including web-based video) and Web-Based Portal	10	18.9
	Telemedicine/Telegenetics (including web-based video) and Group Counseling	7	13.2
	Chatbots only	1	1.9
	Total	**53**	**100**

Table 8. Reported counselors who offer a genetic counseling chatbot and its use by genetic counselor survey participants

		Frequency	Percent
Offer chatbot as part of counseling practice	No	103	95.4
	Yes	5	4.6
	Total	**108**	**100**
What chatbot is used for in counseling practice	General information tool for patients only	2	40
	Screening tool to identify potential patients only	1	20
	Screening tool to identify potential patients and Informing at risk family members of patient testing results	1	20
	Follow up with patients after return of genetic testing results and Informing at risk family members of patient testing results	1	20
	Total	**5**	**100**

3.2 Usage of and familiarity with general chatbots

All survey participants were asked if they used chatbots in their personal life (Table 9). All 212 responded, with the majority choosing yes (n=185, 87.3%). These 185 participants were then asked when was the last time that they had used a chatbot, with

options ranging from "today" to "over a year ago." The largest proportion of participants who had used a chatbot in their personal lives indicated that they had used it "within the past month" (n=52, 28.1%), followed by "within the past week" (n=48, 25.9%). When these individuals were asked how often they used chatbots in general, the largest proportion selected "monthly" (n=44, 23.8%) followed by "every other month" (n=41, 22.2%).

Table 9. Use of general chatbots by survey participants, including last time, frequency, and whether they were considered for personal health

		Frequency	Percent
Use of chatbots in personal life	No	27	12.7
	Yes	185	87.3
	Total	**212**	**100**
Last time chatbot was used	Today	26	14.1
	Within the past week	48	25.9
	Within the past month	52	28.1
	Within the past 6 months	37	20
	Within the past year	19	10.3
	Over a year ago	3	1.6
	Total	**185**	**100**
Frequency of chatbot use	Daily	29	15.7
	Weekly	32	17.3
	Monthly	44	23.8
	Every other month	41	22.2
	Yearly	39	21.1
	Total	**185**	**100**
Consider using chatbot for personal health	No	75	35.4
	Yes	137	64.6
	Total	**212**	**100**

The 185 participants who reported using a chatbot in their personal lives were asked where they most often encountered chatbots (Table 10). Responses included "Phone (Siri, Google Assistant)," "Personal/Home Device (Amazon Alexa, Google Assistant)," "Phone app (Facebook Messenger, personal banking, retail store)," "Internet browser on a personal computer, tablet, or phone," and "Other." Participants were allowed to choose all responses that applied. The largest proportion selected Internet browser only (n=42,

22.7%). This was followed by both Phone and Personal/Home device (n=22, 11.9%) and

Phone and Internet browser (n=18, 9.7%). Nine participants (4.9%) selected all four

options, excluding "other." Participants were offered a free-text response box if they

selected "other" as where they most often encounter chatbots. A complete list of these free-

text responses can be found in Appendix C, Table C-6.

Table 10. Where general chatbots are accessed by survey participants who reported using them

	Frequency	Percent
Internet browser on a personal computer, tablet, or phone only	42	22.7
Phone (Siri, Google Assistant) only	12	6.5
Phone app (Facebook Messenger, personal banking, retail store) only	12	6.5
Personal/Home Device (Amazon Alexa, Google Assistant) only	6	3.2
Other only	1	0.5
Phone and Personal/Home Device	22	11.9
Phone and Internet browser	18	9.7
Phone app and Internet browser	12	6.5
Phone and Phone app	5	2.7
Personal/Home Device and Internet Browser	4	2.2
Personal/Home Device and Phone app	1	0.5
Phone and Phone app and Internet Browser	15	8.1
Phone and Personal/Home Device and Internet browser	13	7
Phone and Personal/Home Device and Phone app	9	4.9
Phone and Personal/Home Device and Phone app and Internet browser	9	4.9
Personal/Home Device and Phone app and Internet browser	4	2.2
Total	**185**	**100**

In addition, the 185 participants who had used a chatbot in their personal lives were

asked how often they used different types of chatbots, with each type having a five-point

Likert Scale from 1-5 (1= "Never," 2="Rarely (up to 30% of the time)," 3="Sometimes (31-

60% of the time)," 4="Often (61-90% of the time)," and 5="Almost Always/Always (91-

100% of the time)"). Types of chatbot included "ordering food," "general questions,"

"product suggestions," "customer service," "product support," "personal banking," "weather

report," and "news report" (Table 11). The majority of participants responded "never" to using 5 of the 8 types of chatbot:

- "ordering food" (n=159, 86.4%)

- "product suggestions" (n=131, 71.6%)

- "personal banking" (n=115, 62.5%)

- "weather report" (n=110, 59.8%)

- "news report" (n=139, 75.5%)

The largest number of "rarely" responses (n=67, 36.8%) was for using chatbots for "general questions." The largest number of "sometimes" responses was for using chatbots for "customer service" and "product support" (n=71, 38.4% and n=58, 31.5%, respectively).

Table 11. How often different types of general chatbots are used by survey participants who reported using them

		Frequency	Percent
Ordering Food	Never	159	86.4
	Rarely (up to 30% of the time)	18	9.8
	Sometimes (31-60% of the time)	5	2.7
	Often (61-90% of the time)	2	1.1
	Almost Always/Always (91-100% of the time)	0	0
	Total	**184**	**100**
General Questions	Never	33	18.1
	Rarely (up to 30% of the time)	67	36.8
	Sometimes (31-60% of the time)	51	28
	Often (61-90% of the time)	26	14.3
	Almost Always/Always (91-100% of the time)	5	2.7
	Total	**182**	**100**
Product Suggestions	Never	131	71.6
	Rarely (up to 30% of the time)	38	20.8
	Sometimes (31-60% of the time)	10	5.5
	Often (61-90% of the time)	3	1.6
	Almost Always/Always (91-100% of the time)	1	0.5
	Total	**183**	**100**
Customer Service	Never	13	7
	Rarely (up to 30% of the time)	52	28.1
	Sometimes (31-60% of the time)	71	38.4
	Often (61-90% of the time)	37	20
	Almost Always/Always (91-100% of the time)	12	6.5
	Total	**185**	**100**
Product Support	Never	44	23.9
	Rarely (up to 30% of the time)	46	25
	Sometimes (31-60% of the time)	58	31.5
	Often (61-90% of the time)	30	16.3
	Almost Always/Always (91-100% of the time)	6	3.3
	Total	**184**	**100**
Personal Banking	Never	115	62.5
	Rarely (up to 30% of the time)	45	24.5
	Sometimes (31-60% of the time)	9	4.9
	Often (61-90% of the time)	13	7.1
	Almost Always/Always (91-100% of the time)	2	1.1
	Total	**184**	**100**

Weather Report	Never		110	59.8
	Rarely (up to 30% of the time)		20	10.9
	Sometimes (31-60% of the time)		21	11.4
	Often (61-90% of the time)		23	12.5
	Almost Always/Always (91-100% of the time)		10	5.4
	Total		**184**	**100**
News Report	Never		139	75.5
	Rarely (up to 30% of the time)		23	12.5
	Sometimes (31-60% of the time)		11	6
	Often (61-90% of the time)		9	4.9
	Almost Always/Always (91-100% of the time)		2	1.1
	Total		**184**	**100**

Those who responded "no" to the question, "Have you ever used a chatbot yourself?" were asked where they thought they might encounter one (Table 12). Of the 27 participants who had never used a chatbot in their personal lives, the largest proportion selected both Phone and Internet browser (n=6, 22.2%), followed by Internet browser only (n=4, 14.8%). These 27 individuals were also asked to speculate how often they might use different types of chatbot, using a five-point Likert Scale from 1-5 (1= "Never," 2="Rarely (up to 30% of the time)," 3="Sometimes (31-60% of the time)," 4="Often (61-90% of the time)," and 5="Almost Always/Always (91-100% of the time)"). These types of chatbot were the same ones that were presented to the participants who had used chatbots in their personal lives, except as noted in the Methods section of this paper (Table 13). The largest numbers of "never" responses were for 4 types of chatbot:

- "product suggestions" (n=11, 40.7%)

- "personal banking" (n=12, 44.4%)

- "weather report" (n=10, 37%)

- "news report" (n=11, 40.7%)

The largest numbers of "sometimes" responses related to how often they might use a

chatbot for "customer service" and "product support" (n=12, 44.4% and n=14, 51.9%,

respectively). Participants were equally split between "never," "rarely," and "sometimes,"

for how often they might use one for "ordering food" (n=7, 25.9%).

Table 12. Where general chatbots might be accessed by survey participants who reported not using them

	Frequency	Percent
Internet browser on a personal computer, tablet, or phone only	4	14.8
Phone (Siri, Google Assistant) only	3	11.1
Phone and Internet browser	6	22.2
Phone and Phone app	2	7.4
Phone and Personal/Home Device	1	3.7
Personal/Home Device and Internet browser	1	3.7
Phone and Phone app and Internet browser	3	11.1
Personal/Home Device and Phone app and Internet	3	11.1
Phone and Personal/Home Device and Phone app	1	3.7
Phone and Personal/Home Device and Phone app and Internet browser	3	11.1
Total	**27**	**100**

All 212 survey participants were asked if they would consider using a chatbot for

their personal health; the majority (n= 137, 64.6%) responded yes.

Table 13. Predicted use of different types of general chatbots by survey participants who reported not using them

		Frequency	Percent
Ordering Food	Never	7	25.9
	Rarely (up to 30% of the time)	7	25.9
	Sometimes (31-60% of the time)	7	25.9
	Often (61-90% of the time)	4	14.8
	Almost Always/Always (91-100% of the time)	2	7.4
	Total	**27**	**100**
Product Suggestions	Never	11	40.7
	Rarely (up to 30% of the time)	7	25.9
	Sometimes (31-60% of the time)	9	33.3
	Often (61-90% of the time)	0	0
	Almost Always/Always (91-100% of the time)	0	0
	Total	**27**	**100**
Customer Service	Never	3	11.1
	Rarely (up to 30% of the time)	5	18.5
	Sometimes (31-60% of the time)	12	44.4
	Often (61-90% of the time)	7	25.9
	Almost Always/Always (91-100% of the time)	0	0
	Total	**27**	**100**
Product Support	Never	4	14.8
	Rarely (up to 30% of the time)	4	14.8
	Sometimes (31-60% of the time)	14	51.9
	Often (61-90% of the time)	5	18.5
	Almost Always/Always (91-100% of the time)	0	0
	Total	**27**	**100**
Personal Banking	Never	12	44.4
	Rarely (up to 30% of the time)	7	25.9
	Sometimes (31-60% of the time)	4	14.8
	Often (61-90% of the time)	4	14.8
	Almost Always/Always (91-100% of the time)	0	0
	Total	**27**	**100**
Weather Report	Never	10	37
	Rarely (up to 30% of the time)	1	3.7
	Sometimes (31-60% of the time)	5	18.5
	Often (61-90% of the time)	9	33.3
	Almost Always/Always (91-100% of the time)	2	7.4
	Total	**27**	**100**
News Report	Never	11	40.7
	Rarely (up to 30% of the time)	4	14.8
	Sometimes (31-60% of the time)	8	29.6
	Often (61-90% of the time)	3	11.1
	Almost Always/Always (91-100% of the time)	1	3.7
	Total	**27**	**100**

3.3 Genetic Counseling chatbots

3.3.1 Familiarity with, and interest in, offering genetic counseling chatbots

All survey participants were asked if they were familiar with any chatbots that had been developed for use in genetic counseling (Table 14), and they were able to select all responses that applied. Options included "GeneFAX (developed by OptraHealth)," "GIA (Genetic Information Assistant, developed by Clear Genetics)," "NEVA (Natera's Educational Virtual Assistant)," "Other (please specify)," and "I am not familiar with any genetic counseling chatbots." The majority (n=121, 57.1%) were not familiar with any genetic counseling chatbots. Of those who were, the largest proportion were familiar with GIA (n=75, 35.4%). Participants who responded "no" to the question, "Do you currently offer a chatbot as part of your genetic counseling practice?" were asked to respond to the question, "How interested are you in offering a chatbot to your patients?" based on a five-point Likert Scale from 1-5 (1= "Not at all," 2="Slightly," 3="Moderately," 4="Very," and 5="Completely") (Table 14). Of these, the largest proportion were only "Slightly" interested in offering a chatbot to their patients (n=94, 46.5%). These individuals were offered a free-text response box if they selected "other" as the genetic counseling chatbot that they were familiar with. A complete list of these free-text responses can be found in Appendix C, Table C-7.

Table 14. Familiarity with genetic counseling chatbots and interest in offering to own patients by survey participants

		Frequency	Percent
Familiarity with Genetic Counseling Chatbots	-GIA (Genetic Information Assistant, developed by Clear Genetics)	75	35.4
	-Other	4	1.9
	-NEVA (Natera's Educational Virtual Assistant)	3	1.3
	-GeneFAX and GIA	3	1.4
	-GeneFAX (developed by OptraHealth)	2	0.9
	-GIA and NEVA	2	0.9
	-GIA and Other	1	0.5
	-GeneFAX and GIA and Other	1	0.5
	-I am not familiar with any genetic counseling chatbots	121	57.1
	Total	**212**	**100**
Interest in offering chatbot to patients	Not at all	37	18.3
	Slightly	94	46.5
	Moderately	45	22.3
	Very	19	9.4
	Completely	7	3.5
	Total	**202**	**100**

3.3.2 Desired features in a genetic counseling chatbot

All 212 survey participants were asked what features they would like to see in a genetic counseling chatbot (Figure 1), and 208 responded. Options included "general genetics information (tailored to your practice/specialty)," "insurance information," "genetic testing information," "background genetic test results information (what are Positive, Negative, Variant of Uncertain/Unknown Significance results and what do they mean)," "genetic testing consent," "disclosure or discussion of positive or negative genetic test results," "providing information to send to at-risk family members about genetic testing options," "ability to contact a genetic counselor via phone, email, or instant message," and "other (please specify)." Participants were asked to select all that apply from

these options. Reported percentages reflect the percent of overall number of times a response was chosen by the 208 participants who answered.

The largest percentage of participants selected general genetics information and insurance information (79.8% and 82.7%, respectively). Only 1.9% selected discussing or disclosing positive genetic test results, while 25% selected discussing or disclosing negative results. Regarding the methods of contacting a genetic counselor, the largest percentage selected ability to contact via phone or via email (78.8% and 74.5%, respectively). Participants were offered a free-text response box if they selected "other" as the feature they would like to see in genetic counseling chatbots. A complete list of these free-text responses can be found in Appendix C, Table C-8.

In addition, participants' responses to the question, "What features would you like to see in a chatbot for genetic counseling patients?" were grouped into two categories: "general information only" and "general and patient-specific information" (Table 15). Participants who chose any combination of "General genetics information," "Insurance information," "Genetic testing information," and/or "Background genetic test results information" were included in the "general information only" category. Those who chose any combination of the above four responses and at least one response from "Genetic testing consent," "Disclosure or discussion of positive genetic test results," "Disclosure or discussion of negative genetic test results," and/or "Providing information to send to at-risk family members about genetic testing options" were included in the category, "general and patient-specific information." There were 8 participants who did not choose any of these options and were not included in either category, leaving 200 participants. The

majority of these (n=154, 77%) responded that they would like to see "general and patient-specific information" in a chatbot developed for genetic counseling.

