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RESEARCH ARTICLE

The Acceptance of Culturally Adapted Signing Avatars Among Deaf and Hard-of-Hearing Individuals

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This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Ethical Committee of Mada Qatar Assistive Technology Center.

ABSTRACT Deaf and Hard of Hearing (DHH) individuals often encounter significant challenges in communication and accessing digital content, with Sign Language as their primary mode of communication. Traditional Sign Language interpretation services and existing accessibility measures may not always be readily available or effective. This study explores the acceptance of signing avatars, specifically the culturally adapted BuHamad avatar, among DHH individuals in Qatar. Semi-structured interviews with 40 DHH participants, representing 10% of the deaf population in Qatar, were conducted using the Technology Acceptance Model (TAM). Factors such as perceived usefulness, ease of use, attitude, and behavioral intention to use the BuHamad avatar were examined through descriptive statistics and thematic analysis of qualitative data. Findings reveal that while participants generally hold positive attitudes towards the signing avatar and its potential to enhance accessibility, they do not view it as a substitute for human interpreters. Key usability issues, including avatar movement and appearance, were identified. This study introduces the Technology Acceptance Model of Signing Avatars (TAMSA) and provides insights into factors influencing the acceptance of signing avatars in Qatar. These insights can guide developers and designers in creating more effective and user-friendly avatars for the DHH community in Qatar and the broader Gulf region.

INDEX TERMS Avatars, sign language, technology acceptance model.

I. INTRODUCTION

Hearing impairment is one of the most prevalent chronic disabilities worldwide. According to the Global Burden of Disease Study, an estimated 1.57 billion individuals identified as Deaf or Hard of Hearing (DHH) in 2019, accounting for 20.3% of the global population [1]. By 2050, this number is projected to exceed 2.5 billion.

This paper focuses on DHH individuals, particularly those within the Deaf community, who primarily communicate using Sign Language in social, educational, and professional contexts [2]. There are over 300 different sign languages globally, each serving not only as a means of communication but also as a representation of cultural and linguistic identity for the Deaf community [3], [4].

Traditional Sign Language interpretation services and current accessibility measures often fall short in meeting the needs of DHH individuals, particularly in non-Western countries. Signing avatars have emerged as a potential solution to enhance accessibility and the utilization of Sign Language in digital content. However, the acceptance of these technologies among DHH individuals, especially in culturally distinct regions like Qatar, remains underexplored.

This study aims to investigate the attitudes and perceptions of DHH individuals toward a culturally adapted signing avatar technology, named BuHamad, in Qatar. Using the

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Technology Acceptance Model (TAM), this research examines factors such as perceived usefulness, ease of use, attitude, and behavioral intention. The findings provide insights into the acceptance of signing avatars and propose a conceptual model, the Technology Acceptance Model of Signing Avatars (TAMSA), to guide future developments in this field.

II. BACKGROUND

A. LINGUISTIC AND CULTURAL DIVERSITY LENS

DHH people whose first or preferred language is Sign Language often regard themselves as a linguistic and cultural minority because they do not have full access to the same linguistic resources as hearing people [5]. They believe that if more people learned sign language, they would not be viewed as disabled. From this perspective, Deaf communities assert their linguistic and cultural identity through the recognition and inclusion of sign languages as mother tongues and minority languages in national laws and policies [6]. The active participation of the World Federation of the Deaf throughout the drafting process of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) resulted in the Convention becoming the inaugural global human rights agreement to explicitly recognize sign languages as an independent entity and give it equal status as spoken languages: 'Language' includes spoken and signed languages and other forms of non-spoken languages'' (Article 2). The convention also acknowledges the specific cultural and linguistic identity of DHH people, ''including sign languages and Deaf culture'' (Article 30.4). In recent years, more and more sign languages have been officially recognized in many United Nations Member States [7]. The government of Qatar formally recognized sign language in 2001 [8]. In 2005, the first institution, The Qatari Center of Social Culture for the Deaf (QCSCD), was established to support the welfare of the Deaf community. The Qatari Supreme Council for Family Affairs proposed the Qatari Unified Sign Language to unify the deaf sign languages of Qatar. The council's description suggests that sign language in Qatar may belong to the Arab Sign Language family. The creation of the Qatar Sign Language aims to unite the Qatari deaf community with the rest of the Middle East by creating a common language. Among other significant efforts to promote the recognition and access to sign language, Mada Qatar Assistive Technology Center launched the research project ''*JUMLA Sign Language*'' in December 2019. This project aims to support researchers and developers in creating innovative tools for DHH, including the first large-scale and annotated Qatari sign language dataset for continuous sign language processing [9].

B. ACCESSIBILITY AND REASONABLE ACCOMMODATION

As we explained above, hearing loss is often viewed as a cultural difference by the Deaf Community [10]. The Deaf Community advocates refraining from defining individuals with hearing loss as disabled or impaired [11]. However, they still strive to recognize sign language as an accessibility accommodation legally. Consequently, in many countries where sign language is recognized as a language, accessibility policies and acts list sign language as an accommodation. Examples include the Americans with Disabilities Act (ADA) and the Accessible Canada Act. Additionally, article 9 of the UNCRPD about accessibility mandates providing various forms of live assistance and intermediaries, such as guides, readers, and professional sign language interpreters, to ensure that DHH individuals have equal access to information and services. However, most web accessibility policies do not involve sign language.

The accessibility needs of DHH individuals have not been adequately addressed by the World Wide Web Consortium (W3C) in the Web Content Accessibility Guidelines (WCAG). In their book ''A Concrete Example of Inclusive Design: Deaf-Oriented Accessibility,'' Bianchini, Borgia, and De Marsico critique the WCAG for falling short in providing accessibility for DHH individuals [4]. The WCAG 1.0 guidelines, established in 1999, primarily focus on the labeling and transcribing audio content but fail to consider alternative methods like sign language. The more recent version of the guidelines, including WCAG 2.0, 2.1, and 2.2, requires websites to have clear, readable, and straightforward website text with subtitles in videos. In the updated guidelines encompassing WCAG 2.0, 2.1, and 2.2, there is a mandate for websites to ensure text is clear, readable, and straightforward, and for videos to be accompanied by subtitles. It is noteworthy that sign language translation is addressed within the WCAG standards, but only as a Level AAA requirement, as detailed in the Understanding 1.2.6 Sign Language provision. Conversely, the provision of textual alternatives for audio content is not merely a recommendation but a compulsory requirement at the basic Level A, underscoring its importance for accessibility. This requirement is preferred but not mandatory, and it only specifies that Sign language interpretation should be provided for all prerecorded audio content in synchronized media.

Sign language is becoming more widely used in mainstream society as a recognized language or an accessibility accommodation for DHH individuals. However, DHH individuals face many barriers, such as reduced exposure to new information, difficulty participating in social networks, and challenges using information and communication technology. These barriers hinder their access to education, employment, and healthcare, and they need fast and affordable translation services to access mainstream services that are readily available to hearing individuals.

C. SIGN LANGUAGE IN THE DIGITAL ERA

For DHH individuals, the Internet and digital content empowered DHH individuals and gave them ''more capability and therefore agency to function independently in hearing society, precisely because it allows them to access everyday goods and services in the hearing world without the necessity to have face-to-face contact with hearing people in off-line space where they encounter marginalization and

discrimination [12]. For instance, social media platforms that primarily rely on written communication are less stigmatizing for DHH individuals as they often disguise their hearing loss [13]. In addition to empowering DHH individuals and increasing access to information and services, Valentine and Skelton found that the internet has revolutionized how DHH people perceive and participate in community life [14]. It has enabled more fluid and flexible forms of communities to emerge online. These online communities are less rigidly policed in behavior and identification compared to traditional Deaf community gatherings, such as Deaf clubs. Moreover, the internet allows for the establishment of specialist support groups with different temporal and spatial registers, which can extend beyond online space. Lastly, the internet also facilitates the emergence of new Deaf spatiality through offline practices.