Figure 1. Desired Genetic Counseling Chatbot Features by all Survey Participants (N=208)
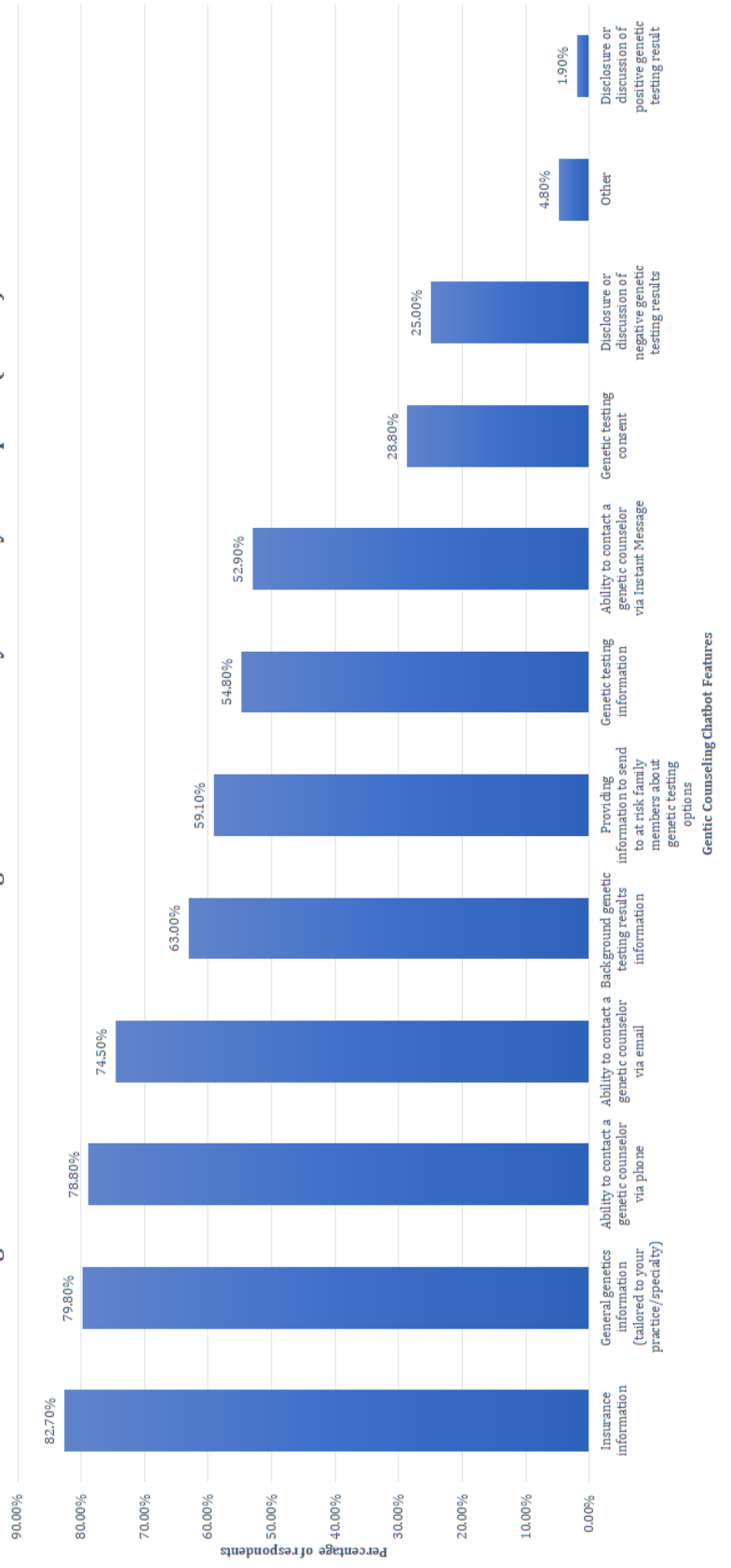
Table 15. Desired type of information included in a genetic counseling chatbot as a dichotomous variable by survey participants

	Frequency	Percent
General Information only	46	23
General and Patient-Specific Information	154	77
Total	**200**	**100**

All participants were asked how likely they would be to offer a chatbot based on the chatbot's method of response (Table 16). The options included, "predetermined responses only," "open text response only," or "both predetermined and open response." A five-point Likert Scale from 1-5 (1= "Not at all," 2="Slightly," 3="Moderately," 4="Very," and 5="Completely") was used. Overall, "open text responses only" was rated the lowest, with an average rating of 2.36. "Predetermined responses only" was second, with an average rating of 2.58. The option for "both predetermined and open text responses" received the highest score, with an average rating of 2.95.

Table 16. How likely would you be to offer a chatbot that only allows predetermined response choices, only allows open text response, or a mixture of both? (Likert scores)

	N	Min	Max	Mean	Std. Deviation
Open text response only	212	1	5	2.36	0.86
Predetermined response only	212	1	5	2.58	1.03
Both predetermined and open text response	212	1	5	2.95	1.04

Participants were also asked when the genetic counseling chatbot should be available to their patients (Table 17). Options included, "after their appointment for only one week," "after their appointment for only one month," "after their appointment indefinitely," "before their appointment for only one week," "before their appointment for

only one month," "any time before their appointment but not after their appointment," or "both before and after their appointment indefinitely." The majority (n=113, 55.1%) selected "both before and after their appointment indefinitely," and the next largest proportion selected "any time before their appointment but not after their appointment" (n=24, 11.7%). This was closely followed by "before their appointment for only one week" (n=23, 11.2%).

Finally, participants were asked how they thought the cost of a genetic counseling chatbot should be managed, if there were a cost associated with its use (Table 17). Options included, "the chatbot should be offered free of charge," "the patient's insurance should be billed," "the patient should pay out of pocket," and "other." The majority of participants selected "the chatbot should be offered free of charge" (n=176, 84.2%), followed by "the patient's insurance should be billed" (n=23, 11%). Participants were offered a free-text response box if they selected "other.". A complete list of these free-text responses can be found in Appendix C, Table C-9.

Table 17. Participants' preferences regarding when chatbot should be available and how to manage cost

		Frequency	Percent
When should a chatbot be available to your patients	-Both before and after their appointment indefinitely	113	55.1
	-Any time before their appointment, but not after their appointment	24	11.7
	-Before their appointment for only one week	23	11.2
	-After appointment indefinitely	20	9.8
	-After their appointment for only one month	14	6.8
	-Before their appointment for only one month	7	3.4
	-After their appointment for only one week	4	2
	Total	**205**	**100**
Cost of the chatbot	The chatbot should be offered free of charge	176	84.2
	The patient's insurance should be billed	23	11
	The patient should pay out of pocket	3	1.4
	Other	7	3.3
	Total	**209**	**100**

3.3.3 Using a chatbot to disclose positive and negative genetic test results

Participants were asked to rate the following scenarios on a five-point Likert Scale from 1-5 (1= "Not at all," 2="Slightly," 3="Moderately," 4="Very," and 5="Completely") based on how likely they would be to offer a chatbot to return <u>negative/normal</u> genetic test results in the context of each of 8 clinical scenarios (Table 18) comprising 2 scenarios (low-risk and high-risk) corresponding to each of 4 different genetic counseling specialties. Whether the scenario was considered low- or high-risk was not included in the scenario description in the survey visible to participants. The scenarios were as follows:

1. Prenatal

   a. Low-risk: "A prenatal patient who is 35 years old and elects NIPT"

   b. High-risk: "A prenatal patient who has abnormal ultrasound findings"

2. Pediatric

.   Low-risk: "A pediatric patient who is being evaluated for autism"

48

a.   High-risk: "A pediatric patient who has a history of metabolic crises"

3. Cancer

.   Low-risk: "An unaffected cancer patient with a family history of cancer with typical age of onset"

a.   High-risk: "A 30-year-old woman with breast cancer and a family history of multiple relatives affected at young ages with breast and ovarian cancers"

4. Adult

.   Low-risk: "An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome"

a.   High-risk: "A pre-symptomatic adult patient with a significant family history of Huntington disease"

Table 18 is organized with the low-risk scenarios first and the high-risk scenarios second, in order of increasing mean response.

Overall, participants rated "a prenatal patient who has abnormal ultrasound findings" the lowest, with an average score of 1.23. This was closely followed by "a pediatric patient who has a history of metabolic crises" (average score 1.24). Participants rated "a prenatal patient who is 35 years old and elects NIPT" the highest (average score 2.56). While most of the responses ranged from 1-5, the two pediatric scenarios ranged only from 1-4 for the low-risk scenario and from 1-3 for the high-risk scenario.

Table 18. How likely would you be to offer a chatbot to return NEGATIVE/NORMAL results in the following scenarios? (Likert scores)

	N	Min	Max	Mean	Std. Deviation
-A pediatric patient who is being evaluated for autism.	211	1	4	1.58	0.87
-An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome.	211	1	5	2.32	1.31
-An unaffected cancer patient with a family history of cancer with typical age of onset.	210	1	5	2.42	1.27
-A prenatal patient who is 35 years old and elects NIPT.	211	1	5	2.56	1.3
-A prenatal patient who has abnormal ultrasound findings.	211	1	5	1.23	0.63
-A pediatric patient who has a history of metabolic crises.	211	1	3	1.24	0.52
-A pre-symptomatic adult patient with a significant family history of Huntington disease.	210	1	5	1.28	0.68
-A 30-year-old woman with breast cancer with a family history of multiple relatives affected at young ages with breast and ovarian cancers.	210	1	5	1.51	0.88

Participants were also asked to rate each of the same scenarios on the same scale based on how likely they would be to offer a chatbot to return positive/abnormal genetic test results (Table 19). Overall, the majority responded "not at all" for all 8 of the scenarios (92.4%, 95.2%, 92.4%, 95.2%, 90%, 91%, 87.1%, and 99%, respectively). Only the two cancer scenarios received a score above "moderately." Of these, one participant selected "completely" for the low-risk scenario, (0.5%) while for the high-risk scenario, two participants selected "very" (1%).

Table 19. Likelihood of survey participants to offer a chatbot to return POSITIVE/ABNORMAL results in low- and high-risk scenarios

		Frequency	Percent
A prenatal patient who is 35 years old and elects NIPT.	Not at all	194	92.4
	Slightly	11	5.2
	Moderately	5	2.4
	Very	0	0
	Completely	0	0
	Total	210	100
A pediatric patient who is being evaluated for autism.	Not at all	194	92.4
	Slightly	9	4.3
	Moderately	7	3.3
	Very	0	0
	Completely	0	0
	Total	210	100
An unaffected cancer patient with a family history of cancer with typical age of onset.	Not at all	189	90
	Slightly	14	6.7
	Moderately	6	2.9
	Very	0	0
	Completely	1	0.5
	Total	210	100
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome.	Not at all	183	87.1
	Slightly	16	7.6
	Moderately	11	5.2
	Very	0	0
	Completely	0	0
	Total	210	100
A prenatal patient who has abnormal ultrasound findings.	Not at all	200	95.2
	Slightly	8	3.8
	Moderately	2	1
	Very	0	0
	Completely	0	0
	Total	210	100
A pediatric patient who has a history of metabolic crises.	Not at all	199	95.2
	Slightly	6	2.9
	Moderately	4	1.9
	Very	0	0
	Completely	0	0
	Total	209	100

A 30-year-old woman with breast cancer with a family history of multiple relatives affected at young ages with breast and ovarian cancers.	Not at all	191	91
	Slightly	8	3.8
	Moderately	9	4.3
	Very	2	1
	Completely	0	0
	Total	210	100
A pre-symptomatic adult patient with a significant family history of Huntington disease.	Not at all	207	99
	Slightly	1	0.5
	Moderately	1	0.5
	Very	0	0
	Completely	0	0
	Total	209	100

3.3.4 Barriers to us of, and concerns about, genetic counseling chatbots

All participants were asked to select what they were most concerned about regarding offering a genetic counseling chatbot to their patients (Table 20). Options included "Privacy/HIPAA," "Compliance with hospital legal and ethical guidelines," "Electronic Medical Record integration," "Accurate/up to date information," "Ease of use," "Ability to access chatbot with necessary technology/internet access," "Ability to access chatbot in a language other than English," "Appropriate language level of chatbot script for patients," "The chatbot being mistaken for the genetic counselor/provider," and "Being unable to assess patient understanding of the information included in the chatbot." Of 212 participants, 209 responded, the majority of whom selected "being unable to assess patient understanding of the information included in the chatbot" as their main concern (n=133, 63.6%). The next largest proportion selected "the chatbot being mistaken for the genetic counselor/provider" (n=27, 12.9%).

Participants were offered a free-text response box at the end of the survey to respond to the prompt, "Describe any barriers you might have to offering a chatbot in your

practice," and 102 of the 212 participants responded. While a formal thematic analysis of these responses was not performed, they were compared to determine if there were any similar concepts seen in multiple responses. Overall, there were three main ideas repeatedly mentioned as barriers to offering a chatbot. The most commonly mentioned barrier was the clarity and/or specificity of the information in the chatbot (n=37, 36%), followed by accessibility (n=33, 32%) and cost of the chatbot (n=26, 25%). A complete list of these free-text responses can be found in Appendix C, Table C-10.

Table 20. Survey participants' main concerns about offering a chatbot to their patients

	Frequency	Percent
-Being unable to assess patient understanding of the information included in the chatbot	133	63.6
-The chatbot being mistaken for the genetic counselor/provider	27	12.9
-Accurate/up to date information	17	8.1
-Compliance with hospital legal and ethical guidelines	7	3.3
-Ease of use	7	3.3
-Privacy/HIPAA	5	2.4
-Electronic Medical Record integration	5	2.4
-Ability to access chatbot with necessary technology/internet access	5	2.4
-Ability to access chatbot in a language other than English	2	1
-Appropriate language level of chatbot script for patients (6th grade reading level)	1	0.5
Total	**209**	**100**

3.4 Univariate analysis

3.4.1 Interest in offering a genetic counseling chatbot to patients

Participants' interest in offering a genetic counseling chatbot to their patients varied significantly, both within the genetic counselor cohort as well as among the entire survey population (Table 21). Within the genetic counselor cohort, interest was significantly associated with counselor specialty and with whether counselors have

administrative/support staff. Within the entire survey population, interest was significantly associated with whether participants would consider using a chatbot for their personal health and with familiarity with genetic counseling chatbots. In order to increase the power of the analysis, responses to the question, "How interested are you in offering a chatbot to your patients?" were condensed into three categories: "Not at all," "Slightly," and "Moderately-Completely".

For this analysis, genetic counselors who selected "other" to the question, "What is your current, PRIMARY specialty?" were categorized into one of the following: Cancer, Pediatrics, Prenatal, Adult, General Genetics, or Laboratory. In addition, the "Laboratory" specialty was renamed to "Laboratory/Non-Patient-Facing" to encompass responses to "Other" that did not involve seeing patients but were not truly Laboratory genetic counseling specialties. Examples include "Research," "Education," and "Insurance." A complete list of responses and which specialty they were re-coded as can be found in Appendix E. For the question, "Are you familiar with any of the following chatbots that have been developed for use in genetic counseling?" responses were grouped into two categories, "Yes" or "No," based on whether the response included one or more genetic counseling chatbots or only included, "I am not familiar with any genetic counseling chatbots."

Among the genetic counseling participants, there were significant differences with respect to being moderately-completely interested in offering a chatbot to their patients for:

- Laboratory/Non-Patient-Facing (n=16, 61.5%) were more likely compared to
  General Genetics (n=3, 23.1%), Adult n=0, (0%), Prenatal (n=3, 18.8%), Pediatrics
  (n=2, 18.2%), and Cancer (n=14, 38.9%) (p=0.03).

- Counselors who did not see patients (n=14, 60.9%) were more likely compared to
  those who saw 1-10 patients per week on average (n=14, 31.1%) and those who
  saw an average of 11-20+ patients per week (n=11, 28.9%) (p=0.04).

- Counselors who did not have administrative/support staff (n=10, 76.9%) were
  more likely compared to those who do have staff (n=29, 31.9%) (p=0.01).

For all participants, including both genetic counselors and genetic counseling students,
there were the following significant differences with respect to being moderately-
completely interested in offering a chatbot to their patients:

- Those who would consider using a chatbot for their personal health (n=61, 45.9%)
  were more likely compared to those who would not use one (n=15, 20.3%)
  (p=<0.001).

- Those who indicated that they were familiar with genetic counseling chatbots
  (n=43, 48.9%) were more likely compared to those who were not (n=33, 27.7%)
  (p=0.007).

Tables detailing all analyses performed are available in Appendix D.

Table 21. Interest in offering a chatbot to patients (univariate analysis)

Question			How interested are you in offering a chatbot to your patients?				
			Not at all	Slightly	Moderately-Completely	Total	p-value
What is your current, PRIMARY specialty? (counselors only)	Cancer	Frequency	4	18	14	36	
			11.1%	50%	38.9%		
	Pediatrics	Frequency	3	6	2	11	
			27.3%	54.5%	18.2%		
	Prenatal	Frequency	3	10	3	16	
			18.8%	62.5%	18.8%		
	Adult	Frequency	0	3	0	3	
			0%	100%	0%		
	General Genetics	Frequency	5	5	3	13	
			38.5%	38.5%	23.1%		
	Laboratory/ Non-Patient Facing	Frequency	4	6	16	26	
			15.4%	23.1%	61.5%		
	Total	**Frequency**	**19**	**48**	**48**	**105**	**0.03a**
			18.1%	**45.7%**	**36.2%**	**100%**	
On average, how many patients do you see per week? (counselors only)	0	Frequency	4	5	14	23	
			17.4%	21.7%	60.9%		
	1-10	Frequency	10	21	14	45	
			22.2%	46.7%	31.1%		
	11-20+	Frequency	5	22	11	38	
			13.2%	57.9%	28.9%		
	Total	**Frequency**	**19**	**48**	**39**	**106**	**0.04b**
			17.9%	**45.3%**	**36.8%**	**100%**	
Do you have administrative/support staff? (counselors only)	No	Frequency	1	2	10	13	
			7.7%	15.4%	76.9%		
	Yes	Frequency	17	45	29	91	
			18.7%	49.5%	31.9%		
	Total	**Frequency**	**18**	**47**	**39**	**104**	**0.01a**
			17.3%	**45.2%**	**37.5%**	**100%**	

Would you consider using a chatbot for your personal health? (all participants)	No	Frequency	26	33	15	74	
			35.1%	44.6%	20.3%		
	Yes	Frequency	11	61	61	133	
			8.3%	45.9%	45.9%		
	Total	**Frequency**	**37**	**94**	**76**	**207**	**<0.001**[b]
			17.9%	**45.4%**	**36.7%**	**100%**	
Are you familiar with any of the following chatbots that have been developed for use in genetic counseling? (all participants)	No	Frequency	25	61	33	119	
			21%	51.3%	27.7%		
	Yes	Frequency	12	33	43	88	
			13.6%	37.5%	48.9%		
	Total	**Frequency**	**37**	**94**	**76**	**208**	**0.007**[b]
			17.9%	**45.4%**	**36.7%**	**100%**	

[a] = derived from Fisher's Exact test of significance

[b] = derived from Pearson Chi-square test of significance

3.4.1.1 Genetic counseling specialty and average number of patients seen

The genetic counseling specialties reported by genetic counselor participants varied significantly with the average number of patients seen per week (Table 24). As one would expect, Laboratory/Non-Patient-Facing genetic counselors were significantly more likely to report seeing no patients per week (n=23, 92%) compared to Cancer (n=0, 0%), Pediatrics (n=0, 0%), Prenatal (n=0, 0%), Adult (n=0, 0%), and General Genetics (n=2, 8%) genetic counselors (p<0.001). Cancer genetic counselors were significantly more likely to report seeing 11-20+ patients per week (n=21, 55.3%) compared to Pediatrics (n=4, 10.5%), Prenatal (n=8, 21.1%), Adult (n=0, 0%), General Genetics (n=4, 10.5%), and Laboratory/Non-Patient-Facing (n=1, 2.6%) genetic counselors (p<0.001).