Although DHH individuals use the internet at similar rates as those who do not (e.g. [15], [16]), recent studies suggest that there is a digital divide between DHH and hearing people [17]. Although more websites are applying WCAG guidelines, they often overlook the linguistic needs and preferences of DHH users by focusing on providing subtitles and translations for videos [18]. According to Ang et al., DHH signers face obstacles on social media platforms that hinder their ability to communicate visually in a timely manner [19]. For instance, written solutions, such as subtitles, are insufficient to address the specific problems and needs of DHH individuals [20]. Some DHH individuals may not have the language skills necessary to comprehend text, and alternative text and captioning may not meet their needs (Ibid). For instance, amidst the COVID-19 pandemic, e-learning played a vital role in school education. DHH students mostly experienced either positive or negative outcomes, as determined by their ability to utilize accessibility features of digital media, such as reading captions [21]. For DHH people who communicate mainly through sign language, it can be difficult to understand text written in a language they consider their second language. For example, Qatari citizens who are DHH have Qatari Sign Language as their native language, while Arabic (spoken) is their second language. Kipp et al. explain that learning a spoken language solely based on written symbols and ambiguous mouth patterns is almost impossible for DHH individuals, which often results in significant difficulties in reading and writing [22]. Despite this fact, DHH individuals often feel pressured to communicate through written text, even if they are not proficient in writing [23]. While uploading videos in sign language is possible, it is often difficult due to poor internet connection, high battery consumption, or limited data volume [24]. Additionally, creating sign language videos for social media can be challenging as the individual must position their smartphone in a way that fully captures their signing, and they may even have to sign while holding the phone, making sign language communication on social media even more complex [25]. This difficulty in accessing digital content may contribute to feelings of social isolation and loneliness among DHH individuals and stigmatization [26]. Furthermore, the absence of sign language translation on the internet could lead to an unfair society that privileges those who can hear (and access written digital content) [27]. In doing so, the Internet is contributing to the maintenance and normalization of hearing hegemony without the necessity of hearing people having to make any accommodations for DHH people, thus leaving the discrimination DHH people encounter unchallenged.

Expanding the translation of digital content into sign languages would significantly enhance accessibility for DHH [28]. This would result in a more authentic and fair experience for this community, as they could have equal access to information in a natural and comfortable medium. By providing translations in sign language, we can take a significant step towards creating an inclusive and accessible digital environment for all [29]. In this context, signing avatars have been proposed as a technology to translate more materials into Sign Language and increase DHH people's access to a wider range of information while enabling them to communicate with hearing people [30].

D. SIGNING AVATAR TECHNOLOGY: A SOLUTION TO EASE COMMUNICATION IN SIGN LANGUAGE

Virtual human avatars or sign language avatars or signing avatars is an embodied conversational technology involving 3D representation of a human-like character that signs content from written text in any sign language or international sign. Sign language avatars are considered to be a technologically advanced solution to address the issue of access to content in sign language [30], particularly in the field of Sign Language Machine Translation (SLMT) [31]. Avatars have proven to be a more flexible and interactive technology that is both timelier and more available compared to 2D video recordings of signers [32]. Avatars simplify the process of editing sign language content and can be customized to meet the specific needs of their users [33]. This includes adjusting the speed of sign language streams, altering viewpoints, and modifying the agent's appearance. The high degree of configurability of avatar' makes them suitable for use in various applications, such as functioning as bilingual dictionaries and as translators between specific sign languages and oral languages. Additionally, they can be used for recreation and learning purposes [34], [35].

In recent years, there has been a growing interest in Sign Language avatars among researchers and developers [30]. Various organizations, including government representatives and corporations, are also promoting technology as a solution to make their services, applications, and products more accessible simultaneously [17]. Recent statements from national and international deaf associations, such as the World Federation of the Deaf, indicate that the excitement about signing avatars, as shown by developers and governmental and private organizations, is not reflected within the Deaf

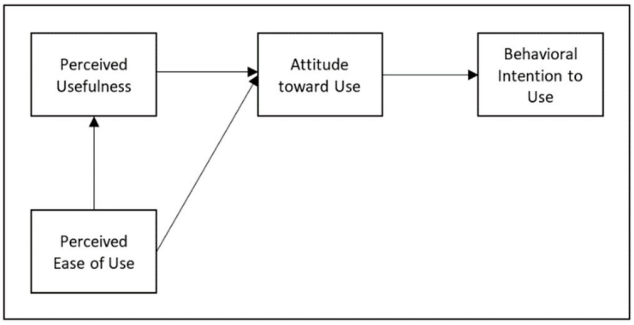

FIGURE 1. Technology acceptance model (TAM) (Davis, 1989).

communities [36]. The Deaf community has been largely critical of avatar systems and their inadequate performance. This critique highlights two issues with the development of sign language technology [37]. Firstly, the developers tend to underestimate the complexity of sign languages, resulting in solutions that are perceived as poor quality (ibid.). Secondly, there is a significant lack of involvement of Deaf communities in the development of these technologies (ibid.). In 2018, the World Federation of the Deaf issued a statement expressing their concerns regarding using avatars in situations where essential and complex information is being delivered live, especially in scenarios that significantly impact the lives of deaf citizens [38]. This includes news broadcasts, public emergency announcements, and political announcements (Ibid).

When introducing a new technology or system, including the signing avatar technology, it is crucial to assess its acceptance. Responsible development and innovation require a thorough examination of the acceptability of any new solution [39]. Failure to do so can result in creating technologies that do not meet the needs and values of individuals, which may not be adopted or abandoned.

E. ACCEPTANCE OF SIGNING AVATAR TECHNOLOGY BY DHH PEOPLE

The technology field, particularly in terms of user acceptance and perspectives, is a highly productive area of research. This area primarily focuses on the Technology Acceptance Model (TAM), considered the main framework for acceptance research. In 1985, Davis proposed the TAM to explain technology acceptance behavior by new users in an organizational context [40]. With this purpose in mind, Fan et al. investigated which variables and constructs influence technology behavior and how user motivation could be measured [41].

As a result, it postulated that user motivation involves three primary constructs: Perceived usefulness (PEU) and Perceived ease of use (EOU), representing cognitive responses, and Attitude toward Technology (ATT), representing affective responses (Figure 1). Technology design features are considered external variables that influence PEU and EOU. Also, in TAM (Ibid), EOU influences PEU; PEU and EOU influence ATT; PEU and ATT directly influence Behavioral intention to use (BI); and BI controls Actual system use. Behavioural intention (BI) is not a construct in the model but a desired outcome.

We conducted a scoping review on how TAM was used in previous studies engaging DHH people. Our search yielded 5 studies presented in Table 1.

Prietch et al. conducted a study on a Speech-to-Text system in Brazil with 11 DHH participants [42]. They used a combination of the TAM and the Unified Theory of Acceptance and Use of Technology (UTAUT) to investigate the impact of various factors on the use of the system. The factors included written communication, educational barriers, technology use, the habit of using captions and subtitles, emotions, technology acceptance, social influence, empowerment, and privacy. Despite facing challenges in understanding written language, the research found that the participants were willing to adopt the Speech-to-Text system.

Prietch and Filgueiras proposed the TAM4IE model by adapting the TAM. TAM4IE considers several variables: subjective perception, perceived usability, perceived usefulness, future expectations, and facilitating conditions [43]. They applied the TAM4IE model to evaluate a mobile application that allows hearing and DHH individuals to communicate using an automatic recognition system. The study concluded that the model comprehensively covers both users' personal motivation and context of use aspects, providing valuable insights for improving communication technologies for the DHH community.

Husainan et al. conducted a study using the TAM model to investigate the factors influencing the motivations, perceptions, and adoption of YouTube among DHH individuals in Saudi Arabia [44]. The study focused on key variables such as perceived ease of use, perceived usefulness, attitude, and behavioral intention. The research revealed that despite YouTube's useful functionalities, the participants were not motivated enough to watch videos on YouTube because the platform is fast-paced, and they preferred more time to read and understand the content.