Table 22. Average number of patients seen per week by genetic counseling specialty in genetic counselor survey participants

			Cancer	Pediatrics	Prenatal	Adult	General Genetics	Laboratory/ Non-Patient Facing	Total	p-value
								Current, primary genetic counseling specialty		
Patients seen per week (average)	0	Frequency	0	0	0	0	2	23	25	
			0%	0%	0%	0%	8%	92%		
	1-10	Frequency	15	7	8	3	7	4	44	
			34.1%	15.9%	18.2%	6.8%	15.9%	9.1%		
	11-20+	Frequency	21	4	8	0	4	1	38	
			55.3%	10.5%	21.1%	0%	10.5%	2.6%		
	Total	**Frequency**	**36**	**11**	**16**	**3**	**13**	**28**	**107**	**<0.001**
			33.6%	**10.3%**	**15%**	**2.8%**	**12.1%**	**26.2%**	**100%**	

3.4.2 Differences between genetic counselors and genetic counseling students

Based on whether participants were genetic counselors or genetic counseling students, responses to several questions in the survey varied significantly in terms of age, where they most often encountered chatbots, familiarity with chatbots that were developed for use in genetic counseling, and what they were most concerned about with respect to offering a chatbot to their patients (Table 22). For this analysis, participant responses to the question "What is your age?" were condensed into three categories ("20-29," "30-39," and "40+").

Genetic counseling students between ages 20-29 years differed significantly from genetic counselors in the same age group (69.2% vs 30.8%; p=<0.001). Genetic counselors who indicated that they most often encounter chatbots on an Internet browser differed significantly from genetic counseling students who indicated the same (73.8% vs 26.2%; p=0.018). There was no significant difference between genetic counselors and genetic counseling students who indicated that they most often encounter chatbots on their Phone and/or Personal/Home Device (45.5% vs 54.5%). Genetic counselors who were familiar

58

with chatbots developed for use in genetic counseling differed significantly from genetic counseling students who indicated the same (61.5% vs 38.5%; p=0.007), and genetic counselors who indicated that they were most concerned about accurate/up-to-date information significantly differed from genetic counseling students who indicated the same (76.5% vs 23.5%; p=0.017). There was no significant difference between genetic counselors and genetic counseling students who indicated that they were most concerned about the chatbot being mistaken for the genetic counselor/provider (51.9% vs 48.1%) or those who indicated they are most concerned about being unable to assess patient understanding (45.9% vs 54.1%). Tables detailing all analyses performed are available in Appendix D.

Table 23. Significant differences between genetic counselor and genetic counseling student responses (univariate analysis)

			Are you a genetic counselor or a genetic counseling student?			
			Genetic Counselor	Genetic Counseling Student	Total	p-value
What is your age? (in years)						
	20-29	Frequency	40	90	130	
			30.80%	69.20%		
	30-39	Frequency	48	10	58	
			82.80%	17.20%		
	40+	Frequency	20	3	23	
			87%	13%		
	Total	**Frequency**	**108**	**103**	**211**	**<0.001[b]**
			51.20%	**48.80%**	**100%**	
Where do you most often encounter chatbots?						
	Phone	Frequency	5	7	12	
			41.70%	58.30%		
	Personal/Home Device only	Frequency	4	2	6	
			66.70%	33.30%		
	Phone app only	Frequency	6	6	12	
			50%	50%		
	Internet browser only	Frequency	31	11	42	
			73.80%	26.20%		
	Other	Frequency	0	1	1	
			0%	100%		
	Phone and Personal/Home device	Frequency	10	12	22	
			45.50%	54.50%		
	Phone and Phone app	Frequency	2	3	5	
			40%	60%		
	Phone and Internet browser	Frequency	5	13	18	
			27.80%	72.20%		
	Personal device and Phone app	Frequency	0	1	1	
			0%	100%		
	Personal/Home device and Internet browser	Frequency	3	1	4	

	Phone app and Internet browser	Frequency	6	6	12	
			50%	50%		
	Phone and Personal/Home device and Phone app	Frequency	2	7	9	
			22.20%	77.80%		
	Phone and Personal/Home device and Internet browser	Frequency	7	6	13	
			53.80%	46.20%		
	Phone and Phone app and Internet browser	Frequency	8	7	15	
			53.30%	46.70%		
	Personal device and phone app and Internet browser	Frequency	0	4	4	
			0%	100%		
	Phone and Personal/Home device and Phone app and Internet browser	Frequency	7	2	9	
			77.80%	22.20%		
	Total	**Frequency**	**96**	**89**	**185**	**0.018[a]**
			51.90%	**48.15**	**100%**	
Are you familiar with any of the following chatbots that have been developed for use in genetic counseling?	Yes	Frequency	56	35	91	
			61.50%	38.50%		
	No	Frequency	52	69	121	
			43%	57%		
	Total	**Frequency**	**108**	**104**	**212**	**0.007[b]**
			50.90%	**49.10%**	**100%**	
What are you most concerned about when it comes to offering a chatbot to your patients?	Privacy/HIPAA	Frequency	1	4	5	
			20%	80%		
	Compliance with hospital legal and ethical guidelines	Frequency	7	0	7	
			10%	0%		

Electronic Medical Record integration	Frequency	2	3	5	
		40%	60%		
Accurate/up to date information	Frequency	13	4	17	
		76.50%	23.50%		
Ease of use	Frequency	3	4	7	
		42.90%	57.10%		
Ability to access chatbot with necessary technology/Internet access	Frequency	2	3	5	
		40%	60%		
Ability to access chatbot in a language other than English	Frequency	2	0	2	
		100%	0%		
Appropriate language level of chatbot script for patients	Frequency	1	0	1	
		100%	0%		
The chatbot being mistaken for the genetic counselor/provider	Frequency	14	13	27	
		51.90%	48.10%		
Being unable to assess patient understanding of the information included in the chatbot	Frequency	61	72	133	
		45.90%	54.10%		
Total	**Frequency**	**106**	**103**	**209**	**0.017a**
		50.70%	**49.30%**	**100%**	

a = derived from Fisher's Exact test of significance

b = derived from Pearson Chi-square test of significance

3.4.3 Differences between desired features in a genetic counseling chatbot

Participants who would like either general information only or general and patient-specific information in a chatbot for genetic counseling patients varied significantly with respect to whether they had used a chatbot themselves, whether they would consider using a chatbot for their personal health, and how likely they were to offer a chatbot to their patients (Table 23). For this analysis, responses to the question, "What features would you like to see in a chatbot for genetic counseling patients?" were grouped into two categories

as described above. There were 8 participants who did not choose any of these options and were not included in either category, leaving 200 participants for the analysis.

Individuals who indicated they would like a chatbot for genetic counseling patients to include general information only were significantly more likely to report never having used a chatbot (41.7% vs 20.5%; p=0.021) and they also were significantly more likely to consider using a chatbot for their personal health than those who would not (43.9% vs 12.7%; p=<0.001). Participants who indicated they would like a chatbot for genetic counseling patients to include general information only were significantly more likely to select "not at all" in response to the question, "How interested are you in offering a chatbot to your patients?" than participants who selected "slightly" or "moderately-completely" (41.4% vs 30.4% vs 8.1%; p<0.001). Tables detailing all analyses performed are available in Appendix D.

Table 24. Desired type of information included in a chatbot developed for genetic counseling (univariate analysis)

			What features would you like to see in a chatbot for genetic counseling patients?			
			General information only	General and patient-specific information	Total	p-value
Have you ever used a chatbot yourself?	No	Frequency	10	14	24	
			41.7%	58.3%		
	Yes	Frequency	36	140	176	
			20.5%	79.5%		
	Total	**Frequency**	**46**	**154**	**200**	**0.021**
			23%	77%	100%	
Would you consider using a chatbot for your personal health?	No	Frequency	29	37	66	
			43.9%	56.1%		
	Yes	Frequency	17	117	134	
			12.7%	87.3%		
	Total	**Frequency**	**46**	**154**	**200**	**<0.001**
			23%	77%	100%	
How interested are you in offering a chatbot to your patients?	Not at all	Frequency	12	17	29	
			41.4%	58.6%		
	Slightly	Frequency	28	64	92	
			30.4%	69.6%		
	Moderately-completely	Frequency	6	68	74	
			8.1%	91.9%		
	Total	**Frequency**	**46**	**149**	**195**	**<0.001**
			23.6%	76.4%	100%	

3.5 Multivariate analysis

3.5.1 Interest in offering a genetic counseling chatbot to patients

Multivariate logistic regression was used to investigate the importance of genetic counseling specialty, average number of patients seen per week, having administrative/support staff, considering the use of a chatbot for personal health, and familiarity with chatbots developed for genetic counseling as independent predictors of

64

how interested participants were in offering a chatbot to their patients. Odds ratio is represented as "Exp(B)" in all regression tables. When looked at in a univariate model, responses regarding interest in offering a chatbot to patients varied significantly based on genetic counseling specialty, average number of patients seen per week, having administrative/support staff, considering the use of a chatbot for personal health, and familiarity with chatbots developed for genetic counseling. For this analysis, responses to the question, "How interested are you in offering a chatbot to your patients?" were condensed into two categories, "Not at all-slightly" and "Moderately-Completely," to create a dichotomous variable. The response, "Not at all-slightly" was coded as '0,' and the response, "Moderately-Completely" was coded as '1'. In addition, responses to the question, "On average, how many patients do you see per week?" were condensed into two categories, "0" and "1-20+," to create a dichotomous variable. The response "1-20+" was coded as '0,' and the response "0" was coded as '1'.

Only participants who identified as genetic counselors responded to the questions regarding genetic counseling specialty, average number of patients seen per week, and having administrative/support staff, while all participants responded to the questions regarding considering the use of a chatbot for personal health and familiarity with chatbots developed for genetic counseling. As such, multivariate logistic regression was performed separately for the questions because they applied to two different groups of participants.

In multivariate analysis, both genetic counseling specialty and having administrative/support staff were independently associated with participants' interest in offering a chatbot to their patients (Table 25). Laboratory/Non-Patient-Facing genetic

counselors were 3 times more likely to be interested in offering a chatbot to patients than those who worked in a clinical specialty (OR=3.14, 95% CI=1.13-8.76, p=0.029). Genetic counselors who did not have administrative/support staff were 4.5 times more likely to offer a chatbot to their patients than those who had support (OR=4.53, 95% CI=1.06-19.31, p=0.041). After adjusting for current genetic counseling specialty, the independent variable average number of patients seen per week was no longer statistically significantly associated with genetic counselors' interest in offering a chatbot to their patients (p=0.655) (Table 26).

Table 25. How interested are you in offering a chatbot to your patients? Effects of counseling specialty and administrative/support staff (genetic counseling participants only) (multivariate analysis)

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
What is your current, PRIMARY specialty? (Clinical or Laboratory genetic counselor)	1.15	0.52	4.79	1	0.029	3.14	1.13	8.76
Do you have administrative/support staff?	1.51	0.74	4.17	1	0.041	4.53	1.06	19.31
Constant	-0.66	1.06	0.39	1	0.534	0.52		

Table 26. How interested are you in offering a chatbot to your patients? Effects of counseling specialty and average patients seen per week (genetic counseling participants only) (multivariate analysis)

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
What is your current, PRIMARY specialty? (Clinical or Laboratory genetic counselor)	1.13	0.80	2.01	1	0.156	3.11	0.65	14.86
On average, how many patients do you see per week?	-0.37	0.84	0.20	1	0.655	1.45	0.28	7.45
Constant	-1.72	1.59	1.18	1	0.278	0.18		

While not significant, a large proportion of the genetic counselors whose primary specialty is cancer also indicated that they were moderately-completely interested in offering a chatbot to their patients. To investigate this further, multivariate logistic regression was performed to see if there was a significant difference between the cancer specialty and other clinical specialties regarding offering a chatbot to their patients (Table 27). When compared to other clinical specialties as the reference group, genetic counselors whose primary specialty was Cancer were almost 3 times more likely to be interested in offering a chatbot to their patients (OR=2.78, CI 95%=1.01-7.72, p=0.049). When compared to clinical specialties other than Cancer, Laboratory/Non-Patient-Facing genetic counselors were 7 times more likely to be interested in offering a chatbot to their patients (OR=7, CI 95%=2.33-21.07, p=0.001).

Table 27. How interested are you in offering a chatbot to your patients?
Effects of laboratory vs cancer counseling specialty (genetic counseling participants only) (multivariate analysis)

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
What is your current, PRIMARY specialty? (Cancer or Other Clinical or Laboratory genetic counselor)			12.01	2	0.002			
Lab vs Other Clinical	1.95	0.56	11.98	1	0.001	7	2.33	21.07
Cancer vs Other Clinical	1.02	0.52	3.88	1	0.049	2.78	1.01	7.72
Constant	-1.48	0.39	14.20	1	0	0.23		

After adjusting for being familiar with chatbots that have been developed for use in genetic counseling and considering using a chatbot for personal health, both of these independent variables remained statistically significantly associated with participants' interest in offering a chatbot to their patients (Table 28). Participants, including both genetic counselors and genetic counseling graduate students, were twice as likely to be

interested in offering a chatbot to their patients if they were familiar with any genetic

counseling chatbots than if they were not (OR=2.28, CI 95%=1.26-4.15, p=0.007).

Participants who would consider using a chatbot for their personal health were 3 times

more likely to be interested in offering a chatbot to their patients than those who would not

consider using one (OR=3.10, CI 95%=1.58-6.07, p=0.001).

Table 28. How interested are you in offering a chatbot to your patients?
Effects of familiarity with genetic counseling chatbots and use of personal health chatbot (all
survey participants) (multivariate analysis)

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B) Lower	Upper
Are you familiar with any of the following chatbots that have been developed for use in genetic counseling?	0.86	0.30	7.36	1	0.007	2.28	1.26	4.15
Would you consider using a chatbot for your personal health?	1.13	0.34	10.86	1	0.001	3.10	1.58	6.07
Constant	-1.69	0.32	27.45	1	0	0.18		

3.5.2 Desired types of information included in a genetic counseling chatbot

Multivariate logistic regression was used to investigate the importance of

considering the use of a chatbot for personal health, interest in offering a chatbot to

patients, and use of chatbots in general as independent predictors of what types of

information participants wanted included in a genetic counseling chatbot. Odds ratio is

represented as "Exp(B)" in all regression tables. When looked at in a univariate model,

responses to the question, "What features would you like to see in a chatbot for genetic

counseling patients?" varied significantly based on whether participants would consider

using a chatbot for their personal health, their interest in offering a chatbot to their

patients, and whether they had used a chatbot in general. For this analysis, responses to the

question, "What features would you like to see in a chatbot for genetic counseling patients?" were condensed into the two categories described above to create a dichotomous variable. The response, "general information only" was coded as '0,' and the response, "general and patient-specific information" was coded as '1'.

In multivariate analysis, including whether participants would consider using a chatbot for their personal health, their interest in offering a chatbot to their patients, and whether they had used a chatbot in general, only the variables, "considering using a chatbot for personal health" and "interest in offering a chatbot to their patients" remained significant (Table 29). Participants who would consider using a chatbot for their personal health were 4 times more likely to select both general and patient-specific information than general information only (OR=4.01, CI 95%=1.90-8.43, p<0.001). Participants who were more interested in offering a chatbot to their patients were 4.5 times more likely to want both general and patient-specific information included in a genetic counseling chatbot (OR=4.65, CI 95%=1.78-12.12, p-0.002). After adjusting for their likelihood to offer a chatbot to their patients and whether they would consider using a chatbot for their personal health, the response of participants who had used a chatbot was no longer significantly associated with predicting what type of information they wanted included in a genetic counseling chatbot (p=0.121).