Shahin and Watfa conducted a study on Amazon's Alexa in the United Arab Emirates, specifically on the Tap-to-Alexa accessibility option [45]. The study had 70 DHH participants and used a modified TAM to measure various factors such as educational background, technical skills, technology awareness, device ownership, ease of learning, input complexity, perceived usefulness, perceived ease of use, input ease of use, input perception, motivation, input method, reason for use, intention of use, experience, need for technical support, input system performance, confidence while using the input method, and integration.

Alias and Yusof evaluated hearing Assistive Technology using the original TAM model [46]. The model measured perceived ease of use, perceived usefulness, attitude, and intention to use. The technology translates Sign Language into textual and audio forms. The study found that the responses to the technology were positive, and it was deemed acceptable.

TABLE 1. Technology acceptance studies with DHH people.

Reference	Location	Technology	Participants	TAM used Model	Variables	Gaps
[42]	Brazil	Speech-To-Text system	11 DHH participants	Combination of TAM and UTAUT	Written communication, educational barriers, technology use, habit of using captions and subtitles, emotions, technology acceptance, social influence, empowerment, and privacy	Limited focus on sign language technology and cultural adaptation
[43]	Brazil	Mobile application (SESSAI) that facilitates communication between hearing persons and DHH individuals via an automatic recognition system	16 DHH participants	TAM4IE (proposed)	Subjective perception, perceived usability, perceived usefulness, future expectations, and facilitating conditions.	
[44]	Saudi Arabia	YouTube	8 DHH female participants	TAM	Perceived ease of use, perceived usefulness, attitude, behavioral intention	Did not address sign language avatars or cultural adaptations
[45]	United Arab Emirates	Amazon's Alexa (Tap-to-Alexa accessibility option)	70 DHH participants	Modified TAM	Educational background, awareness, technical skills, technology awareness, device ownership, ease of learning, input complexity, perceived usefulness, perceived ease of use, input ease of use, input perception, motivation, input method, reason for use, intention of use, experience, need for technical support, input system performance, confidence while using the input method, integration.	
[46]	Malaysia	Hearing Assistive Technology: Sign Language translation application for hearing-impaired communication	30 DHH participants	TAM	Perceived ease of use, perceived usefulness, attitude, intention to use	Limited focus on culturally adapted sign language technology

The findings from our review indicate some limitations in applying the TAM to study DHH individuals' acceptance of technology. First, despite its popularity, there is a lack of studies using the TAM to examine the acceptance of Signing Language avatar technology among DHH individuals.

The application of TAM in this area could provide a comprehensive understanding of the factors that influence the acceptance and adoption of this technology. Second, one of the main criticisms of previous studies applying TAM, in general, is the overuse of quantitative research methods [47]. These methods may not be suitable for comprehensively analyzing complex relationships, like the interaction between DHH people and Signing avatar technology. Finally, it is essential to note that traditional TAM research has another limitation: it only focuses on explaining technology acceptance. In addition, Vogelsang et al. suggest that developing recommendations to increase acceptance would significantly enhance scientific work's relevance and practical implications [47].

In this study, we aim to gain insights into the perceptions, attitudes, and experiences of individuals who are deaf or hard of hearing (DHH) towards avatar signing technology. Our goal is to identify potential barriers and facilitators to its use, which could ultimately lead to developing more accessible

and user-friendly avatar signing technology for the DHH community. We propose a conceptual model that outlines how the acceptance of signing avatar technology among the DHH community in Qatar is shaped by different factors relevant to this population.

III. LIMITS AND CONTRIBUTION

Existing literature has primarily focused on Western contexts, with limited research on the acceptance of signing avatars in non-Western regions such as the Middle East. Moreover, many studies have utilized quantitative methods, often overlooking the nuanced interactions between DHH individuals and signing avatar technology.

Our study addresses these gaps by exploring the acceptance of a culturally adapted signing avatar, BuHamad, among DHH individuals in Qatar. We employ a mixed-methods approach, combining descriptive statistics with thematic analysis of qualitative data, to provide a comprehensive understanding of the factors influencing acceptance. By introducing the Technology Acceptance Model of Signing Avatars (TAMSA), we offer a framework tailored to the specific cultural and technological context of Qatar, contributing to the broader discourse on accessibility and technology acceptance in diverse cultural settings.

This study contributes to the understanding of DHH individuals' acceptance of signing avatars in Qatar, providing insights that can inform the design and development of more effective and user-friendly avatars. Our findings highlight the importance of cultural adaptation and user involvement in technology development, offering practical recommendations for developers and policymakers.

IV. METHODOLOGY

The study employed a mixed-methods approach, integrating qualitative and quantitative data to provide a comprehensive understanding of the acceptance of signing avatars among DHH individuals in Qatar.

Quantitative Component: descriptive statistics were used to analyze demographic information, technology usage patterns, and participants' attitudes toward signing avatars. This provided a broad overview of the sample characteristics and general trends in the data.

Qualitative Component: semi-structured interviews were conducted with 40 DHH participants to gather in-depth qualitative insights. Thematic analysis was performed on the interview transcripts to identify key themes and sub-themes related to perceived usefulness, ease of use, attitudes, and behavioral intentions toward signing avatars.

Integration of Methodologies: the quantitative data helped to contextualize the qualitative findings by highlighting general patterns and trends within the sample. For instance, descriptive statistics provided a snapshot of participants' technology usage and attitudes, which were then explored in greater depth through thematic analysis. The qualitative insights enriched the quantitative findings by providing detailed narratives and explanations behind the observed trends. This complementary use of methodologies allowed for a more nuanced understanding of the factors influencing the acceptance of signing avatars, thereby strengthening the validity of the conclusions.

FIGURE 2. The signing avatar is "BuHamad."

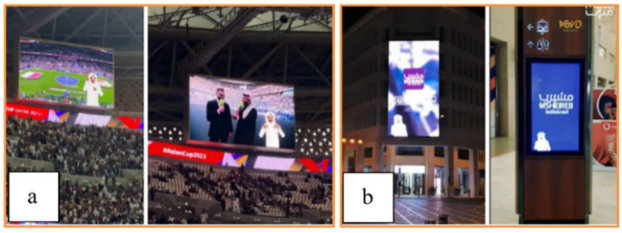

FIGURE 3. Practical deployment of avatar technology for sign language translation of audio announcements (a) within Stadiums at the AFC Asian Cup 2023; (b) across Urban Streets and Shopping Centers.

A. BuHamad: THE CULTURALLY ADAPTED AVATAR

Scholarly research underscores that technology-based interventions tailored to one cultural context may not garner acceptance within another cultural milieu [48]. Initial efforts have been dedicated to developing avatars that encapsulate specific cultural identities. Empirical studies, including numerous focus groups with members of the Qatari Deaf and Hard of Hearing (DHH) community, suggest that for an avatar to be effective, it must exhibit a high degree of realism, including naturalistic movements and authentic facial expressions [49].

The avatar has been designed to reflect Qatari cultural norms, donning traditional Qatari attire, namely the "Gutra" (headscarf) and "Thobe" (long robe) (Figure 2). This technology has found application in various public domains, including its deployment in stadiums to facilitate the translation of auditory announcements during the Asian Cup 2023 (refer to Figure 3. A), as well as its use in urban settings and shopping centers for the translation of advertisements into Qatari Sign Language (refer to Figure 3. B). Furthermore, this avatar technology has been integrated into digital platforms to enable the translation of web content into sign language (refer to Figure 4).