Table 29. What features would you like to see in a chatbot for genetic counseling patients? Effects of general chatbot use, considering using a chatbot for personal health, and interest in offering a chatbot to patients (all survey participants) (multivariate analysis)

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B) Lower	Upper
Have you ever used a chatbot yourself?	0.81	0.52	2.41	1	0.121	2.26	0.81	6.31
Would you consider using a chatbot for your personal health?	1.39	0.38	13.36	1	<0.001	4.01	1.90	8.43
How interested are you in offering a chatbot to your patients?	1.54	0.49	9.88	1	0.002	4.65	1.78	12.12
Constant	-0.73	0.50	2.12	1	0.145	0.48		

3.6 McNemar-Bowker test of symmetry

McNemar-Bowker's test of symmetry was used to investigate the scenarios regarding low-risk negative genetic test result delivery to see if there was a preference among participants for being more or less likely to offer a chatbot to those patients (Table 30, 31, 32, 33, 34, and 35). The majority of these scenarios had on average a higher Likert score, reflecting higher likelihood to offer a genetic counseling chatbot to return those results to patients than was found for the high-risk negative genetic testing scenarios, which is why they were chosen for this analysis. Participants who were less interested in using a chatbot to disclose negative genetic test results to a pediatric patient being evaluated for autism or to an adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome were significantly more interested in using a chatbot to disclose negative genetic test results to a 35-year-old prenatal patient who elected NIPT (p<0.001 and p=0.044, respectively). Participants who were less interested in using a chatbot to disclose negative genetic test results to a pediatric patient being evaluated for autism were significantly more interested in using a chatbot to disclose

70

negative genetic test results to an unaffected cancer patient with a family history of cancer with typical age of onset (p<0.001). Participants who were more interested in using a chatbot to disclose negative genetic test results to an adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome were significantly more likely to be less interested in using a chatbot to disclose negative genetic test results to a pediatric patient who is being evaluated for autism (p<0.001).

There was no preference for interest in using a chatbot to disclose negative test results between the low-risk cancer and prenatal scenarios (p=0.152), or between the low-risk adult and cancer scenarios (p=0.597). The majority of participants were either less interested in either scenario or more interested in both scenarios.

Table 30. Preference for likelihood to offer a chatbot to disclose negative genetic testing results in prenatal vs cancer clinical scenarios

			A prenatal patient who is 35 years old and elects NIPT (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
An unaffected cancer patient with a family history of cancer with typical age on onset (neg)	Not at all - Slightly	Frequency	88	30	118	
		Percent	**41.9**	**14.3**	**56.2**	
	Moderately - Completely	Frequency	19	73	92	
		Percent	**9**	**34.8**	**43.8**	
	Total	Frequency	107	103	210	
		Percent	**51**	**49**	**100**	**0.152**

Table 31. Preference for likelihood to offer a chatbot to disclose negative genetic testing results in prenatal vs pediatric clinical scenarios

			A prenatal patient who is 35 years old and elects NIPT (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
A pediatric patient who is being evaluated for autism (neg)	Not at all - Slightly	Frequency	102	74	276	
		Percent	**48.3**	**35.1**	**83.4**	
	Moderately - Completely	Frequency	5	30	35	
		Percent	**2.4**	**14.2**	**16.6**	
	Total	Frequency	107	104	211	
		Percent	**50.7**	**49.3**	**100**	**<0.001**

Table 32. Preference for likelihood to offer a chatbot to disclose negative genetic testing results in prenatal vs adult clinical scenarios

			A prenatal patient who is 35 years old and elects NIPT (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome (neg)	Not at all - Slightly	Frequency	87	36	123	
		Percent	**41.2**	**17.1**	**58.3**	
	Moderately - Completely	Frequency	20	68	88	
		Percent	**9.5**	**32.2**	**41.7**	
	Total	Frequency	107	104	211	
		Percent	**50.7**	**49.3**	**100**	**0.044**

Table 33: Preference for likelihood to offer a chatbot to disclose negative genetic testing results in cancer vs pediatric clinical scenarios

			An unaffected cancer patient with a family history of cancer with typical age of onset (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
A pediatric patient who is being evaluated for autism (neg)	Not at all - Slightly	Frequency	114	62	176	
		Percent	**54.3**	**29.5**	**83.8**	
	Moderately - Completely	Frequency	4	30	34	
		Percent	**1.9**	**14.3**	**16.2**	
	Total	Frequency	118	92	210	
		Percent	**56.2**	**43.8**	**100**	**<0.001**

Table 34. Preference for likelihood to offer a chatbot to disclose negative genetic testing results in cancer vs adult clinical scenarios

			An unaffected cancer patient with a family history of cancer with typical age on onset (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome (neg)	Not at all - Slightly	Frequency	92	31	123	
		Percent	**43.8**	**14.8**	**58.6**	
	Moderately - Completely	Frequency	26	61	87	
		Percent	**12.4**	**29**	**41.4**	
	Total	Frequency	118	92	210	
		Percent	**56.2**	**43.8**	**100**	**0.597**

Table 35. Preference for likelihood to offer a chatbot to disclose negative genetic testing results in pediatric vs adult clinical scenarios

			A pediatric patient who is being evaluated for autism (neg)			
			Not at all - Slightly	Moderately - Completely	Total	p-value
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome (neg)	Not at all - Slightly	Frequency	120	3	123	
		Percent	**56.9**	**1.4**	**58.3**	
	Moderately - Completely	Frequency	56	32	88	
		Percent	**26.5**	**15.2**	**41.7**	
	Total	Frequency	176	35	211	
		Percent	**83.4**	**16.6**	**100**	**<0.001**

IV. DISCUSSION

Chatbots were first introduced into the genetic counseling field in 2017, and since that time, new genetic counseling chatbots have been developed and patient perspectives have been investigated regarding their use. At the 2019 National Society of Genetic Counselors conference, chatbots were mentioned in multiple presentations, and there was a panel discussion dedicated to the topic (Ready, Schmidlen, & Wicklund, 2019). Genetic counseling chatbots are poised to be the next major technological advancement in the field. However, provider perspectives about chatbots, which have not been assessed in the literature to date, should be a part of this discussion. The aim of this study was to investigate genetic counselors' and genetic counseling graduate students' perspectives on, and their interest in, using chatbots designed specifically for their field. This includes their ideas on what information and functions genetic counseling chatbots should have. With this information, genetic counseling chatbots can be developed and refined to better reflect the desires and concerns of the providers in the field and to become a useful tool rather than a novelty.

4.1 Interest in using a genetic counseling chatbot

When asked to rate their interest in offering a chatbot to their patients, the largest proportion of participants, including both genetic counselors and genetic counseling students, responded that they were only "slightly" interested (46.5%). Responses to this question ("How interested are you in offering a chatbot to your patients?") were compared to demographic information for all participants as well as more specific variables, such as use of a general chatbot, in order to test for the following hypothesis: Demographic factors,

genetic counseling specialty, the number of patients seen per week, use of alternative counseling methods, and familiarity with general chatbots will determine which populations of participants are more likely to be interested in offering genetic counseling chatbots to their patients. The initial predictions were that participants who are younger, see a larger number of patients per week, are using alternative counseling methods, and are already familiar with general chatbots would be more likely to be interested in offering genetic counseling chatbots. The results of this study have shown that almost none of these variables in particular was a significant factor in determining interest in offering genetic counseling chatbots. However, genetic counseling specialty was a significant factor; those who worked in a laboratory or were non-patient-facing were approximately three times more likely to be moderately to completely interested in offering a genetic counseling chatbot to their patients. Interestingly, though, there was no significant difference between cancer and laboratory/non-patient-facing genetic counselors in the univariate analysis. When looked at as separate populations compared to other clinical genetic counselors, however, those who worked in the cancer specialty were almost three times more interested in offering a genetic counseling chatbot. In the univariate analysis, the average number of patients seen per week was significantly associated with interest in offering a chatbot (p=0.04).

Contrary to predictions, the genetic counselors who saw no patients were more interested in offering a chatbot. However, when this variable was looked at during multivariate analysis, after adjusting for clinical specialty, that significance disappeared (p=0.655). Since the Laboratory/Non-Patient-Facing genetic counselors are the participants who were seeing no patients per week (p<0.001), the average number of

76

patients seen per week variable was measuring the same population as the clinical specialty variable. Interestingly, the majority of cancer genetic counselors (55.3%, p<0.001) reported seeing 11-20+ patients per week. When compared to other clinical genetic counselors, cancer genetic counselors were more likely to be interested in offering a chatbot. This indicates that there may be different variables that are driving the interest in offering a chatbot for different specialties, given that Laboratory/Non-Patient Facing counselors do not see patients. Their interest in using a chatbot is clearly not based on the numbers of patients they saw, but the opposite may be true for the cancer genetic counselors, who saw the most patients per week. In fact, it is possible that non-patient facing genetic counselors may be more interested in offering a chatbot because they do not have a direct connection to patients. On the other hand, the reason that cancer genetic counselors may be more interested in offering a chatbot is because they are seeing a large number of potentially complicated patients per week, and using a chatbot could reduce their workload by taking over some of the routine parts of sessions. Given that in this study there were confounding variables, further research is needed to determine the exact relationship between the average number of patients seen per week, clinical specialty, and how it may influence interest in offering a genetic counseling chatbot.

Besides clinical specialty, the other significant variable that increased the interest genetic counselor participants had in offering a genetic counseling chatbot was whether or not they had administrative/support staff. While a majority of participants reported having staff of some kind (87.7%), those who did not have any were 4.5 times more likely to be interested in offering a genetic counseling chatbot to their patients. This relationship was still significant after adjusting for genetic counseling specialty (p=0.04). Interest in offering

a genetic counseling chatbot clearly differed depending on the access that genetic counselors had to administrative/support staff, which was not directly related to genetic counseling specialty but may still play a role. It may be that different specialties have different needs that may be more easily fulfilled by a chatbot or are easily automated. In addition, it may be that participants who have administrative/support staff are less likely to be interested in chatbots because they already have a system in place for the routine tasks that a chatbot would perform. For instance, genetic counseling graduate students may be trained to call out genetic test results and may call patients to discuss what to expect in their genetic counseling appointment and to gather relevant patient information ahead of time. Or, while administrative assistants generally do not call out genetic test results, they do schedule patients and answer insurance information inquiries. Those genetic counselors who do not have that assistance, however, may be more interested in using a chatbot because it could perform those tasks that different types of administrative/support staff usually carry out.

While the significant variables for the genetic counseling cohort were genetic counseling specialty and administrative/support staff, there were also some for all participants that correlated with interest in offering a chatbot. These included both familiarity with genetic counseling chatbots and using a chatbot for personal health. A majority of all participants would consider using a chatbot for their personal health (64.6%), and they were three times more interested in offering a chatbot to their patients than those who would not consider using a chatbot for their personal health. On the other hand, a majority of participants were not familiar with any genetic counseling chatbots (57.1%). Those who were familiar with them, however, were slightly more than twice as

78

likely to be interested in offering one to their patients. If participants who knew about genetic counseling chatbots were familiar with what information was in them, how they were being used, and how patients could interact with them, this might have made them more comfortable with the idea of offering a similar chatbot to their own patients. Their awareness of patient satisfaction with the chatbots could be influencing them to be more interested in pursuing it themselves. In a similar vein, participants who would consider using a chatbot for their personal health could see the potential benefit that a chatbot could provide. Thus, as healthcare providers themselves, they may be more interested in offering such an option to their own patients. Those who were not comfortable with the idea of using chatbots for themselves, however, might have been more hesitant to offer one to their patients. They might have assumed that their patients had the same resistance as they did to using a chatbot, or they may not have wanted to offer their patients a tool that they would not be willing to use themselves. Alternatively, they may not have understood the chatbot and how it works and, thus, may not have wanted to put themselves in the position of having to explain to their patients a tool they themselves did not understand or want to use. Counselors who have more certainty about using a chatbot for health-related purposes, or more familiarity with what chatbots can do in the genetic counseling setting, specifically, are likely to be less hesitant to offer one to their patients.

4.2 Desired features and information in genetic counseling chatbots

Chatbots have a variety of potential uses. This can be seen in existing genetic counseling chatbots such as GIA, which currently has three different interfaces being used within the Geisinger health system. Even chatbots in use in a non-medical setting can

provide customer service, such as responding to inquiries for general information about the news and the weather, or facilitating the ordering of food to be delivered. The question for genetic counseling chatbots, then, becomes not what features and information they can contain and provide, but what genetic counselors want the chatbots to do in order for them to be an asset to the profession.

In terms of information, participants were primarily interested in having a genetic counseling chatbot provide general information about insurance coverage to their patients (82.7%), followed closely by general genetics information that is tailored to the counselor's specialty (79.8%). Both of these topics encompass basic information that can be applicable to almost all patients, regardless of their specific reason for referral to a genetic counselor. These discussions do not necessarily have to be facilitated by a genetic counselor, but if a patient had a more nuanced question that the chatbot could not answer, the genetic counselor could still be reached by the patient. The majority of participants wanted a chatbot to have the option for them to be contacted via telephone (78.8%), closely followed by email (74.5%). While instant messaging was an option for participants, only 52.9% selected it. A potential reason for this discrepancy could be that instant messaging may be seen as too similar to a chatbot and not as personal as a phone call or an email. Furthermore, phone calls can be scheduled and emails can be sent during normal business hours, while being accessible by instant messaging may lead patients to believe that they can receive a response at all hours. Thus, only being available by phone or email allows providers not only to continue to manage their workload but also to respond to patient inquiries.

Interestingly, the majority of participants (77%) wanted a genetic counseling chatbot to do more than just provide information to their patients, such as providing a function that involves discussing patient-specific information. The majority of participants (59.1%) wanted that function to be providing information to send to at-risk family members about genetic testing options. This would require the chatbot to discuss the patient's genetic test results with another individual and to discuss that individual's risk and potential need for genetic testing. While this is essentially the same as providing a family letter, the chatbot is not necessarily limited to what would be written on a piece of paper. This is consistent with what Schmidlen, et al (2019) found in their study regarding patient perspectives on their family cascade testing chatbot interface, which has the ability to answer questions that relatives might have, both about their family member's result and the implications for their own health.

Chatbots can be a robust interactive tool, not just a source of information. This idea seems to be reflected among the participants who were interested in offering a chatbot to their patients, since a significant number of them (91.9%; $p < 0.001$) wanted that chatbot to include both general and patient-specific information that could assist them in their practices in more than one way and could provide a range of services to their patients. This may lead to the chatbot being seen as worth the time and investment for both the provider and the patient. Ultimately, there was clearly a desired place for a chatbot in the participants' genetic counseling practices, whether it was for discussing insurance information or being used to help patients inform their family members about their genetic test results.

4.3 Preferred scenarios for offering chatbots to disclose negative genetic test results

Only 25% of participants would want a chatbot to be able to disclose or discuss negative genetic test results as a feature in general. This is consistent with their opinions about specific genetic testing scenarios and how likely they would be to offer a chatbot to disclose negative test results in those contexts; the majority were not at all likely to offer a chatbot, especially for the high-risk scenarios. However, for the low-risk scenarios, there was some variation in responses, which, on average, indicated that more participants were slightly to moderately likely to offer a chatbot to disclose negative test results.

McNemar's test of symmetry was used to investigate whether there were certain specialties where participants were more likely to offer a chatbot to disclose negative test results in a low-risk scenario. This analysis showed that when compared to all other scenarios, participants were the least likely to want to offer a chatbot to disclose negative test results in the low-risk pediatric scenario, which involves a patient who is being evaluated for autism. Participants who did not want to offer a chatbot in this scenario were significantly more interested in offering one in the prenatal, cancer, and adult low-risk scenarios (35.1%, p<0.001, 29.5%, p<0.001, and 26.5%, p<0.001, respectively). Autism is a heterogeneous multifactorial condition that has a significant genetic component. The standard of care for evaluating a patient with autism includes several tests, such as a chromosomal microarray and analysis for fragile X syndrome, but even if all of them were negative it would neither rule out the diagnosis of autism, nor would it preclude additional testing, such as analysis of a panel of genes associated with syndromic and non-syndromic autism spectrum disorder. When compared to the prenatal or cancer scenarios in this

82

study, which involve testing for genetic conditions that have specific, known causes, it makes sense that participants would be more hesitant to offer a chatbot to disclose negative test results in an evaluation for autism. There is much more information to discuss with a patient following a negative genetic test result for autism, whereas a negative cancer panel result is more informative and usually does not result in additional testing.

Even when compared with the low-risk adult scenario, which involves a patient being evaluated for Ehlers-Danlos syndrome, a negative genetic test result in that setting still might be more informative than for autism. It may be that if another scenario had been used for the low-risk pediatric setting, the results might have been different. Regardless, the likelihood to offer a chatbot to disclose genetic test results depends on both the scenario and the type of result being returned to the patient. While participants may be more likely to offer one to disclose negative genetic test results, the clinical setting and what the patient is being tested for are significant factors that must be taken into account as well.

4.4 Barriers to current chatbot use

The majority of participants indicated that their main concern about offering a chatbot to their patients was being unable to assess patient understanding of the information included in the chatbot (63.6%). This sentiment was echoed by 37 of the 101 participants who wrote a free-text response to, "Describe any barriers you might have to offering a chatbot in your practice." Many of these responses specifically mentioned returning genetic test results, both positive and negative, and how, even in the setting of negative test results, there is more information that must be discussed aside from the

83

result itself. For instance, one participant commented, "...Just because you had a normal NIPT this does NOT mean your ultrasound anomalies will go away…" The participants also mentioned that they were concerned that a chatbot would not be able to properly assess how the patients are reacting to this information. Specific comments included, "chatbots aren't GCs so there's no way for the chatbot to recognize emotions, and tailor a session for the patient," and "I'm worried about not being able to analyze patient comprehension and understanding…" This is reasonable because genetic counselors not only provide information for patients but also counsel them, which means engaging with patients to help them understand how their test results affect them and their families. So, while it may be true that a majority of participants preferred a genetic counseling chatbot that included both general and patient-specific information, it appears that returning genetic test results was not a desirable function for a genetic counseling chatbot.

It is important to note that the response, "Being unable to assess patient understanding of the information included in the chatbot" does not necessarily specify what information the chatbot would disclose. Participants could have interpreted this question in many ways, including anything from a chatbot that provided a great deal of information to one that only disclosed genetic test results. Thus, it is impossible to determine what types of misinterpretation of information by patients were of concern to the participants. Given their written responses, their main apprehension seems to involve genetic test results, such as the NIPT example above, but it is possible that even items such as general genetic information or insurance information could be misinterpreted by the patient. This potentially could lead to unnecessary confusion that would have to be addressed by the counselor, anyway. More research is needed to investigate the types of

information that should be included in a chatbot, how genetic counselors perceive this information, and how it can be presented effectively to patients.

There were several other themes that appeared frequently in participants' free-text responses. Of the 101 responses, 33 mentioned chatbot accessibility in some form. Many responses mentioned concerns about the technology required for patients to access a chatbot. One participant noted, "...I work in a very rural area. There are individuals with limited access to technology, individuals with a limited education and/or ability..." While the vast majority of individuals in the United States have a mobile phone that can access the internet, there is still a significant population that does not. If the chatbot is only accessible via mobile phone, this would present a significant barrier to use by that portion of the population. Many individuals may not even have reliable access to Internet service, so using the chatbot via an Internet browser on a desktop or laptop computer may not be feasible. The mobile phones of some individuals may not be technologically current enough for a chatbot application to function. Being able to design a chatbot that works with the majority of mobile phones may be more difficult, time-consuming, and costly than the benefit of being able to provide a chatbot.

In addition to considering the cost of developing the chatbot, there are other costs associated with a chatbot as well, such as the cost of maintaining the chatbot and the potential cost to patients who may not be able to afford to use much data on their Internet plan. Because so few chatbots are currently being used in genetic counseling, it is unclear what the cost is to those institutions that currently use them. The majority of participants responded that they would want a chatbot to be able to be offered to their patients free of

charge (84.2%). This is reasonable, because charging patients to use a tool to receive information that they could obtain during an appointment (likely to be covered by insurance) is unnecessary, unless they would find it useful for reviewing the information before and/or after the appointment. However, being willing to offer a chatbot free of charge does not take into account all of the other costs of implementing such a tool. Staff, such as IT personnel, might be needed to keep the chatbot current and to troubleshoot problems that might occur. Training might be required for genetic counselors who are planning to use the chatbot so they would know what information is included, which other functions the chatbot might be able to perform, and how to use the application effectively. These thoughts were echoed in many participant free-text responses: "…Cost/IT support for monitoring of the chatbot," "…Cost for service and maintenance (including personnel needed)," …overall cost for integration into the health system IT Department." Ultimately, cost is one of the many logistical concerns that will have to be addressed before genetic counseling chatbots can be effectively implemented.

4.5 Development of future genetic counseling chatbots

One of the purposes of this study was to help inform the development of future genetic counseling chatbots. Based on the responses received from participants regarding when to offer a chatbot, cost, and types of information included, several recommendations can be made. As previously discussed, the ideal genetic counseling chatbot should be offered free of charge to patients. This would ensure that there would be no financial barrier to using the chatbot. Also, it should function as an extension of the genetic counseling appointment itself, rather than a separate entity. The chatbot should be

available to patients for an indefinite period of time, both before and after their

appointments to allow patients to access the chatbot when it is best for them. By having it

available before their appointment, patients could ask questions, provide information

about themselves, and be prepared prior to their appointment. Even if they did not use the

chatbot before their appointments, having access to it afterwards would still allow them to

ask questions and have information repeated to them or available for them to review with

their relatives. This could help with retention of important points from the session and to

provide a connection to the genetic counselor. A large proportion of genetic counselors

wanted a chatbot to have the ability to connect patients with a genetic counselor, either via

phone, email, or instant message. It is important to have such access so that a genetic

counselor can answer questions the patient may have that the chatbot cannot or should not

address. It would be helpful to have both phone and email options and to allow counselors

to choose between them, depending on what works best for them and their patients.

The majority of participants wanted a genetic counseling chatbot to have both

predetermined and open text response options for the patients who are using them. This

would give patients the most flexibility when interacting with the chatbot and also would

allow patients to ask their own questions. One participant wrote in a free-text response to

the prompt, "Please specify what you would like to see in a genetic counseling chatbot,"

"...What if the patients ask the wrong questions or don't know what to ask?" Having

predetermined responses could provide a starting place for patients who are new to

genetic counseling and help them generate their own questions from the chatbot's

responses. Furthermore, for the "wrong" questions that the chatbot doesn't know how to

answer, a patient would have the option of connecting to a genetic counselor, and a

response could be added to the chatbot addressing that question for future patients. Similarly, while the chatbot may be programmed with many of the most commonly asked questions, whether about genetics in general, insurance information, or genetic testing, it is impossible to anticipate every question a patient may have. If the chatbot were unable to find an adequate answer in its database, then a genetic counselor could be contacted for additional information. Both the GeneFAX and GIA chatbots are programmed with predetermined responses as well as the ability for users to enter their own questions. Given the results of this survey, this is clearly the precedent that should be continued going forward as new chatbots are developed. It also highlights the importance of having an option to reach a genetic counselor through the chatbot in order to provide more detailed information in case the chatbot is unable to respond to a particular user-generated question.

Overall, participants wanted both general and patient-specific information to be included in a genetic counseling chatbot. The one area that nearly all participants agreed should not be included, however, is disclosure or discussion of positive genetic test results. Given that currently, there are no genetic counseling chatbots that return any genetic test results, positive or negative, this should continue to be the case going forward. However, there is a distinction to be made between disclosing genetic test results and discussing them with a patient. Simply telling a patient that they tested positive or negative is different from having a discussion about what those results mean. While chatbots are helpful for routine interactions, returning genetic test results requires both careful explanations that are tailored to the patients' educational level and emotional state and attention to psychosocial issues. This is especially true for positive genetic test results,

which is likely why so many participants did not choose it as a desired feature of a genetic counseling chatbot. Removing these aspects of genetic counseling interactions could negatively impact patients and their health, which is not the point of using chatbots as a tool. If anything, chatbots should be utilized so that genetic counselors could spend more time with those patients who need it and/or see more patients as the need increases, so genetic counseling chatbot functions should be limited to things that do not require in-person interaction. However, it could be useful for a chatbot to be able to discuss genetic test results after an appointment, once they have been returned by a genetic counselor. For instance, the chatbot could remind patients what a mutation is or what the risks to other family members are, explain a variant of uncertain significance (VUS) test result, or recommended guidelines for cancer surveillance. This would be helpful information, even in the setting of a negative test result, and easy for a chatbot to provide, which could explain why 25% of participants were interested in having a genetic counseling chatbot disclose or discuss negative genetic test results. However, this is still the minority, and more research must be done to investigate scenarios in which genetic counselors are comfortable using a chatbot to return negative genetic test results. Currently, the best option for genetic counseling chatbots is not to provide genetic test results, though discussion of these after an appointment might be something to consider in the future.

There is also the question of how best to integrate chatbots into the genetic counseling clinic workflow. While this study did not address this question specifically, it was mentioned by several participants in their free-text responses. As more research is done regarding genetic counseling chatbots, this will be an important area to explore.

4.6 Study limitations

In addition to those discussed above, there are several other important limitations of this study that warrant mention. Overall, the demographics of the participants closely matched those of the National Society for Genetic Counselors' 2019 and 2020 Professional Status Survey (Professional Status Survey 2019: Executive Summary, 2019) (Professional Status Survey 2020: Executive Summary, 2020). As such, the results of our study are reflective of the genetic counseling profession as surveyed by NSGC. However, there are still several limitations to the current study. Overall, the sample size was relatively small. A larger number of participants would increase the power of analysis and potentially reveal more statistically significant differences. The participant population was also split into two sub-groups, genetic counselors and genetic counseling graduate students. While these sub-groups were evenly split, this further reduced the power of analysis since there were some questions that were only asked of each specific sub-group. Those results are only generalizable to that group in particular and not to all participants.

Furthermore, the majority of both this study's participants as well as the NSGC PSS are female, white/Caucasian, and between the ages of 20-29. There are other genetic counselors who do not fit these demographics, and their opinions regarding using genetic counseling chatbots are just as valid. Incorporating their perspectives into future studies would be helpful for more broadly addressing the concerns of genetic counseling professionals.

The study was also limited by its design. For example, the genetic testing scenarios were written so that there was a low- and high-risk scenario for each genetic counseling

setting. However, these scenarios were not identified as such to the participants. Even if they had been, it is possible that the participants may not have agreed with the classifications. This could have skewed the data, since what is considered high- and low-risk is open to interpretation in individual settings. Thus, in future studies of the potential situations in which a genetic counseling chatbot might disclose test results, a more extensive list of scenarios may be necessary.

Finally, selection bias is another limitation to consider. Given that the survey was only available electronically, individuals who participated may be more technologically-knowledgeable and thus potentially more interested in using chatbots. Though the survey was not particularly long, individuals who had more free time may have been more inclined to answer the survey, which may not be representative of genetic counselors or genetic counseling graduate students as a whole. In addition, a link to the survey was advertised on Twitter by a genetic counselor who uses chatbots herself. Not only does Twitter require technology to access it, potentially confounding the data, but the post may have reached an audience that was more likely to be interested in using chatbots as well, which also could have introduced bias into the study. While there are many genetic counselors who use Twitter and many or most may be part of the NSGC email listserv, these platforms do not encompass the entire genetic counseling community, so by advertising mainly to these populations, the potential participants for our study may have been limited.

4.7 Recommendations for future study

For future study, in addition to the areas discussed above, there are several important issues that warrant investigation. In response to the current global COVID-19

pandemic, there has been an increase in the use of telemedicine by genetic counselors, medical geneticists, and other health professionals. However, the data collection for this survey ended before social distancing began in the United States. Because of the increasing need for genetic counselors to interact with their patients remotely and electronically, it is possible that the rapidly expanding usage of telemedicine might change genetic counselors' opinions on the place of chatbots in genetic counseling.

While this study was able to identify several variables that predict interest in offering a genetic counseling chatbot to patients, there likely are many more items of potential interest that were not included. Even those variables that were not significant in this study may turn out to be so when looked at in a larger population of genetic counselors and/or graduate students. Trying to determine why several variables were important predictors of interest would also be helpful, such as why considering using a chatbot for personal health is significantly correlated with interest in offering a genetic counseling chatbot. This may identify ways in which to increase the interest of other genetic counselors.

Besides genetic counselors and genetic counseling graduate students, surveying clinical geneticists would also provide important insight into what should be included in genetic counseling chatbots. Geneticists often provide their own counseling for patients in addition to working with genetic counselors. As such, they would provide a unique perspective on the usage of chatbots in genetic counseling and clinical genetics settings.

Finally, while this study was able to identify several barriers to offering a genetic counseling chatbot, additional research should be done in order to determine how best to

overcome those barriers. It may be that there are some obstacles that cannot be overcome, especially in terms of access to the chatbot. Identifying how to assess patients' understanding of chatbot-provided information and which topics are of most concern to genetic counselors will be necessary, as will determining how to implement a chatbot into a clinic's workflow. Ultimately, it is unlikely that there will be a single chatbot that could be used across all clinics and all genetic counseling specialties, but being able to provide options that could actually assist genetic counselors in their work is entirely possible. Chatbots have the potential to be very powerful tools for genetic counselors, but exactly what shape they will take is still being investigated and refined. The role chatbots will play in the genetic counseling field requires both continued research and the input of genetic counselors to ensure they will be useful to the profession.

REFERENCES

"ABGC Fall Digest." *ABGC Fall Digest*, 25 Nov. 2019.

Bennett, Robin L. *The Practical Guide to the Genetic Family History*. Wiley-Blackwell, 2010.

Bio-IT World Staff. "OptraHEALTH, InformedDNA Partner To Expand Access To Genetics Experts." Bio-IT World, 8 Nov. 2019, www.bio-itworld.com/2019/11/08/optrahealth-informeddna-partner-to-expand-access-to-genetics-experts.aspx.

Brandtzæg, Petter Bae, and Asbjørn Følstad. "Why People Use Chatbots." Internet Science Lecture Notes in Computer Science, vol. 10673, 2017, pp. 377–392.

Buchanan, Adam Hudson, et al. "Alternate Service Delivery Models in Cancer Genetic Counseling: A Mini-Review." Frontiers in Oncology, vol. 6, 13 May 2016.

Burns, Kaitlyn, et al. "Genetic Counseling Job Market in the United States and Canada: An Analysis of Job Advertisements 2014–2016." *Journal of Genetic Counseling*, June 2019.

Calzone, Kathleen A., et al. "Randomized Comparison of Group Versus Individual Genetic Education and Counseling for Familial Breast and/or Ovarian Cancer." *Journal of Clinical Oncology*, vol. 23, no. 15, 2005, pp. 3455–3464.

Christian, Susan, et al. "Defining the Role of Laboratory Genetic Counselor." *Journal of Genetic Counseling*, vol. 21, no. 4, Nov. 2011, pp. 605–611.

Clement, J. "United States: Mobile Phone Internet User Penetration 2023." *Statista*, 2 Dec. 2019, www.statista.com/statistics/275587/mobile-phone-internet-user-penetration-us/.

Cloutier, Mireille, et al. "Group Genetic Counseling: An Alternate Service Delivery Model in a High Risk Prenatal Screening Population." *Prenatal Diagnosis*, vol. 37, no. 11, 2017, pp. 1112–1119.

Cohen, Stephanie A., et al. "Analysis of Advantages, Limitations, and Barriers of Genetic Counseling Service Delivery Models." *Journal of Genetic Counseling*, vol. 25, no. 5, 2016, pp. 1010–1018.

Du, Li, and Shmuel I. Becher. "Genetic and Genomic Consultation: Are We Ready for Direct-to-Consumer Telegenetics?" Frontiers in Genetics, vol. 9, Mar. 2018, p. 550.

Følstad, Asbjørn, and Petter Bae Brandtzæg. "Chatbots and the New World of HCI." Interactions, vol. 24, no. 4, 23 June 2017, pp. 38–42.

"Genomic Data Toolkit - Family History Tools Inventory." Global Alliance for Genomics & Health, 2018, www.ga4gh.org/genomic-data-toolkit/.

Gordon, Erynn S., et al. "The Future Is Now: Technology's Impact on the Practice of Genetic Counseling." American Journal of Medical Genetics Part C: Seminars in Medical Genetics, vol. 178, no. 1, 2018, pp. 15–23.

Gray, J, et al. "A Pilot Study of Telegenetics." Journal of Telemedicine and Telecare, vol. 6, no. 4, 2000, pp. 245–247.

Hoskovec, Jennifer M., et al. "Projecting the Supply and Demand for Certified Genetic Counselors: A Workforce Study." *Journal of Genetic Counseling*, vol. 27, no. 1, 2017, pp. 16–20.

Invitae Corporation. "Invitae to Acquire Clear Genetics." PR Newswire: Press Release Distribution, Targeting, Monitoring and Marketing, 11 Nov. 2019, www.prnewswire.com/news-releases/invitae-to-acquire-clear-genetics-300955258.html.

Io, H. N., and C. B. Lee. "Chatbots and Conversational Agents: A Bibliometric Analysis." 2017 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 2017, pp. 215–219.

Klotzbach, Chris, and Lali Kesiraju. "Flurry State of Mobile 2017: With Captive Mobile Audiences, New App Growth Stagnates." Flurry Blog, 10 Jan. 2018, www.flurry.com/blog/post/169545749110/state-of-mobile-2017-mobile-stagnates.

Laranjo, Liliana, et al. "Conversational Agents in Healthcare: A Systematic Review." *Journal of the American Medical Informatics Association*, vol. 25, no. 9, Nov. 2018, pp. 1248–1258.

McCuaig, Jeanna, et al. "Next-Generation Service Delivery: A Scoping Review of Patient Outcomes Associated with Alternative Models of Genetic Counseling and Genetic Testing for Hereditary Cancer." *Cancers*, vol. 10, no. 11, 2018, p. 435.

McWalter, Kirsty, et al. "Genetic Counseling in Industry Settings: Opportunities in the Era of Precision Health." *American Journal of Medical Genetics Part C: Seminars in Medical Genetics*, vol. 178, no. 1, 2018, pp. 46–53.

Molteni, Megan. "So Much Genetic Testing. So Few People to Explain It to You." *Wired*, Conde Nast, 1 May 2019, www.wired.com/story/so-much-genetic-testing-so-few-people-to-explain-it-to-you/.