B. PARTICIPANTS

A total of 40 participants from the Deaf community in Qatar, who were over the age of 18 and self-identified as DHH, were recruited using firstly network sampling method, then

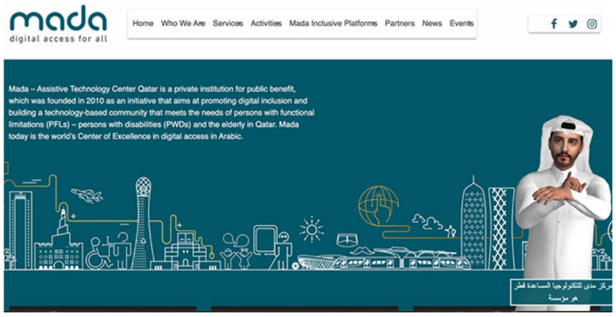

FIGURE 4. Integration of avatar technology "BuHamad" in web platforms for the translation of digital content into sign languages.

the snowball sampling methods via community organizations [50]. All applicants were compensated in exchange for their time. Table 2 displays the demographic characteristics of the 40 study participants. The population has an equal distribution of males and females. The age range of participants varies from 22 to 62 years, with an average age of approximately 34.6 years. Half of the individuals in the study are 31 or younger, with a median age of 31. The youngest 25% are below 28 years old, and the oldest 25% are 40. All participants are residents of Qatar. Table 2 shows that most participants are from Qatar (9), followed by seven from Sudan and six from Yemen. The rest of the participants are from Syria (3), Iran (4), and Palestine (3). Some countries are represented by only one or two individuals, such as Jordan and Iraq. Regarding education, 34 out of 40 participants have completed secondary education, while two have primary education, and two have not attended school. Only two participants reported having a university-level education. More than half of the participants, 22 out of 40, are employed. Of the 40 participants, 16 are not working, while only two are retired (as shown in Table 1). Thirty-six participants (90%) responded that they live with their family members. 4 participants (10%) chose not to disclose their living situation.

C. INSTRUMENT

Recruitment and data collection for general research often do not consider the unique research needs of DHH people. In many cases, DHH people are excluded because study materials and data collection tools are inaccessible, and researchers need to be trained to modify materials to include them in their study population. In our study, we drafted written materials using clear and concise wording, including outreach documents, informed consent, and interview questions. A sign language interpreter reviewed the interview questions in their textual version to ensure they were accessible to the DHH audience and the sign language interpreter who acts as the moderator. We adapted the questions and interview guide based on feedback from the interpreter. Then, we developed and embedded Qatari Sign Language videos. This allows sign and written language to be presented simultaneously (Figure 6) to accommodate DHH participants who prefer to communicate in Sign Language and

TABLE 2. Characteristics of the participants.

Characteristics		Total
Age group	18-24	5
	25-34	20
	35-44	7
	45-54	7
	55-62	1
Gender	Male	20
	female	20
Residency	Qatar	40
Country of Origin	Qatar	9
	Sudan	7
	Yemen	6
	Iran	1
	Syria	3
	Egypt	2
	Pakistan	2
	Somalia	2
	Jordan	1
	Palestine	2
	Iraq	1
Educational level	I did not go to school	2
	Primary level	2
	Secondary level	34
	University level	2
Employment status	Do not work	16
	Work	22
	Retired	2
Living Setting	With Family members	36
	Prefer not to answer	4

FIGURE 5. Sign and written language are presented simultaneously in all the interview questions (The question in the image is number 33, "Have you ever seen a virtual sign language interpreter? Yes or No).

those who communicate only in literary language or use both literary and Sign Language. The interview consisted of multiple-choice, Likert-scale, and free-response questions, all provided in both English text and QSL video. The content of the QSL videos was validated with 2 DHH participants.

D. PROCEDURE

The interviews were conducted at Mada Qatar Assistive Technology Center between January and April 2023. Each

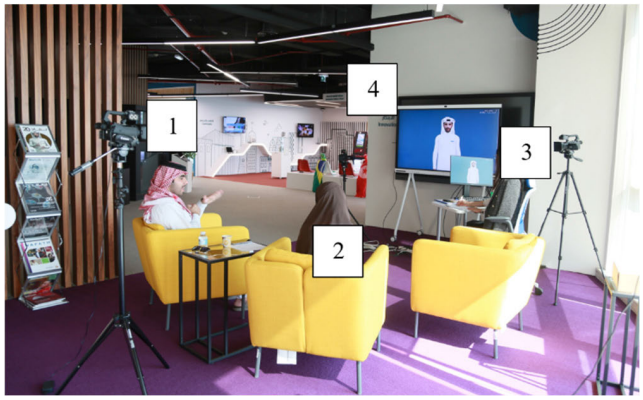

FIGURE 6. Overview of the interview's settings and setup: (1) The participant, (2) a Sign Language Interpreter, (3) a member of the research team, (4) Screen-playing questions one by one in sign language and text.

participant received orientation and support from a member of the research team and a native QSL interpreter. The person with DHH, served as interpreter who translate unclear parts for the participant during the interview. The research team member served as the moderator, starting and concluding the interview, handling any technical issues that arose and taking notes on the interview process. The moderator positioned himself in front of the activated camera and began by presenting the introductory segment. The purpose of the research is explained and confidentiality and its use solely for research purposes. of collected data. After outlining the procedure, the moderator sought the interviewee's agreement to participate before the recording began. Subsequently, a written copy of the consent form was provided to the participant, who was asked to sign after a presentation of the content using Sign Language. The moderator can also indicate the place for the signature or signature stamp.

Upon the interviewee's completion of the form and agreement, the assistant activated the camera in zoom-out mode, positioning it in front of both the interviewee and SL interpreter. The moderator assured the participants that they could replay the pre-recorded questions as often as needed, eliminating the feeling of exerting undue pressure. The assistant is responsible for providing the support requested by the interviewee. Afterward, the assistant played two pre-recorded videos concerning the BuHamad avatar. The first video is on a website, while the second is on a mobile application. Following the videos, the assistant gave a brief description of the avatars. Pre-recorded questions related to the acceptance section are presented (Figure 6).

E. ETHICAL CONSIDERATIONS

All participants taking part in the study were guaranteed confidentiality and anonymity. Signed consent forms were obtained from all participants before starting the interviews. Participants were informed of their right to withdraw from the study at any time. This was done both in written and signed versions. Additionally, to ensure the highest standards of privacy and confidentiality, all data related to the participants was anonymized. Doing so safeguarded their personal information and identities, enabling them to express their views freely and without reservation.

F. DATA ANALYSIS

Data analysis involved translating QSL signs into English, data entry in Excel and NVivo, descriptive statistics, systematic coding, and themes generation. We used descriptive statistics and thematic analysis of qualitative data to arrive at the findings presented in this paper. The thematic analysis involved a flexible, deductive, and inductive approach with three stages [51]. The first stage (deductive) involved creating a coding scheme that used pre-defined codes specified by the Technology Acceptance Model (TAM). The analysis considered participants' perceptions of three high-level TAM themes related to Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Intention of Use (IU). This approach allowed for a more comprehensive analysis of the data. During the second stage, the initial coding was reviewed. New themes beyond the proposed variables within the TAM that might influence the participants' acceptance of signing avatar technologies beyond the proposed variables were identified. In the third stage, the research team connected codes and offered an adapted version of the TAM for signing avatar technology and the DHH community in Qatar. The research team met weekly during the data analysis period (from March to September 2023) to reach a consensus among all members on the emerging themes' structure and interpretation. Findings are reported using narrative descriptions.

V. FINDINGS AND DISCUSSION

The following section presents the results of interviews conducted with 40 DHH participants who live in Qatar. The findings are presented in two sections. The first section will provide descriptive statistics and narratives related to the participants' use of technology, communication modes, and proficiency levels. The second section will present the four key themes used for analysis: Perceived Usefulness, Perceived Ease of Use, Attitude, and Behavioral Intention to Use. We have also identified sub-themes that are associated with these high-level thematic constructs.

A. PARTICIPANTS' COMMUNICATION MODES AND USE OF TECHNOLOGY

1) HEARING STATUS

Our study included a diverse group of DHH people. Out of 40 participants, 25 (62.5%) were born deaf or hard of hearing, while 15 (37.5%) developed hearing loss later in life. This indicates that a majority experienced hearing loss from birth. Among those who developed hearing loss later, 7 (46.7%) lost their hearing before age 2, 5 (33.3%) between ages 3 and 7, 2 (13.3%) between ages 8 and 12, and 1 (6.7%) was unsure of the onset. Twelve (30%) attributed their deafness to infection, while 3 (7.5%) were unsure of the cause. Seventeen (42.5%) participants require assistive technologies to hear, 12 (30%)

can hear partially, and one (2.5%) hears only high-pitched voices. Ten (25%) cannot hear at all.