Nadarzynski, Tom, et al. "Acceptability of Artificial Intelligence (AI)-Led Chatbot Services in Healthcare: A Mixed-Methods Study." *Digital Health*, vol. 5, 2019, p. 205520761987180.

Palanica, Adam, et al. "Physicians' Perceptions of Chatbots in Health Care: Cross-Sectional Web-Based Survey." *Journal of Medical Internet Research*, vol. 21, no. 4, May 2019.

Pereira, Juanan, and Óscar Díaz. "Using Health Chatbots for Behavior Change: A Mapping Study." *Journal of Medical Systems*, vol. 43, no. 5, Apr. 2019.

Pritzlaff, Mary, et al. "An Internal Performance Assessment of CancerGene Connect: An Electronic Tool to Streamline, Measure and Improve the Genetic Counseling Process." *Journal of Genetic Counseling*, vol. 23, no. 6, Dec. 2014, pp. 1034–1044.

Professional Status Survey 2019: Demographics and Methodology. National Society of Genetic Counselors, 2019, https://www.nsgc.org/p/cm/ld/fid=68.

Professional Status Survey 2020: Demographics and Methodology. National Society of Genetic Counselors, 2020, https://www.nsgc.org/p/cm/ld/fid=68.

Professional Status Survey 2020: Executive Summary. National Society of Genetic Counselors, 2020, https://www.nsgc.org/p/cm/ld/fid=68.

Professional Status Survey 2020: Work Environment. National Society of Genetic Counselors, 2020, https://www.nsgc.org/p/cm/ld/fid=68.

1980-2002 Professional Status Survey Trends Report. National Society of Genetic Counselors, 2004, https://www.nsgc.org/p/do/si/topic=153.

Radziwill, Nicole, and Morgan Benton. "Evaluating Quality of Chatbots and Intelligent Conversational Agents." Apr. 2017.

Ready, K., Schmidlen, T., Wicklund C., panelists. Meeting the demand for Genetic Counseling Through Artificial Intelligence: Can We Clone Our Skill Set?. NSGC 38th Annual Conference, 8 Nov. 2019, Grand Ballroom, Salt Palace Convention Center, Salt Lake City, UT.

Schmidlen, Tara, et al. "Patient Assessment of Chatbots for the Scalable Delivery of Genetic Counseling." *Journal of Genetic Counseling*, vol. 28, no. 6, 2019, pp. 1166–1177.

Shawar, Bayan Abu, and Eric Atwell. "Chatbots: Are They Really Useful?" *LDV Forum*, vol. 22, Jan. 2007, pp. 29–49.

Silver, Laura. "Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally." *Pew Research Center's Global Attitudes Project*, Pew Research Center, 30 Dec. 2019, www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/.

"The Digital Revolution in Genomics: OptraHEALTH® Launches GeneFAX™, Free to Use Conversational AI Powered App for Consumers." News Category Global Banking & Finance Reviews, 16 Oct. 2018, www.globalbankingandfinance.com/category/news/the-digital-revolution-in-genomics-optrahealth-launches-genefax-free-to-use-conversational-ai-powered-app-for-consumers/.

Versel, Neil. "Chatbots, Telehealth Help Extend Reach of Genetic Counselors." *GenomeWeb*, 29 Apr. 2019, www.genomeweb.com/informatics/chatbots-telehealth-help-extend-reach-genetic-counselors.

Weizenbaum, Joseph. "ELIZA---a Computer Program for the Study of Natural Language Communication between Man and Machine." Communications of the ACM, vol. 9, no. 1, Jan. 1966, pp. 36–45.

Welch, Brandon M., et al. "Review and Comparison of Electronic Patient-Facing Family Health History Tools." *Journal of Genetic Counseling*, vol. 27, no. 2, June 2018, pp. 381–391.

"What Is MyCode?" *MyCode Community Health Initiative*, www.geisinger.org/precision-health/mycode.

"Who Are Genetic Counselors?" *National Society of Genetic Counselors*, 2020, www.nsgc.org/page/whoaregcs.

Wurmser, Yoram. "US Time Spent with Mobile 2019." *EMarketer*, 30 May 2019, www.emarketer.com/content/us-time-spent-with-mobile-2019.

APPENDIX A: Survey

Finding a place for chatbots: experiences, views, and ideas for future applications in genetic counseling

Lead Researcher

Jordann Wallis, Genetic Counseling Graduate Student

Department of Pediatrics, Division of Genetic and Genomic Medicine, University of California Irvine

Phone: 714-456-5837 Email: jordannw@hs.uci.edu

Faculty Sponsor

Maureen Bocian, MD, FAAP, FACMG

Professor of Pediatrics

Division of Genetic and Genomic Medicine, University of California Irvine

Phone: 714-456-6873 Email: mebocian@hs.uci.edu

· Please read the information below and ask questions about anything that you do not understand. A researcher listed above will be available to answer your questions.

· You are being asked to participate in a research study being conducted as part of a Master's Thesis at the University of California, Irvine. Participation in this online study is voluntary.

You must be at least 18 years old to participate in the study.

You must be attending a genetic counseling master's program or a practicing genetic counselor within the United States to participate in the study

· If you chose to participate in the study, you will be asked to complete an anonymous survey. The questions in the

survey will ask about your familiarity with, usage of, and opinions regarding chatbots, both in general and those that have been developed for use specifically in genetic counseling settings. This survey will also address what information should be included in genetic counseling chatbots and the potential barriers to their use by genetic counselors.

· You may choose to skip questions or discontinue the survey at any time. The survey is anonymous, and your responses are anonymous. You are free to withdraw from this study at any time.

· The survey is expected to take about 10-15 minutes.

· There are no direct benefits from participation in the study. However, the goal of this study is to investigate the current perspective of genetic counselors and genetic counseling students regarding the use of chatbots in this field. We hope this study will guide the development and refinement of current and future chatbots used in genetic counseling settings.

· All research data collected will be stored securely and confidentially within a secure server through the Department of Pediatrics, Division of Genetic and Genomic Medicine within UCI.

· Questions? If you have any comments, concerns, or questions regarding this study please contact the researchers listed at the top of this form.

· If you want to participate in this study, click the START button to begin the survey.

Please select START to begin the survey.	◯ START
Where do you live?	◯ United States (including Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands) ◯ Canada ◯ International (outside North America)

Section 1 - Demographic Information

What is your gender?
- ○ Female
- ○ Male
- ○ Other (please specify)
- ○ Prefer not to say

Please specify your gender here

_____

What is your age?
- ○ 20-29
- ○ 30-39
- ○ 40-49
- ○ 50-59
- ○ 60+

What is your race?
- ☐ American Indian or Alaskan Native
- ☐ Asian
- ☐ Asian Indian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White or Caucasian
- ☐ Other (please specify)
- ☐ Prefer not to respond

Please specify your race here

_____

What part of the United States do you live in?
- ○ Region 1 (CT, MA, ME, NH, RI, VT)
- ○ Region 2 (DC, DE, MD, NJ, NY, PA, VA, WV, PR, VI)
- ○ Region 3 (AL, FL, GA, KY, LA, MS, NC, SC, TN)
- ○ Region 4 (AR, IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, OK, SD, WI)
- ○ Region 5 (AZ, CO, MT, NM, TX, UT, WY)
- ○ Region 6 (AK, CA, HI, ID, NV, OR, WA)

What is the highest degree or level of school you have completed? If you are currently enrolled, what is the highest degree you have received.
- ○ Bachelor's Degree
- ○ Master's Degree
- ○ Professional Degree (MD, DO, PsyD, EdD, JD, etc.)
- ○ Doctoral Degree (PhD , DPhil, etc.)

Are you a genetic counselor or a genetic counseling student?
- ○ Genetic Counselor
- ○ Genetic Counseling Graduate Student

What year are you currently?
- ○ 1st year
- ○ 2nd year
- ○ 3rd year

What is your current, PRIMARY specialty?
- ○ Cancer
- ○ Pediatrics
- ○ Prenatal
- ○ Adult
- ○ General Genetics
- ○ Laboratory
- ○ Other (please specify)

Please specify your primary specialty here

_____

How many years have you been practicing in your current, PRIMARY specialty?	○ < 1 year ○ 1-4 years ○ 5-9 years ○ 10-14 years ○ 15-19 years ○ 20-24 years ○ 25+ years
On average, how many patients do you see per week?	○ 0 ○ 1-10 ○ 11-20 ○ 21-30 ○ 31-40 ○ 41+
Do you have administrative or support staff?	○ Yes ○ No
What type of support staff do you currently have? Please select all that apply	☐ Administrative/support staff ☐ Nurse(s) ☐ Genetic Counseling Assistant(s) ☐ Volunteer(s) ☐ Genetic Counseling Student(s)
Who calls out POSITIVE/ABNORMAL testing results in your current place of work? Please select all that apply.	☐ Myself ☐ Other genetic counselors in my office ☐ Administrative/support staff ☐ Other (please specify) ☐ Does not apply
Please specify here	_____
Who calls out NEGATIVE/NORMAL testing results in your current place of work? Please select all that apply.	☐ Myself ☐ Other genetic counselors in my office ☐ Administrative/support staff ☐ Other (please specify) ☐ Does not apply
Please specify here	_____
Do you use alternative counseling methods? Examples include telegenetics (counseling patients over the phone or via video consultation), group counseling, or using web-based portals to return results or communicate with patients.	○ Yes ○ No
Which of the following alternative counseling methods do you/have you used? Please select all that apply.	☐ Telemedicine/Telegenetics (including web-based video) ☐ Group Counseling ☐ Web-Based Portal ☐ Chatbots ☐ Other (please specify)
Please specify what alternative counseling methods you have used here	_____

Section 2 - Digital Literacy/Chatbot Questions

A chatbot is a computer program that uses artificial intelligence and natural language processing to simulate conversation with human users. Usually they are in the form of text messages or instant messaging, like on an app or in a web browser. Depending on the chatbot, users can either respond by choosing predetermined responses or type in their own questions. You may have interacted with a chatbot without realizing it. Some of the most common uses of chatbots on the Internet today are for product suggestions on retail websites, customer support, and personal financial assistance, among many others. In fact, Siri, Amazon Alexa, and Google Assistant are all very sophisticated chatbots that use voice commands as well as text. For the following questions, please think about your personal experience with chatbots .

The following is a mock up of a chatbot that you might use on your phone

Hello! How can I help you today?

How much money do I have in my checking account

I can help with that! One moment while I look up your account

I see that you have $100.01 in your checking account. Anything else I can help with?

I'd like to transfer money from my savings account

...

Have you ever used a chatbot yourself?   ○ Yes
                                                 ○ No

When was the last time you used a chatbot?	○ Today
	○ Within the past week
	○ Within the past month
	○ Within the past 6 months
	○ Within the past year
	○ Over a year ago

How often would you say you use chatbots?	○ Daily
	○ Weekly
	○ Monthly
	○ Every other month
	○ Yearly

Where do you most often encounter chatbots? Please select all that apply	☐ Phone (Siri, Google Assistant)
	☐ Personal/Home Device (Amazon Alexa, Google Assistant)
	☐ Phone app (Facebook Messenger, personal banking, retail store)
	☐ Internet browser on a personal computer, tablet, or phone
	☐ Other (please specify)

Please specify where you most often encounter chatbots here _____

How often do you use chatbots for the following activities? Please choose the category that most closely represents your average usage

	Never	Rarely (up to 30% of the time)	Sometimes (31-60% of the time)	Often (61-90% of the time)	Almost Always/Always (91-100% of the time)
Ordering food	○	○	○	○	○
General questions	○	○	○	○	○
Product suggestions	○	○	○	○	○
Customer service	○	○	○	○	○
Product support	○	○	○	○	○
Personal banking	○	○	○	○	○
Weather report	○	○	○	○	○
News report	○	○	○	○	○

Where do you think you would be most likely to encounter a chatbot? Please select all that apply.	☐ Phone (Siri, Google Assistant)
	☐ Personal/Home Device (Amazon Alexa, Google Assistant)
	☐ Phone app (Facebook Messenger, personal banking, retail store)
	☐ Internet browser on a personal computer, tablet, or phone
	☐ Other (please specify)

Please specify where you think you would be most likely to encounter chatbots here _____

For each of the following activities, how often do you think you would use a chatbot? Please choose the category that most closely represents your predicted usage

	Never	Rarely (up to 30% of the time)	Sometimes (31-60% of the time)	Often (61-90% of the time)	Almost Always/Always (91-100% of the time)
Ordering food	○	○	○	○	○
Product suggestions	○	○	○	○	○
Customer service	○	○	○	○	○
Product support	○	○	○	○	○
Personal banking	○	○	○	○	○
Weather report	○	○	○	○	○
News report	○	○	○	○	○

Would you consider using a chatbot for your personal health?

○ Yes
○ No

Section 3 - Genetic Counseling Chatbot Questions

There are several chatbots that are currently used by genetic counselors, as well as chatbots that are being developed. Many of these chatbots are being developed by companies that specializes in artificial intelligence (AI) and chatbots, which can then be customized by the genetic counselor(s) in the clinic(s) where they are being used. The chatbot can give users predetermined options to respond, allow users to enter their own responses, or use a mixture of both. The genetic counselors write the script that the chatbot uses, which can be updated/edited as needed. For the following questions, imagine that this chatbot will be available to purchase by your company/hospital/medical group/etc. Only patients in your clinic/place of work will be able to access this chatbot. This chatbot will only be accessed by a secure link provided to your patients. Please see the image for an idea of what the chatbot would look like when your patients use it.
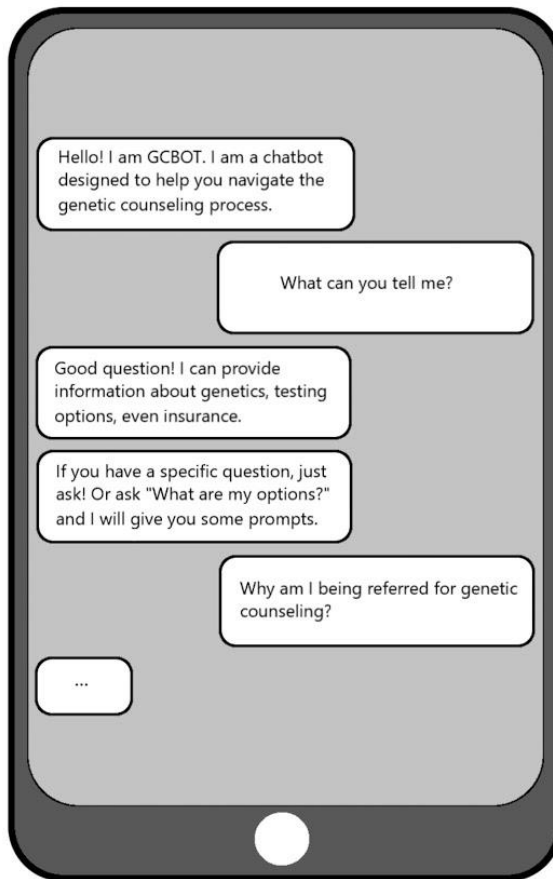
Are you familiar with any of the following chatbots that have been developed for use in genetic counseling? Please select all that apply.	☐ GeneFAX (developed by OptraHealth) ☐ GIA (Genetic Information Assistant, developed by Clear Genetics) ☐ NEVA (Natera's Educational Virtual Assistant) ☐ Other (please specify) ☐ I am not familiar with any genetic counseling chatbots
Please specify what genetic counseling chatbots you are familiar with here	_____
Do you currently offer a chatbot as part of your genetic counseling practice?	○ Yes ○ No
What do you use the chatbot for? Please select all that apply.	☐ Screening tool to identify potential patients ☐ Follow up with patients after return of genetic testing results ☐ Informing at risk family members of patient testing results ☐ General information tool for patients ☐ Other (please specify)
Please specify what you use the chatbot for here	_____
How interested are you in offering a chatbot to your patients?	○ Not at all ○ Slightly ○ Moderately ○ Very ○ Completely
What features would you like to see in a chatbot for genetic counseling patients? Please select all that apply.	☐ General genetics information (tailored to your practice/specialty) ☐ Insurance information ☐ Genetic testing information ☐ Background genetic testing results information (what are Positive, Negative, Variant of Uncertain/Unknown Significance results and what do they mean) ☐ Genetic testing consent ☐ Disclosure or discussion of positive genetic testing results ☐ Disclosure or discussion of negative genetic testing results ☐ Providing information to send to at risk family members about genetic testing options ☐ Ability to contact a genetic counselor via phone ☐ Ability to contact a genetic counselor via email ☐ Ability to contact a genetic counselor via Instant Message ☐ Other (please specify)
Please specify what you would like to see in a genetic counseling chatbot here	_____

How likely would you be to offer a chatbot that only allows predetermined response choices, only allows open text response, or a mixture of both?

	Not at all	Slightly	Moderately	Very	Completely
Predetermined responses only	○	○	○	○	○
Open text response only	○	○	○	○	○
Both predetermined and open response	○	○	○	○	○

If you were to offer a chatbot, when would you like it to be available to your patients?	○ After their appointment for only one week ○ After their appointment for only one month ○ After appointment indefinitely ○ Before their appointment for only one week ○ Before their appointment for only one month ○ Anytime before their appointment, but not after their appointment ○ Both before and after their appointment indefinitely
If there is a cost for giving your patients access to the chatbot, how do you think it should be managed?	○ The chatbot should be offered free of charge ○ The patient's insurance should be billed ○ The patient should pay out of pocket ○ Other (please specify)
Please specify how you think the cost should be managed here	_____

How likely would you be to offer a chatbot to return NEGATIVE/NORMAL results in the following scenarios?

	Not at all	Slightly	Moderately	Very	Completely
A prenatal patient who is 35 years old and elects NIPT.	○	○	○	○	○
A prenatal patient who has abnormal ultrasound findings.	○	○	○	○	○
A pediatric patient who is being evaluated for autism.	○	○	○	○	○
A pediatric patient who has a history of metabolic crises.	○	○	○	○	○
An unaffected cancer patient with a family history of cancer with typical age of onset.	○	○	○	○	○
A 30-year-old woman with breast cancer with a family history of multiple relatives affected at young ages with breast and ovarian cancers.	○	○	○	○	○
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome.	○	○	○	○	○

A pre-symptomatic adult patient with a significant family history of Huntington disease.   ○   ○   ○   ○   ○

How likely would you be to offer a chatbot to return POSITIVE/ABNORMAL results in the following scenarios?

	Not at all	Slightly	Moderately	Very	Completely
A prenatal patient who is 35-years-old and elects NIPT.	○	○	○	○	○
A prenatal patient who has abnormal ultrasound findings.	○	○	○	○	○
A pediatric patient who is being evaluated for autism.	○	○	○	○	○
A pediatric patient who has a history of metabolic crises.	○	○	○	○	○
An unaffected cancer patient with a family history of cancer with typical age of onset.	○	○	○	○	○
A 30-year-old woman with breast cancer with a family history of multiple relatives affected at young ages with breast and ovarian cancers.	○	○	○	○	○
An adult patient with a Beighton score of less than 4 who is being evaluated for Ehlers-Danlos Syndrome.	○	○	○	○	○
A pre-symptomatic adult patient with a significant family history of Huntington disease.	○	○	○	○	○

Of the following, what are you most concerned about when it comes to offering a chatbot to your patients?

○ Privacy/HIPAA
○ Compliance with hospital legal and ethical guidelines
○ Electronic Medical Record integration
○ Accurate/up to date information
○ Ease of use
○ Ability to access chatbot with necessary technology/Internet access
○ Ability to access chatbot in a language other than English
○ Appropriate language level of chatbot script for patients (6th grade reading level)
○ The chatbot being mistaken for the genetic counselor/provider
○ Being unable to assess patient understanding of the information included in the chatbot

---

Describe any barriers you might have to offering a chatbot in your practice.

_____

APPENDIX B: Survey Advertisements

Advertisement distributed at National Society of Genetic Counselors' 2019 annual conference:

Advertisement attached to email correspondence regarding the survey:

Email sent to genetic counseling graduate program directors:

Dear Program Directors,

My name is Jordann Wallis and I am a second-year genetic counseling student at the University of California, Irvine. As part of my Master's thesis, I am conducting a survey of both genetic counselors and genetic counseling students titled: **Finding a place for chatbots: experiences, views, and ideas for future applications in genetic counseling**. To this end, I am kindly requesting your students' participation in my survey. The aim of my research is to investigate the current perspective of genetic counselors and genetic counseling students regarding the use of chatbots in this field and to help guide the development and refinement of current and future genetic counseling chatbots.

For this study, I am recruiting all students currently enrolled in a genetic counseling graduate training program, including both first-year (class of 2021) and second-year (class of 2020) students.

Participation in this research study consists of taking a short, anonymous online survey. The survey contains a demographic questionnaire, questions regarding students' use of chatbots in their personal life, and questions regarding genetic counseling chatbots, including what information should be included in them, whether they should be used to disclose positive and/or negative genetic test results, and potential barriers to using chatbots as a genetic counseling tool. The survey is expected to take about 10-15 minutes to complete. Participation is completely voluntary, and participants may opt out at any time.

This research study is completed in partial fulfillment of a Master's thesis for the University of California, Irvine Genetic Counseling Program. This study is exempt from review under the self-determination guidelines at the Institutional Review Board at the University of California, Irvine.

Please forward this invitation to your first- and second-year students.

To access the survey, please follow this link: https://is.gd/chatbotGC

The survey will remain open until **February 29th, 2020**.

Thank you very much for your time,

Jordann Wallis

University of California, Irvine

MS in Genetic Counseling, Class of 2020

APPENDIX C: All free-response answers

Answers are copied here exactly as the participant wrote them. All typographical errors and misspellings have been left as-is.

C-1: Please specify your race here
Hispanic
Middle Eastern
Hispanic/Latino
Latino
Hispanic
Middle eastern
Hispanic
Latina
Mexican/Hispanic

C-2: Please specify your primary specialty here
Ophthalmology
0.5 FTE is research. 0.5 FTE is clinical and is split between pediatric and adult.
Education
Product management
Neurology
Metabolic
Insurance
Inpatient
Research
Education
Biochemical/Metabolic
ART/Infertility/PGT
Education
Cardiology
Public Health
Genomic medicine
education
Adult Cardiology
Research/Immunology
Population genomics and screening
Precision Medicine

C-3: Who calls out POSITIVE/ABNORMAL testing results in your current place of work? Please specify here.
Genetic counseling students under supervision
Genetic Counseling student, physicians
Doctor
In-person visits preferred and primarily performed
Genetic Counseling students
Geneticist
Telephone result disclosure is done by GCs who work for our sequencing partner
Physicians/residents
GCs that cover customer service call out critical results to ordering clinicians.
contacted by email to schedule results visit
Lab test reports are sent out

C-4: Who calls out NEGATIVE/NORMAL testing results in your current place of work? Please specify here
often send a letter instead of a call
Genetic counseling students under supervision
genetic counseling assistants
Genetic Counseling students
Genetic counseling assistant
Many negative results are directly released to the ordering provider without call out
In-person visits preferred and primarily performed
Nurses
Genetic counseling students
Genetic Counseling Interns
Genetic Counseling students
Results are released electronically
Physicians/residents
Work with a lab, negative results auto released to patient but they can still schedule counseling appointment after
Lab test reports are sent out

C-5: Please specify what alternative counseling methods you have used here
EPIC EMR is the web based portal referenced - used for direct patient contact and negative result disclosures

C-6: Please specify where you most often encounter chatbots here
When calling doctors offices or the Pharmacy to refill prescriptions

C-7: Please specify what genetic counseling chatbots you are familiar with here
FamGenix
the ones that were talked about at AEC NSGC 2019
Invitae
Invitae has one that I tried out
Invitae chatbot for DTC testing
Invitae's ChatBOT
geisinger
I don't know the name of it but it's one that Geisinger presented on at NSGC conference
Genetics Maven (Metis Genetics)

C-8: Please specify what you would like to see in a genetic counseling chatbot here
not sure
Scheduling chatbot would help the scheduling team (not genetics directly)
We would use it for customer service inquries: price, TAT, CPT codes, sample type, etc
I don't like chatbots and wouldn't use them. What if the patients ask the wrong questions or don't know what to ask?
Ability to determine whether a self-referral to GC would be useful/recommended
How to prepare for a GC appt, what a GC does, expectations for an appt
Collect a family history/medical history pre-appointment
Providing a check in for patients that have already had a blood draw/given a sample for testing
recap of session after the visit with a genetic counselor
general admin things for patient portal, like how to print results or add shared provider
Being able to gather additional patient information/screen patients before coming to clinic.
Language options

C-9: Please specify how you think the cost should be managed here
A nominal fee could be charged.
No idea
not sure
I imagine the institution/organization hosting the chat bot would be the one paying for its use?
Hospital
The chatbot should be offered free of charge, however, maybe only checked during working office hours (i.e. when a genetic counselor would be available to answer the phone if the patient called in)

116

C-10: Describe any barriers you might have to offering a chatbot in your practice.

institutional approval liability concerns

Logistics of offering it, would patients even use it (work in a low vision clinic, would need adaptations for our patients). Time commitment for the GC.

As a laboratory genetic counselor, a chatbot may not have the information in order to provide interpretation of the results identified through the laboratory or answer the questions received from providers as they are quite specific. Patient access to the service.

Not personalized enough, patients not feeling comfortable with the technology Money from clinical service lines

We do a lot of pretest counseling and I feel that chat bots are good in the pretest counseling setting. In order for us to us chatbots we'd need to move to a system of having more post-test consults (almost all of our results are over the phone)

Patients may not have access to internet/tools to access internet. If only offered in English, patients who don't speak English could not use.

Cost Implementation   Misuse Privacy issues Poor understanding

I think many patients do not want to receive their information this way

EMR integration, institution buy in and approval, upfront/ongoing costs

Lack of internet access in rural areas

A lot of the concerns noted in the above question come to mind. I work in a very rural area. There are individuals with limited access to technology, individuals with a limited education and/or ability, and individuals who have to travel 4+ hours to reach me (who may neglect their appointment if they have access to something like a chat box).

I think there are significant limitations for individuals who do not have smart phones OR who have smart phones but aren't savvy at using them.

Being able to offer a chatbot in languages other than English (especially Spanish). Having a way to log all chats and keep a record of them in the EMR so that their providers can be aware of it. Would have to run it through institution's legal team/liability assessment. Transparency that it is a chatbot and not a substitute for a medical provider.

In the prenatal world where patients are often is more a crisis mindset regarding fetal findings or fetal screening results, I think an in-person consult or phone counseling is much better.

would be worried about liability--both if pt misunderstands the chatbot, or the chatbot misunderstands the pt question. Also documentation--I suppose the chat would be archived in the medical record?? but even then I think that would be an unwieldy way to go back and see what was actually said.

Cost/billing of the service to the patient. Cost/IT support for monitoring of the chatbot

Access to a cell phone that has text/chatting capabilities and reliable cell phone access- many of our patients use old flip phones or are on pay-as-you-go plans and don't pay their bills. I don't think many people would use this in my patient population. Most aren't even aware they are seeing a genetic counseling before they get to my clinic.

Documentation in medical record Access to chatbot (i.e. not all patients have internet access)

N/A

I am not a decision-maker for technology implementation at my center. Unless there are very rigorous security and safety features, this would not be a consideration for clinical use at my center. All concerns listed above are relevant barriers. My center views direct, personal interaction as an indicator of higher quality of care; chat bot implementation would remove the personal interaction and would not be perceived as an enhancement by our leadership or patients.

Not particularly a barrier, but personally I feel much more comfortable with a chat bot performing many of the pre-test counseling portions of a session. However, I still believe that a genetics professional, including GCs, should be involved in the post-test counseling, especially for positive/abnormal results review.

Cost, currently have a small IT team

Cost and ability to customize. I work in a low resource setting and it would be difficult to get hospital to pay for a chatbot. Our patient population is also unique and we would want to be able to customize the chatbot (which usually costs money).

Uptake would likely be low since no other providers at my hospital offer this.

Cost of implementing the chatbot

I don't trust that the bot would fully understand patient questions the way a GC can. Sometimes a GC can tell why a patient is confused by the way they ask questions, and I don't believe a bot could do this. I would not trust a bot to return results, positive or negative. I don't think it can personalize a result the way a GC can.

Language access due to highly ethnically diverse patient population. Consideration of education levels. Cost for service and maintenance (including personnel needed).

EMR integration and cost are two top concerns.

Cost to institution to develop or buy access to a chatbot Getting providers to agree on in which clinical scenarios chatbots should be used

I could see this being offered as part of the Epic MyChart interface, but basically as a different way to access the same information that is in patient after visit summaries. I don't see much of a utility for a chatbot in a pediatric setting.

how to bill using chatbot verses standard method

Compliance with hospital regulations/ HIPPA

Wide range of literacy, and socioeconomic status. Concerned about low literacy, non-English-speaking patients

I'm not in clinical practice so I'm afraid my responses may skew your data.

Complete unwillingness by me! I find using chat bots dehumanizing and demoralizing, and can't imagine subjecting patients to it given what I see as my duty to afford them dignity and respect.

At this point, almost infinite. Implementing a platform, providing easy access to patients to this platform, integrating these conversations into the EMR, implementing clinical protocols for what uses are/are not appropriate, difficulty of writing all script options; need more published evidence of efficacy and accuracy and usefulness of chatbots in diff situations to even consider offering; not appropriate for most patients at this point so cost would be prohibitive

A chatbot cannot address emotions. Patients/families can have a wide spectrum of emotions at all stages of the genetic counseling process and I do not feel it serves patients well to use this in replace of information that should be shared by a person.

I would be worried they would not be able to have all of their questions answered and it would make it very impersonal

Language barriers Patients with low health-literacy Patients with low technical ability   I work at a large institution and change happens slowly. There would be many legal and systematic hoops to jump through.

Who would pay for the service and how to show if it is having a positive or negative impact

Cost

It can sometimes be obvious that you're interacting with a chatbot, and patients might be frustrated not interacting with a human

1) Difficult to offer a chatbot to people of a low socioeconomic background who have difficulty accessing technology 2) Imperative to be able to offer chatbot in languages other than English in order to to reach out to a diverse patient population 3) Offering a chatbot would be problematic in the sense that we would not have that personal interaction that makes the genetic counseling profession so unique 4) Highly concerned of giving positive/abnormal test results to a patient using chatbot.

I have tried to contact Clear with no response. Chatbot does not integrate into EMR (that I know of). Need more admin support to test and launch product.

Patients' willingness to engage in and use the application Patients' access to the internet (either via smartphone or internet)

I think it may come off as insensitive to the patient to receive automated responses when dealing with potentially life altering health outcomes for themselves or a loved one. I worry that patients will feel alone and will not receive face-to-face support or may not attend a genetic counseling appointment after interacting with a chatbot. I think most things except basic logistical questions should be dealt with face-to-face to assess patient understanding and provide emotional support.

Whether the chatbot is offered in other languages, but most importantly whether the patient will actually pay attention to the chat.

So many

I don't know if it's something that patients would actually use

Psychosocial implications when delivering results

Being unable to assess patient's emotional response/feelings to the information included in the chatbot.

NA, not practicing yet

It would have to be programmed for so many different languages

Patient related; socioeconomic status (access to phone or computer), language, intellectual functioning Hospital related: billing

Due to being a genetic counseling student, I am assuming for future practice... I would assume cost to the patient and overall cost for integration into the health system IT Department would be barriers.

I would never use a chatbot to disclose positive results as I believe delivering these results requires psychosocial counseling and a human connection which chatbots aren't able to provide. Chatbots would be great for the education portion of the counseling session, however, chatbots aren't able to support a patient like I am able to with carefully timed silence, compassion, and empathy.

Resources needed and hiring a computer science expert to ensure the chat bot is working. Finding the best way to gauge the effectiveness of the chat box for patients. Finding when is the best time to allow patients to use the chat bot and what should be included in the chat bot. A chat bot will never replace a genetic counselor and I don't believe it should be used for results disclosure, so proper usage for the chat box is necessary.

I imagine that using a chatbot for post test counseling could be problematic for ensuring a patients receive psychosocial counseling, especially if positive. I think the other major barrier is how to pay for the services of a chatbot, especially for Genetic counselors who work in smaller hospitals.

Concern about how smoothly the chatbot is integrated into the clinic workflow (e.g. making sure all people who want to schedule an appointment actually make it onto a schedule). Piloting the chatbot for the patient population it is intended for to ensure it addresses all of the areas it should and that the end user comprehends what the chatbot discussed.

I wonder how the chatbot would be offered, through a certain website link, an app, or on a clinic's webpage. I could see challenges for clinics that do not have a webpage made specifically for genetic counseling services. That would need to be added and the chatbot would need to be a feature of the webpage.

I am worried that my employer will reduce the number of genetic counselors or force GC to become more automated

In a lot of these scenarios there is a lot of clarifying information someone needs to hear. Just because you had a normal NIPT this does NOT mean your ultrasound anomalies will go away, or just because your cancer testing was normal does NOT mean you are not at risk to get cancer and you still need reminders to do needed screenings. With a chatbot you cannot assess if the patient actually processed that or understood that rather than just reading their answer.

I would want to spend a significant amount of time getting familiar with the chatbot and understanding how the chatbot works

I think that human contact, either over the phone or in person, should be the goal for results disclosures. This allows for handling of the person's emotional responses. I would really only use these services, in theory, for general genetics questions, questions about insurance, questions about resources, things that are more factual and less emotionally involved

I'm worried about not being able to analyze patient comprehension and understanding. It may not be feasible for all patients to use a chatbot, so I don't want to rely on it.

chatbots aren't GCs so there's no way for the chatbot to recognize emotions, and tailor a session for the patient

I fear insurance companies will use it as a cop out to not cover gc appointments.

I wouldn't know who I need to reach out to in order to implement it. I would be very hesitant to offer a chatbot for any positive/more nuanced result (e.g. negative in the context of personal or family history of cancer), or if I felt the patient had a lot of anxiety.

Older individuals in a rural area that are much less technologically literate than those who may use a chat bot.

I would not feel comfortable having a chatbox give a positive diagnosis unless it was paired with a quiz or something to identify the level of understanding of the patient.