2) SIGN LANGUAGE PROFICIENCY

SL proficiency levels set implications around whether the participants will utilize the signing avatar, as users must be fluent in the appropriate SL language to understand the electronically generated signing on the virtual platform. Quandt et al. found that DHH individuals who learned ASL earlier gave worse ratings to the virtual signing avatars, possibly due to movement quality issues of the computer-generated movements [52].

Most participants (37) understood Arabic Sign Language, and 24 understood English, with 14 reporting limited English proficiency. Other SLs included Qatari (4), international (4), Korean (1), German (1), and Japanese (1). Nineteen participants rated their SL skills as very good (47.5%), 15 as good (37.5%), and 6 as acceptable (15%).

3) COMMUNICATION MODES

At Home: Most participants use a combination of communication modes, with Sign Language (SL) being the most prevalent mode. Six individuals exclusively communicate via SL, thirteen participants opt for speaking, four pair SL with writing, four employ a mix between speaking, SL, and lip reading, and a further five integrate speaking, SL, with writing. When examining combinations of communication modes, 32.5% (13) of individuals state that they say and use SL at home.

At Work: Regarding work, for those who are working (22) or retired (2), different modes or combinations of communication modes are used, including Sign Language (SL), speaking, writing, lip reading, or a combination of modes. When examining combinations of communication modes, 12.5% (5) state that they say, sign, and write. Following this, 7.5% (3) use SL/signing only, 5% (2) write only, 5% (2) register and speak, 5% (2) write and use simple signs, 5% (2) write and use SL, and 5% (2) write and lip-read at work.

During the interviews, some participants mentioned using other modes of communication besides the ones already discussed. Most participants (31, 77.5%) use a combination of all the communication methods. However, a few participants used "Writing" (3, 7.5%), "Reading lips" (4, 10%), "Gesturing" (1, 2.5%), and "SL + lip reading" (1, 2.5%) as their primary communication methods.

4) LITERACY SKILLS

Reading Skills: Most participants can read Arabic. 22 (55%) reported they "can read but cannot understand" Arabic text, 15 (37.5%) can read and understand it, and 3 (7.5%) cannot read Arabic.

Writing Skills: Regarding Arabic writing proficiency, 31 participants (77.5%) can write with some mistakes, 7 (17.5%) can write without mistakes, 2 cannot write Arabic, and one understands simple words but cannot write them (as shown in Figure 7).

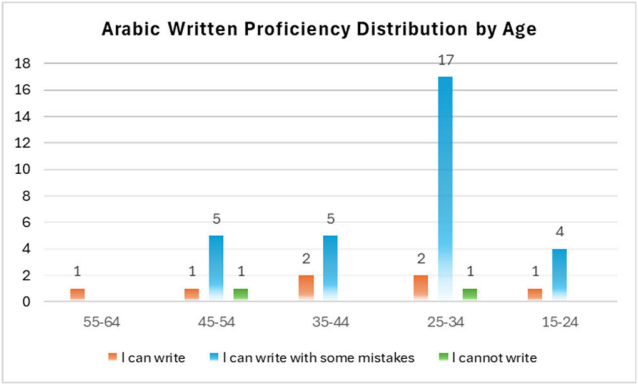

FIGURE 7. Arabic written proficiency distribution by age.

5) DIGITAL LITERACY

Our findings revealed that most participants are familiar with smartphones, computers, and other technologies. Most also note that they can navigate the web content or have support when they need help navigating the web. However, regarding the avatar, many DHH individuals agree (23, 57.5%) or strongly agree (11, 27.5%) that they need to learn or become more familiar with using avatars. Only four neither agreed nor disagreed (10%), and two disagreed with the statement (5%).

Smartphones: Most participants frequently use a smartphone. Twenty-six participants (65%) reported using a smartphone "Frequently." Twelve participants (30% of participants) reported that they use a smartphone "Rarely." Only 2 participants (5%) said: "Do not use a smartphone." A significant number of participants who use smartphones reported multiple uses. Thirty-two of them use their smartphones for communication, followed by social media (22), entertainment (10), and learning/searching for information (15). A few reported using smartphones for work/utility (9). One participant said religious use. None reported health management.

Computers: Out of the participants, 45% rarely used computers, while 35% used them frequently. Additionally, 20% reported not using a computer at all. Most participants (60%) use their computers for work/utility, followed by learning/searching information (30%), communication (17.5%), and entertainment (12.5%). Only one participant reported using their computer for social media, while none reported health management or religious use.

Others: Most participants (30, 77.5%) use smartphones and computers. However, some participants (10, 22.5%) also use other technologies. Most of the 10 participants who reported using other technologies used smartwatches (7, 17.5%). One participant said using a magnifying glass (1, 2.5%), and another reported using an iPad (1, 2.5%). One participant (2.5%) did not provide any response. These devices are used for various purposes. Participants who used smartwatches (7, 17.5%) used them as an alarm (6, 15%), for communication (6, 15%), for reminders (3, 7.5%), and for work (1, 2.5%). The participants who used the magnifying glass (1, 2.5%) reported using it to "read small and non-visible text and

photos." The iPad participant (1, 2.5%) reported using it to "translate speech/text to sign language and vice versa."

Digital (Web) Content: To evaluate technological proficiency, the ability to navigate and understand web content is an important aspect. Among the participants, 30.75% reported frequently using the Internet to navigate web pages, such as reading news. On the other hand, 22.5% of participants (9 individuals) said they rarely use the Internet for this purpose. Only 1 participant (2.5%) reported that they do not have access to the Internet. According to the interview findings, most participants (55%) reported an "Acceptable" understanding of the content on the websites and web applications they visited. About 30% of the participants reported a "Good" understanding level, while 10% reported a "Very Good" level. Only 5% of the participants reported a "Low" understanding level, and none reported a "Very Low" level.

When the participants needed help understanding web content, 77.5% of them asked for help from a friend or a family member. Seven participants (17.5%) responded that they asked for help from an SL interpreter, and 2 participants (5%) used other techniques like searching on Google.

6) PREVIOUS EXPERIENCE WITH THE AVATARS

During the study, 40 participants were involved, of which 18 had previous experience with a signing avatar, while the remaining 22 had no knowledge. Surprisingly, only 3 participants could identify BuHamad as a signing avatar correctly. When asked about their overall experience with SL avatars, 17 participants had a positive experience, while only one participant had a negative experience.

Of the 18 participants who had seen signing avatars, 16 found them easy to understand, while 2 participants felt they were difficult to comprehend.

7) ATTITUDE TOWARD SIGNING AVATARS

According to our study, 92.5% of the participants believe that using signing avatars while browsing websites and mobile is a good idea. However, despite this positive attitude towards the technology, many participants (17, 42.5%) agreed they would prefer signing avatars over a human interpreter or video. Meanwhile, many participants (13, 32.5%) neither agreed or disagreed, disagreed (4, 10%). The remaining participants were split between strongly agreeing (4, 10%), strongly disagreeing (1, 2.5%), and expressing a mix of NAD or disagreement (2.5%). Consistently, our findings show that 50% of the participants believed that using SL avatars could help access digital content when a human interpreter or family member was unavailable. However, the other half of the participants needed clarification about its usefulness. For instance, one participant in our study noted that "the avatar cannot replace a human interpreter, but it can help with understanding," highlighting the complex relationship between attitudes towards the technology and the unique environmental context in which it is used. Some participants compared the avatar to a human interpreter and pointed out the differences. They noted that facial expressions were missing, and the signs varied from those of a human interpreter. As a result, they thought that a human interpreter was better than a sign language avatar. However, in situations where a human interpreter was not available, an avatar was valuable. The study also found that 72.5% of the participants would use avatar technology if no human interpreter or SL video were available. However, 67.5% of the participants believed avatars could not replace human interpreters.

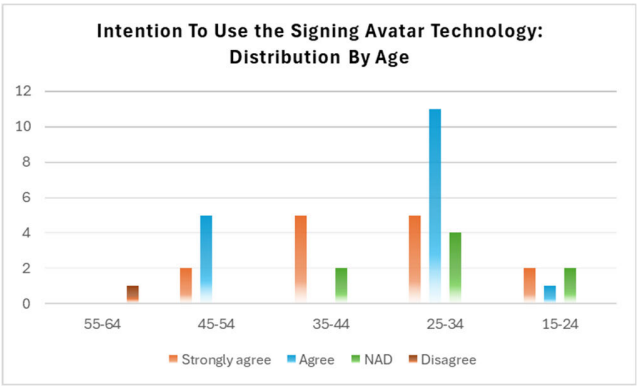

FIGURE 8. Intention to use the signing avatar technology: Distribution by Age.

In other words, while many support signing avatars, many remain critical and skeptical and do not see them replacing human interpreters. This is consistent with findings from Tran et al., who reported that US DHH users had concerns about signing technologies that impacted their attitudes toward them [53].

8) BEHAVIOURAL INTENTION TO USE THE SIGNING AVATAR TECHNOLOGY

Even though 92.5% of the participants believe that signing avatars while browsing websites and mobile is a good idea, as presented in the Attitude section, our findings show that only 77.5% of the participants expressed interest in using avatars in web applications and digital content. Of these, 62.5% plan on using them regularly or all the time. One participant suggested the likelihood that "the Deaf community will gradually become familiar with it over time." In fact, out of the 40 participants, 22 had no prior experience with signing avatars. Moreover, only three participants could correctly identify BuHamad as a signing avatar.

Most of those showing positive behavioral intention to use the avatars are under 35 (19 out of 31), as shown in Figure 8. 27 out of 40 participants with suitable to very good sign language skills intend to use the signing avatar technology in digital content and web applications (Figure 9).

Surprisingly, those who were skeptical (8) or did not intend to use the technology (1) belonged to the category of those who could write with some mistakes or were proficient in written Arabic (Figure 10).

9) PERCEIVED EASE OF USE OF BUHAMAD

According to the interviews, 80% of the participants believe that learning how to use the signing avatar in general is easy,

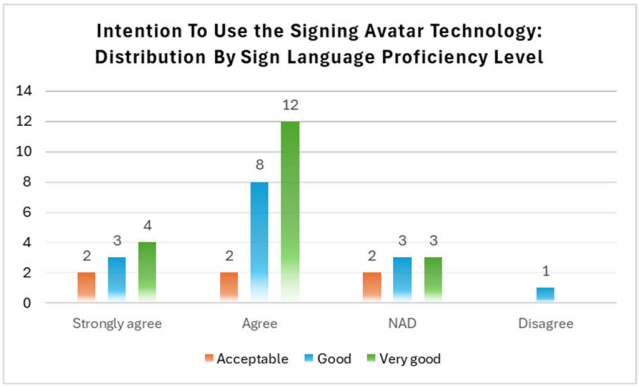

FIGURE 9. Intention to use the signing avatar technology: distribution by sign language proficiency level.

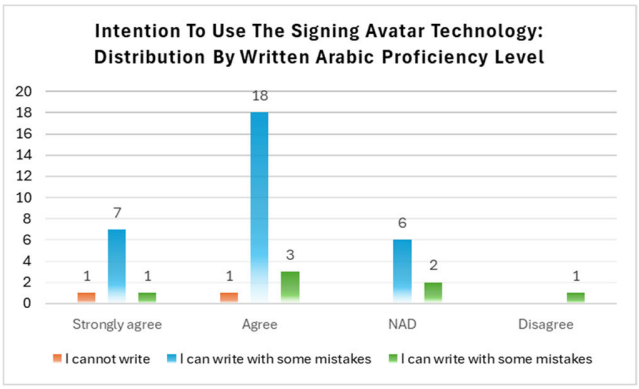

FIGURE 10. Intention to use the signing avatar technology: distribution by written Arabic proficiency level.

and 70% said that it is easy to remember how to use the avatar technology again later. Moreover, the participants not only found the avatar easy to use but also believed that it had the potential to promote accessibility for DHH persons (70% of the participants).

When visualizing the signing avatar, BuHamad, the participants have identified certain intrinsic features that may restrict its accessibility and usability, ultimately impacting their perception of the technology's ease of use. Our thematic analysis identified features that can be grouped into appearance, facial and body expressions, and sign language movement production.

Appearance: BuHamad offers a culturally adapted technology for Qatari sign language, appearing in traditional Qatari clothing and translating textual content into Qatari sign language. However, some participants noted challenges with the background and avatar color contrast, making BuHamad's appearance less accessible. One participant added that the background needs to be stable to enhance the clarity of communication. To address this issue, the accessibility guidelines proposed by WCAG 2.2 should be applied.

Although Pauser & Wagner find that the aesthetic of the avatar itself (e.g., hair color) is not a significant influence on how the DHH community perceives the technology, future development of BuHamad could allow for more flexibility, enabling end-users to select the gender, colors, and attire of the avatar [54]. This would reflect the diversity of end-users and better meet their needs.

Facial and body expressions: Some participants have criticized the avatar's lack of facial expressions, making its facial and body expressions appear unnatural and less human-like. The facial and body expressions of the avatar do not appear natural, falling short of human-like fluidity. In addition, the flexibility of the avatar's body does not match that of a human interpreter, resulting in a disparity in quality. During the discussion, two of the participants provided feedback regarding the position of the hands. They pointed out that the hands were folded too closely to the shoulders, which looked unnatural and not like an average person's body position. They suggested that the hands should be positioned more relaxed and naturally to make the overall posture appear more comfortable and authentic. Improvements in this area are needed to achieve more human-like movement and improve the overall quality of the signing experience. This is congruent with the findings of Soudi et al. [55], which identify that DHH individuals have a negative perception of avatars with worse non-manual markers, including facial expression and eye gaze.

Movement: Another manual marker that impacts how well the avatar is perceived is movement [55]. One of the participants found an issue with the positioning of the avatar's hands, which are folded too closely to the shoulder. Another participant stated that the avatar's movements lack natural fluidity. Similarly, Quandt et al. (2022) identified movement quality issues seen in computer-generated avatars as a challenge'' and ''movement quality and appearance significantly impact users' ratings of signing avatars.'' Additionally, when visualizing the signing avatar BuHamad, participants identified the signing speed as an issue. Sign language proficiency, age, and level of hearing loss can impact the understanding of sign language. Thus, the technology should allow the user to control the sign speed.

Sign Language Production: The avatar's body lacks the flexibility of a human interpreter, resulting in non-clear and difficult-to-understand signs, particularly for longer ones, as stated by 7 participants. This sentiment is echoed by the findings of Wolfe et al. [59], who saw ''a lack of an avatar technology that effectively displays generated sign language in a manner that is legible and acceptable to end users.'' As a result, missing or flawed SL production and content quality issues are a recurring concern for the DHH community [53].

10) NEED FOR SUPPORT

According to our findings, 82.5% of the participants believe having someone available to help them with avatar usage is crucial. To make it easier to use signing avatars, most participants (55%) found it essential to have someone available to help them if they face difficulties with the technology. An additional 27.5% strongly agreed with this. Only 12.5% noted that they neither agree nor disagree, while 2.5% disagreed with this notion.