You wouldn't be able to determine patient understanding or their emotional response. Therefore you wouldn't be able to address any psychosocial considerations.

No way to assess patient understanding or provide psychosocial support. it is also more challenging to discuss the nuances of what a test result might mean for a particular individual.

Access to a smart-phone or compatible device

Without the ability to interact with a patient, I would not be able to assess their understanding or address psychosocial concerns they have, especially with a positive diagnosis.

I think a lot of the barriers will lie in convincing other practitioners and holdouts of the benefits of the technology (workload & access).

Language barriers, technology barriers (if someone does not have a smart phone or doesn't know how to text), cost of implementation, does not have the capacity to assess patient understanding or answer all patient questions, very limited utility

I would not use a chat bot to give results to patients. I think a human is essential for relaying results and empathizing with a patient, even if a negative/normal result. Additionally, I think financials could pose a problem for the chatbot.

I don't think any positive results should be disclosed with a chatbot to allow to questions to be answered properly but also to provide psychosocial support. I also don't think it should be used to consent, testing options, or important discussion points.

the chatbot cannot see the patient's reactions and cannot tell if the patient understood a concept or if the patient needs psychosocial assistance.

1. The technology for patients to utilize chatbots. 2. Being able to integrate the chatbot into a prenatal setting.

I worry that using a chatbot will not allow for actual counseling of patients. Information-giving is important, but most of the time, it needs to be done in conjunction with counseling.

Technology setup/implementation...sharing resources between providers, etc

Literacy, health literacy, access to technology/internet to use this

Time/money to implement. How to get feedback from patients on their interactions to make sure information is understood.

I want to know the inner workings of the chatbot before deploying it with patients. Since most chatbot code is proprietary and likely not available for me as the provider to review the logic, it makes me worried about potential incorrect responses.

The initial processing of building the programing needed is a big barrier, as is the work it would take to implement the chatbot. I think the limited psychosocial support that chatbots can give is also an overall barrier or reservation I have when thinking about offering a chatbot to patients.

Identifying the resources to create, implement, and update chatbot

hospital regulations and paying for the chatbot

ability for the chatbot to discern what the patient is asking -security of the chatbot, especially if it has access to patient information

How it would be funded, who would set it up, how would it be offered to patients, how would providers AND patients be educated on how to use it,

introduction of the technology into our clinic.

Computer literacy of many patients

In my use of chatbots personally, they have not been able to meet my personal specific needs or specific questions that I had. I always needed to talk to a customer service rep. etc. I am concerned that the chatbots will not be enough to answer the patient's questions that they have and just might not be that useful.

Language options, type of content, quality of content

I don't see patients, but I work in a community that includes a large of rural and underserved individuals that may not have access to internet speeds that would be needed for a chatbot.

Cost

Generally I think the access barrier (to a chatbot period, to a chatbot in other languages, etc.) is the biggest one I foresee in practice. Personally, my biggest hesitation is in utilizing chatbots on the back end for results disclosure. Even in the scenarios above, there are so many caveats and implications that I would want to be sure a patient understood that I would not feel comfortable relying solely on a chatbot.

technology to set up / manage

Establishing rapport with patients, providing quality medical care

Billing for the service. Finding a way to streamline services to best utilize the chatbot (which role should the chatbot fill vs GC vs GCA).   Also, great research question! Good luck with your project :-)

APPENDIX D: Chi-square tables for non-significant univariate analyses

How interested are you in offering a chatbot to your patients?

		Not at all	Slightly	Moderately-Completely	Total	p-value (Chi-square)	p-value (Fisher's Exact)
What is your age?	20-29	23	58	45	126		
	30-39	11	27	16	54		
	40+	3	9	9	21		
Total		37	94	70	201		0.865
Are you a genetic counselor or a genetic counseling student?	Genetic Counselor	19	48	34	101		
	Genetic Counseling Student	18	46	37	101		
Total		37	94	71	202	0.906	
How many years have you been practicing in your current, PRIMARY specialty?	<1 year	2	7	7	16		
	1-4 years	12	21	15	48		
	5-9 years	4	11	7	22		
	10+ years	1	9	5	15		
Total		19	48	34	101		0.758
What type of support staff do you currently have?	Administrative/support staff only	7	14	6	27		
	Genetic Counseling Assistants only	1	2	2	5		
	Administrative/support staff and Genetic Counseling Assistants	0	6	6	12		
	Administrative/support staff and Genetic Counseling Students	3	7	3	13		
	Administrative/support staff and Nurses	1	6	1	8		
	Genetic Counseling Assistants and Students	0	1	1	2		
	Administrative/support staff and Nurses and Genetic Counseling Students	0	4	0	4		
	Administrative/support staff and Nurses and Genetic Counseling Assistants	2	2	1	5		

	Administrative/support staff and Genetic Counseling Assistants and Volunteers	1	0	1	2	
	Administrative/support staff and Volunteers and Genetic Counseling Students	0	2	0	2	
	Administrative/support staff and Genetic Counseling Assistants and Students	0	0	2	2	
	Administrative/support staff and Nurses and Genetic Counseling Assistants and Students	1	0	1	2	
	Administrative/support staff and Nurses and Volunteers and Genetic Counseling Students	0	0	1	1	
	Administrative/support staff and Genetic Counseling Assistants and Students and Volunteers	0	1	0	1	
	All of the above	1	0	0	1	
Total		17	45	25	87	0.208
Who calls out POSITIVE/ABNORMAL testing results in your current place of work?	Myself only	5	17	13	35	
	Other genetic counselors in my office only	0	0	4	4	
	Myself and other genetic counselors in my office	8	21	10	39	
	Myself and administrative/support staff	0	1	0	1	
	Myself and other genetic counselors in my office and others	2	2	2	6	
	Does not apply	4	7	5	16	
Total		19	48	34	101	0.341
Who calls out NEGATIVE/NORMAL testing results in your current place of work?	Myself only	5	14	13	32	
	Other genetic counselors in my office only	0	2	2	4	

	Administrative/support staff only	0	1	0	1		
	Other only	0	1	0	1		
	Myself and other genetic counselors in my office	7	16	8	31		
	Myself and administrative/support staff	0	2	0	2		
	Myself and other	1	2	0	3		
	Other genetic counselors in my office and administrative/support staff	0	0	1	1		
	Myself and other genetic counselors in my office and administrative/support staff	1	3	0	4		
	Myself and other genetic counselors in my office and others	1	1	3	5		
	Does not apply	4	6	7	17		
Total		19	48	34	101		0.773
Do you use alternative counseling methods?	No	10	21	18	49		
	Yes	9	27	16	52		
Total		19	48	34	101	0.66	
Which of the following alternative counseling methods have you used?	Telemedicine/Telegenetics (including web-based video) only	4	20	10	34		
	Chatbots only	0	0	1	1		
	Telemedicine/Telegenetics (including web-based video) and Group Counseling	1	4	2	7		
	Telemedicine/Telegenetics (including web-based video) and Web-Based Portal	4	3	3	10		
Total		9	27	16	52	0.284	
Have you ever used a chatbot yourself?	No	8	9	8	25		
	Yes	29	85	63	177		
Total		37	94	71	202		0.179
When was the last time you used a chatbot?	Today	6	13	6	25		

	Within the past week	6	20	21	47	
	Within the past month	8	24	19	51	
	Within the past 6 months	6	17	13	36	
	Within the past year	2	10	3	15	
	Over a year ago	1	1	1	3	
Total		29	85	63	177	0.723
How often would you say you use chatbots?	Daily	6	13	10	29	
	Weekly	3	15	11	29	
	Monthly	8	15	21	44	
	Every other month	3	26	9	38	
	Yearly	9	16	12	37	
Total		29	85	63	177	0.116
Where do you most often encounter chatbots?	Phone (Siri, Google Assistant) only	1	7	4	12	
	Personal/Home Device (Amazon Alexa, Google Assistant) only	0	2	2	4	
	Phone app (Facebook Messenger, personal banking, retail store) only	1	8	2	11	
	Internet browser on a personal computer, tablet, or phone only	9	17	15	41	
	Other	1	0	0	1	
	Phone and Personal/Home Device	9	10	3	22	
	Phone and Phone app	0	2	2	4	
	Phone and Internet browser	2	12	4	18	
	Personal/Home Device and Phone app	0	0	1	1	
	Personal/Home Device and Internet Browser	0	2	2	4	
	Phone app and Internet browser	1	6	5	12	
	Phone and Personal/Home Device and Phone app	0	5	4	9	
	Phone and Personal/Home Device and Internet browser	2	7	4	13	
	Phone and Phone app and Internet Browser	2	4	7	13	
	Personal/Home Device and Phone app and Internet browser	0	0	4	4	

	Phone and Personal/Home Device and Phone app and Internet browser	1	3	4	8	
Total		29	85	63	177	0.248
Where do you think you would be most likely to encounter a chatbot?	Phone (Siri, Google Assistant) only	3	0	0	3	
	Internet browser on a personal computer, tablet, or phone only	1	2	1	4	
	Phone and Personal/Home Device	0	1	0	1	
	Phone and Phone app	0	2	0	2	
	Phone and Internet browser	1	2	2	5	
	Personal/Home Device and Internet browser	0	1	0	1	
	Phone and Personal/Home Device and Phone app	0	0	1	1	
	Phone and Phone app and Internet browser	1	1	1	2	
	Personal/Home Device and Phone app and Internet	0	0	2	2	
	Phone and Personal/Home Device and Phone app and Internet	2	0	1	3	
Total		8	9	8	25	0.35

		Genetic Counselor	Genetic Counseling Student	Total	p-value (Chi-square)	p-value (Fisher's Exact)
Have you ever used a chatbot yourself?	No	12	15	27		
	Yes	96	89	185		
Total		108	104	212	0.47	
When was the last time you used a chatbot?	Today	10	16	26		
	Within the past week	29	19	48		
	Within the past month	30	22	52		
	Within the past 6 months	19	18	37		
	Within the past year	6	13	19		
	Over a year ago	2	1	3		
Total		96	89	185		0.182
How often would you say you use chatbots?	Daily	14	15	29		
	Weekly	19	13	32		
	Monthly	25	19	44		
	Every other month	21	20	41		
	Yearly	17	22	39		
Total		96	89	185	0.666	
Would you consider using a chatbot for your personal health?	No	37	38	75		
	Yes	71	66	137		
Total		108	104	212	0.729	
How likely would you be to offer a chatbot that only allows predetermined response choices?	Not at all	16	17	33		
	Slightly	34	38	72		
	Moderately	36	30	66		
	Very	15	16	31		
	Completely	6	1	7		
Total		107	102	209		0.39
How likely would you be to offer a chatbot that only allows open text response choices?	Not at all	15	16	31		
	Slightly	48	41	89		
	Moderately	36	37	73		

128

	Very	6	6	12		
	Completely	1	2	3		
Total		106	102	208		0.94
How likely would you be to offer a chatbot that allows both predetermined and open text response choices?	Not at all	11	7	18		
	Slightly	29	24	53		
	Moderately	33	38	71		
	Very	30	27	57		
	Completely	4	7	11		
Total		107	103	210	0.624	
If you were to offer a chatbot, when would you like it to be available to your patients?	After their appointment for only one week	1	3	4		
	After their appointment for only one month	5	9	14		
	After appointment indefinitely	8	12	20		
	Before their appointment for only one week	10	13	23		
	Before their appointment for only one month	5	2	7		
	Any time before their appointment, but not after their appointment	13	11	24		
	Both before and after their appointment indefinitely	61	52	113		
Total		103	102	205		0.512
If there is a cost for giving your patients access to the chatbot, how do you think it should be managed?	The chatbot should be offered free of charge	92	84	176		
	The patient's insurance should be billed	7	16	23		
	The patient should pay out of pocket	2	1	3		
	Other	5	2	7		
Total		106	103	209		0.112

What features would you like to see in a chatbot for genetic counseling patients?

		General information only	General and patient specific information	Total	p-value (Chi-square)	p-value (Fisher's Exact)
What is your age?	20-29	29	96	125		
	30-39	13	40	53		
	40+	4	17	21		
Total		46	153	199		0.906
Are you a genetic counselor or a genetic counseling student?	Genetic Counselor	24	77	101		
	Genetic Counseling Student	22	77	99		
Total		46	154	200	0.796	
What is your current, primary specialty?	Cancer	9	25	34		
	Pediatrics	3	5	8		
	Prenatal	2	14	16		
	Adult	2	1	3		
	General Genetics	5	7	12		
	Laboratory/Non-Patient Facing	3	24	27		
Total		24	76	100		0.07
How many years have you been practicing in your current, PRIMARY specialty?	<1 year	5	12	17		
	1-4 years	11	37	48		
	5-9 years	6	16	22		
	10+ years	2	12	14		
Total		24	77	101		0.763
On average, how many patients do you see per week?	0	3	20	23		
	1-10	13	29	42		
	11-20+	8	28	36		
Total		24	77	101	0.259	
Do you use alternative counseling methods?	No	11	42	53		
	Yes	13	35	48		

		24	77	101	0.456
Total					

What type of support staff do you currently have?	Administrative/support staff only	7	21	28
	Genetic Counseling Assistants only	1	5	6
	Administrative/support staff and Genetic Counseling Assistants	5	8	13
	Administrative/support staff and Genetic Counseling Students	5	7	12
	Administrative/support staff and Nurses	0	8	8
	Genetic Counseling Assistants and Students	0	2	2
	Administrative/support staff and Nurses and Genetic Counseling Students	1	4	5
	Administrative/support staff and Nurses and Genetic Counseling Assistants	1	3	4
	Administrative/support staff and Genetic Counseling Assistants and Volunteers	0	2	2
	Administrative/support staff and Volunteers and Genetic Counseling Students	1	1	2
	Administrative/support staff and Genetic Counseling Assistants and Students	0	2	2
	Administrative/support staff and Nurses and Genetic Counseling Assistants and Students	0	1	1
	Administrative/support staff and Nurses and Volunteers and Genetic Counseling Students	0	1	1

	Administrative/support staff and Genetic Counseling Assistants and Students and Volunteers	1	0	1	
	All of the above	1	0	1	
Total		23	65	88	0.415
Who calls out POSITIVE/ABNORMAL testing results in your current place of work?	Myself only	8	27	35	
	Other genetic counselors in my office only	0	3	3	
	Myself and other genetic counselors in my office	12	24	36	
	Myself and administrative/support staff	0	1	1	
	Myself and other genetic counselors in my office and others	1	5	6	
	Does not apply	3	17	20	
Total		24	77	101	0.663
Who calls out NEGATIVE/NORMAL testing results in your current place of work?	Myself only	7	24	31	
	Other genetic counselors in my office only	1	2	3	
	Administrative/support staff only	0	2	2	
	Other only	1	0	1	
	Myself and other genetic counselors in my office	9	20	29	
	Myself and administrative/support staff	1	1	2	
	Myself and other	0	3	3	
	Other genetic counselors in my office and administrative/support staff	0	1	1	
	Myself and other genetic counselors in my office and administrative/support staff	1	2	3	

	Myself and other genetic counselors in my office and others	1	4	5	
	Does not apply	3	18	21	
Total		24	77	101	0.596
Which of the following alternative counseling methods have you used?	Telemedicine/Telegenetics (including web-based video) only	10	23	33	
	Chatbots only	0	1	1	
	Telemedicine/Telegenetics (including web-based video) and Group Counseling	2	4	6	
	Telemedicine/Telegenetics (including web-based video) and Web-Based Portal	1	7	8	
Total		13	35	48	0.708
When was the last time you used a chatbot?	Today	2	22	24	
	Within the past week	9	38	47	
	Within the past month	11	39	50	
	Within the past 6 months	9	26	35	
	Within the past year	5	12	17	
	Over a year ago	0	3	3	
Total		36	140	176	0.506
How often would you say you use chatbots?	Daily	3	24	27	
	Weekly	6	25	31	
	Monthly	6	37	43	
	Every other month	12	28	40	
	Yearly	9	25	35	
Total		36	140	176	0.247
Are you familiar with any of the following chatbots that have been developed for use in genetic counseling?	No	25	67	88	
	Yes	25	87	112	
Total		46	154	200	0.797

APPENDIX E: Genetic Counseling specialty re-coded responses

What is your current, PRIMARY specialty?

Free text response	Re-coded response
Ophthalmology	General Genetics
0.5 FTE is research. 0.5 FTE is clinical and is split between pediatric and adult.	General Genetics
Education	Laboratory/Non-Patient Facing
Product management	Laboratory/Non-Patient Facing
Neurology	General Genetics
Metabolic	General Genetics
Insurance	Laboratory/Non-Patient Facing
Inpatient	General Genetics
Research	Laboratory/Non-Patient Facing
Education	Laboratory/Non-Patient Facing
Biochemical/Metabolic	General Genetics
ART/Infertility/PGT	Prenatal
Education	Laboratory/Non-Patient Facing
Cardiology	General Genetics
Public Health	Laboratory/Non-Patient Facing
Genomic medicine	Laboratory/Non-Patient Facing
education	Laboratory/Non-Patient Facing
Adult Cardiology	Adult
Research/Immunology	Laboratory/Non-Patient Facing
Population genomics and screening	General Genetics
Precision Medicine	General Genetics