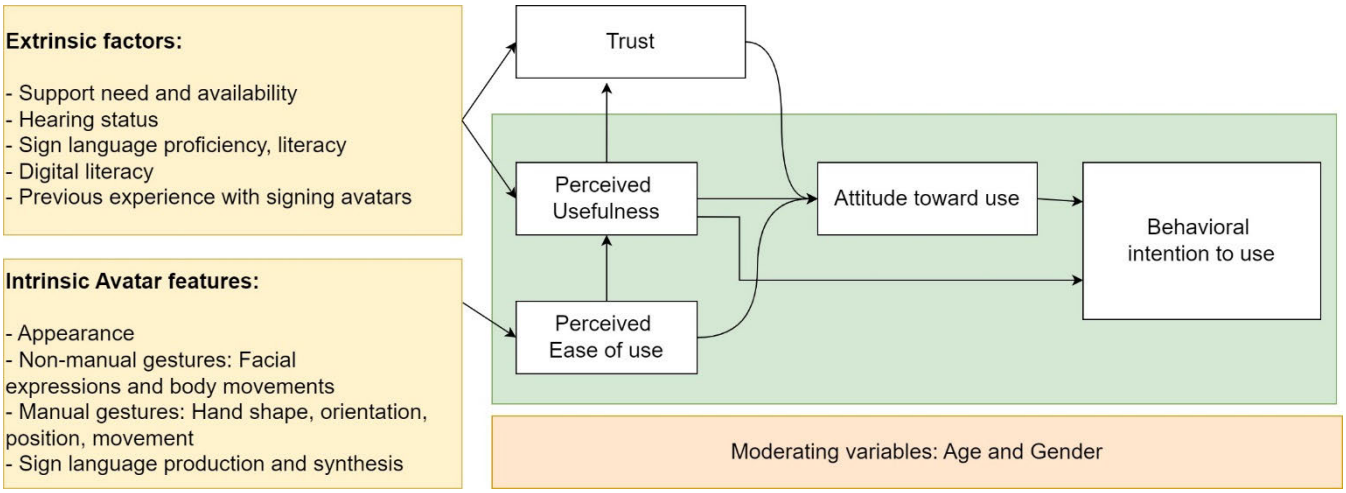

FIGURE 11. Technology acceptance model of signing avatars (TAMSA).

11) PERCEIVED USEFULNESS

Potential Uses of Avatars: Our findings indicate that 80% of the participants believed that SL avatars could help navigate the internet more effectively. Additionally, more than half of the participants (57.5%) thought avatars could be a valuable tool for quickly accessing digital content, especially when a human interpreter is unavailable. The participants suggested that avatars could be integrated into websites and social media platforms to improve content comprehension. One participant mentioned that she sometimes finds it difficult to understand written text, and using avatars could greatly help in such cases. For instance, one participant suggested using avatars to translate the Holy Quran.

In addition, 80% of the participants expressed their desire to have signing avatars available on their smartphones or computers. Two participants suggested that avatars could be expanded to translate voice messages, faxes, and speeches into sign language, making it an invaluable communication tool. Three participants also indicated that Bu Hamad could be useful in translating spoken language into sign language and vice versa. This can be particularly helpful if an individual needs an interpreter, but they are all available. The avatar can effectively translate signs to speech and vice versa, facilitating communication between deaf and non-deaf individuals.

Other participants suggested incorporating avatars on smartphones to translate Arabic words and using them on video calls to communicate with others.

Moreover, 72.5% of the participants agreed that Sign Language avatars can be used for job or study-related tasks. For example, one participant suggested that using these avatars to explain complex subjects such as mathematics can be beneficial. Additionally, five participants suggested placing these avatars in public areas such as hospitals, airports, and banks, particularly at ATMs, to facilitate communication with DHH individuals. Some participants also suggested adding sign language translations to English text at airports since navigating between gates can be challenging. The avatar can also translate messages from websites or banks that are often difficult to understand. Lastly, some participants suggested using the avatar to display soccer match results in public places.

Limitations to the Uses of BuHamad: The participants suggested that using these avatars should be limited to situations where no human interpreter is available. Additionally, they recommended using BuHamad primarily for short sentences. Comprehension becomes challenging when longer sentences are used, and the avatar is more likely to make mistakes. One participant explained that using the avatar on websites is beneficial but not at conferences or live events. As a future development, one participant suggested incorporating English Sign Language (SL) and Qatari Sign Language (QSL), especially for deaf individuals studying English.

VI. PROPOSED MODEL

This study investigates the acceptance of signing avatar technology among DHH individuals in Qatar. We have extended the TAM and developed a research model called TAMSA (**T**echnology **A**cceptance **M**odel of **S**igning **A**vatars) (Figure 11), presented. This model offers behavior intention as the dependent variable, with attitude as a mediating variable. It builds on trust and the perception of ease of use and usefulness and describes the factors that may impact them, which are extrinsic and intrinsic to BuHamad. The TAMSA model considers intrinsic factors specific to the technology-based solution, BuHamad, and extrinsic factors associated with DHH users and their environment.

Based on previous research on our study's findings, we formulate these research hypotheses about the relationship between the proposed constructs. Thus, five hypotheses were elaborated, which are listed below:

- H1: Trust significantly influences Perceived usability and Perceived usefulness.

- H2: Perceived usability and Perceived usefulness have a significant influence on Behavioral intention.
- H3: Perceived usability has a significant influence on Perceived usefulness.
- H4: Extrinsic factors have a significant influence on Behavioral intention.
- H5: Intrinsic features of the signing avatar significantly influence Perceived usefulness and Trust.

A. PERCEIVED USEFULNESS AND EASE OF USE

Our proposed model, similar to the original TAM, suggests that the behavioral intention of DHH users to use signing avatar technology is influenced by two factors: perceived usefulness and perceived ease of use [40]. Perceived usefulness (PU) refers to the extent to which the user perceives that the new technology will aid them in performing the task at hand, while perceived ease of use (PEoU) refers to the extent to which the individual believes using the technology would be free of effort. As proposed by the original TAM, perceived ease of use and usefulness influence DHH users' behavioral intention to use technology. However, unlike TAM, in TAMSA, we suggest that both constructs have equal weight on the scale based on evidence proposed by [42] and [43].

Previous studies with TAM showed that perceived usefulness and ease of use alone cannot fully represent the complexity of DHH's acceptance of emerging technology. Therefore, based on our findings and others from studies such as [43], [44], and [45], we added a set of three variables: intrinsic avatar factors, extrinsic avatar factors, and trust.

B. INTRINSIC AVATAR FEATURES

Our research study revealed that participants identified several characteristics of the signing avatar, named BuHamad, that could hinder its accessibility and usability. These features, if perceived as unfavorable, may impact the overall ease of use of the technology, as highlighted by our findings. Our analysis categorized these characteristics into appearance, facial and body expressions, and sign language movement production. Our findings support previous studies that identified similar avatar features impacting the ease of use of signing avatar technology, such as studies [54], [55].

C. EXTRINSIC FACTORS

Extrinsic factors refer to the external influences that affect the use of the signing avatar technology. Based on our findings, several variables may be proposed as affecting the trust in the signing avatar technology and its perceived usefulness. Extrinsic factors englobe all factors nonrelated to the technology that would affect its acceptance, including technical support, and several characteristics of the end user such as his/her literacy level, sign language proficiency, and hearing status and level. Previous research supports our findings and corroborates how some factors, such as technical support, could affect the acceptance of technology by DHH users [45].

D. TRUST

Our model follows the hypotheses tested by other TAM-related studies that have proposed trust (or trusting beliefs)) as an antecedent of perceived usefulness and after perceived ease of use while having a direct effect on attitude [56]. Trust is a state of mind in which an individual is willing to be vulnerable due to positive expectations about another person's intentions or actions [57]. Various studies in information systems have consistently demonstrated the significance of trust in the acceptance and adoption of new technologies [58]. However, to our knowledge, this relationship has not been explored within the Deaf community, particularly in relation to signing avatar technology. Our research indicates that DHH people are less likely to trust signing avatar technology than human interpreters. Therefore, TAMSA has included 'Trust' as a new factor that could potentially influence DHH individuals' acceptance of avatars.

E. MODERATING VARIABLES

According to our model, DHH users' acceptance of signing avatars is influenced by age and gender. These two variables, age, and gender, are exogenous variables, meaning they are unaffected by other variables. While our exploratory and descriptive study does not provide significant evidence for these variables, previous studies have consistently identified age and gender as key factors contributing to the acceptance of technology among different users [58].

F. LIMITATIONS AND CONSIDERATION OF FUTURE APPLICATION

TAMSA does not consider other variables identified in previous research, such as Facilitating Conditions. Facilitating Conditions are defined as ''the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system'' [57]. Previous research on the acceptance of technology by DHH people has identified that the variable Facilitating Conditions significantly affects the use of technology by HHH people, not the intention of use (behavioral intention to use) [43].

To further enhance our understanding of signing avatar technologies, future research should focus on evaluating the quality of experience (QoE) using mean opinion scores (MOS) for converting text to sign language. This evaluation should encompass both domain-specific and generic environments to assess the effectiveness and user satisfaction across various contexts. By conducting these studies, researchers can gain valuable insights into the performance and acceptance of signing avatars, ensuring they meet the needs and expectations of DHH individuals in diverse settings. Such studies would also help identify specific areas for improvement, leading to the development of more refined and user-friendly signing avatar technologies.

G. GENERAL REMARKS

Based on this evidence, TAMSA excluded the variable Facilitating Conditions and included some of its sub-elements, such

as technical support, as an extrinsic factor in our model. It's noteworthy that no other organizational elements were identified in our participants' discourse. This could be justified by the fact that the signing avatar technology is at the early stages of its implementation, and we believe that this variable could be more relevant for technology that has already been implemented. Additionally, our model is based solely on our findings, adapted to Qatar's DHH community. A cultural adaptation should be considered when transferring this model to any other culture or context. Culture becomes a facilitating condition when the technology adheres to cultural values.

Furthermore, our model needs to be pilot-tested and validated through further testing of the proposed hypotheses, using various analyses such as chi-squared tests for independence to understand the relationship between categorical variables, Kruskal-Wallis tests for ordinal variables, and Pearson Correlation Coefficient to measure the level of correlation between variables. In addition, we will calculate the significance of the correlation. This will be the focus of a subsequent paper.

VII. LIMITATION OF THE STUDY

Despite the significant insights provided by this study, several limitations should be acknowledged:

- The study involved 40 participants, representing 10% of the DHH population in Qatar. While this sample size is adequate for an exploratory study, it may not fully capture the diversity of experiences and perceptions within the broader DHH community. Future research should include larger and more diverse samples to enhance generalizability.
- The study focused on DHH individuals in Qatar, a specific cultural and linguistic context. The findings may not be directly applicable to DHH communities in other regions with different cultural and linguistic characteristics. Comparative studies across different cultural contexts are needed to validate and expand upon the findings.
- The current implementation of the BuHamad avatar may have limitations in terms of realism and fluidity of movements, which could affect user acceptance. Future research should focus on improving the technological aspects of signing avatars to enhance their usability and acceptance.
- The study employed a mixed-methods approach, combining qualitative and quantitative data. While this approach provides a comprehensive understanding of the factors influencing acceptance, it may not capture all the nuances of user experiences. Longitudinal studies and real-world usability testing could provide deeper insights into the long-term acceptance and effectiveness of signing avatars.
- The study identified trust as a significant factor influencing acceptance. However, the factors contributing to trust in signing avatar technology need further exploration. Future research should investigate the specific elements that build or undermine trust among DHH users.

VIII. RECOMMENDATIONS FOR AN AUTHENTIC ENGAGEMENT OF DHH INDIVIDUALS IN TECHNOLOGY R&D

Throughout the research process and based on our findings, our team developed practical strategies and recommendations to ensure the equitable inclusion of DHH individuals in research and technology development. Here are the main recommendations proposed:

A. ENGAGING AND BUILDING TRUST WITH DHH PEOPLE

Existing research indicates that end-users are more likely to embrace technologies perceived as usable and compatible with their needs. Engaging DHH individuals at every stage of technology-based solution design, development, and deployment is crucial to ensure optimal usability and acceptance in practice. Even with an evident positive attitude towards the signing avatar technology, as shown in our study, the Deaf community is still lukewarm in their enthusiasm for signing avatars. Indeed, deep structural issues are present in this technology and its acceptance by DHH people due to the systematic underestimation of the complexity entailed in sign languages, the quality of solutions, and the lack of direct participation of deaf communities (Angelini, 2023). Tran, Ladner, & Bragg (2023) have found similar sentiments in the US, where everyday concerns are identified to be ''hearing people profiting from ASL.'','' ''ignoring the values and needs of the deaf community,'' and ''limited involvement of deaf people in leadership or as contributors.''

Because of the insular nature of the Deaf community and the mistrust DHH people may have for external, hearing researchers, research teams must prioritize building trust and rapport with project partners. To facilitate open and transparent communication, we set aside time up front and throughout the project for researchers and stakeholders to discuss project goals, review progress, and address questions. For example, our team participated in formal training on Deaf culture. Researchers met quarterly with the interpreter and throughout the project to discuss the study, review our progress, and address study challenges and staff concerns.

B. WORKING IN AN INTERDISCIPLINARY APPROACH

Developing successful sign language recognition, generation, and translation systems like BuHamad requires expertise in various fields, including computer sciences, natural language processing, human-computer interaction, linguistics, and Deaf culture. Currently, research in this area is limited by separate disciplinary silos, which address limited aspects of the DHH individuals' needs. This study adopted an interdisciplinary approach to engage DHH individuals to address this research gap. In addition, we had a team member who was DHH fluent in Qatari sign language and familiar with their culture. This was an essential factor that allowed the team to

understand signing nuances, as well as the social norms and customs of the Deaf community.

C. PROVIDING ACCESSIBLE AND DIVERSE FORMS OF COMMUNICATION

Multiple, accessible forms of communication are vital to ensuring that research with DHH people is successful and respectful. In our project, certified interpreters were arranged for interviews and translations. Throughout our study, we relied on a combination of interpreters, technology (recorded videos), and simplified textual content to facilitate interviews with DHH individuals.

Our study's practical lessons and recommendations can assist other researchers, developers, DHH people, and other participants in relevant studies and technology development projects. They bridge the significant research gaps that impact the availability and accessibility of DHH solutions.

D. IMPLICATIONS FOR A WIDER INTERNATIONAL AUDIENCE

Our study's findings have substantial implications for a global audience. The acceptance and integration of culturally adapted signing avatars, such as BuHamad, underscore the necessity of incorporating cultural and linguistic diversity in technology development. This approach can be applied globally to create inclusive and effective technological solutions for diverse DHH communities. Furthermore, signing avatars can bridge communication gaps in regions with limited access to human interpreters, enhancing digital accessibility and inclusivity worldwide. By applying insights from this research, developers and policymakers can better address the unique needs of DHH populations, fostering a more inclusive digital environment globally.

IX. CONCLUSION

Signing avatars have the potential to make sign languages more accessible and valuable in everyday life, which can help overcome the challenges faced by the Deaf community when it comes to accessing information. Although there is a growing interest in this technology at the research level, it is still in its early stages of implementation. In this study, we specifically explored the acceptance of the culturally adapted signing avatar, BuHamad, by DHH people in Qatar from a human rights perspective and considering the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD). BuHamad offers an alternative means of communication and access to digital content instead of relying solely on spoken language or reading text. With its appearance of a Qatari person, BuHamad is a technology-based solution that empowers the cultural and linguistic identity of DHH residents in Qatar. We have applied the Technology Acceptance Model to understand better the acceptance of signing avatars and the factors influencing it among the DHH Qatari residents. We have also proposed a conceptual model that outlines the acceptance of signing avatars among this community.

Future research should expand the sample size and diversity to include a broader range of DHH individuals from different cultural backgrounds. Comparative studies across different cultural contexts are necessary to validate and generalize the findings. Additionally, there should be a focus on technological advancements to improve the realism and usability of signing avatars. Employing longitudinal studies and real-world usability testing will help understand the long-term acceptance and effectiveness of signing avatars. Finally, exploring the factors contributing to trust in signing avatar technology will be crucial for developing strategies to enhance user trust and acceptance. By addressing these limitations and exploring these directions, future research can build on the foundations laid by this study and contribute to the development of more effective and widely accepted signing avatar technologies for DHH communities globally.

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