The Iterative Development and Evaluation Framework for Kazakh-Russian Signing Avatars Targeted to Native Deaf Signers

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Abstract

Nowadays, existing research predominantly focuses on already well-researched sign languages. However, the most extensive studies of sign language in Kazakhstan, which adhere to international standards, started about a decade ago. Native deaf signers in Kazakhstan can often suffer from insufficient educational opportunities, which may result in limited reading proficiency too. Sometimes, deaf signers can recognize letters and read words, but they may not fully understand the overall concept and need to break it down into a sequence of simpler ideas to comprehend it better. Consequently, signing avatars have the potential to interpret internet statements, movie subtitles, or YouTube videos, and this sign language production may increase accessibility and improve communication between deaf and hearing individuals, as well as between humans and avatars. An equally critical challenge is how to develop a tool that will help deaf signers evaluate the performance, appearance, and naturalness of signing avatars without relying on written text across all sign languages, particularly in underserved communities. This paper outlines the iterative development of the Kazakh-Russian Sign Language interpreting avatar, ongoing improvements to the evaluation instrument, and a comparative analysis of this instrument with another evaluation method designed to attain the same objective.

Keywords: signing avatars, HCI, sign language generation, assessment, questionnaire

1. Introduction

Recent advancements in Virtual Avatars (i.e., human-like virtual characters) and testing of their implementations have transitioned these entities from niche gaming studies to mainstream research in education and collaboration (Audrezet et al., 2025; Gasch et al., 2025; Ouhnni et al., 2025). By the same way, all these breakthroughs have the potential to greatly enhance the presence, popularity, and applicability of avatars in the near future for sign languages(Quandt et al., 2022). Generative approaches provide more novel options to enhance the visibility of sign languages, engagement, interactivity, and scalability. Natural language processing implemented for sign languages may allow providing any information to end-users in different languages, including sign languages; and virtual avatars could improve the access to information in sign languages (Naert et al., 2020), especially when there is no physical presence for deaf signers.

Sign language performing characters, or signing avatars, have been a prominent focus in the domains of human-agent interaction (HAI) and human-computer interaction (HCI) research for nearly two decades(Huenerfauth and Hanson, 2009; Kennaway et al., 2007; Lombardo et al., 2010; Kipp et al., 2011b). Due to their promising potential for facilitating communication between deaf and hearing individuals through the translation of written or spoken to sign language and vice versa, they were especially sought after as a valuable tool by mainly hearing researchers.

The research results generally affirm the efficacy and potential of signing avatars in facilitating solving challenges often faced by native deaf signers and improve information accessibility (Kipp et al., 2011a; Adamo-Villani et al., 2016; Bouzid et al., 2016). However, more recent research has identified a problem in the development of suitable avatars that are user-friendly, grammatically accurate, and comprehensible for the deaf (Bragg et al., 2019). Nonetheless, members of Deaf communities often perceive sign language interpreting systems as insufficient (Wolfe et al., 2022).

This counterproductivity, as Wolfe (Wolfe et al., 2022) contends, is likely attributable to the subpar quality of signing, evidenced by the display of robotic gestures that lack both naturalness and clarity. A potential explanation for this may be attributed to the homogeneity of research teams, including mainly hearing researchers and a deficiency of inclusivity, leading to the ongoing challenges faced by deaf sign language users in stating their requirements. So, the involvement of the deaf community is essential in the evaluation of sign language systems, as their insights can address challenges in experimental design (Huenerfauth and Kacorri, 2015; Roelofsen et al., 2021) and identify areas for improvement (Kipp et al., 2011b; Gibet et al., 2011; Schnepp et al., 2012; Roelofsen et al., 2021).

Although quite often bilingual (Gibet et al., 2011),

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many deaf signers consider the sign language as their first language. Therefore, administering a questionnaire in a written format, as is commonly practiced, is not suitable (Farwell, 1976). Consequently, interaction with the Deaf community must be conducted in their first language (Gibet et al., 2011; Bosch-Baliarda et al., 2019).

Secondly, research indicates that complex and ambiguous concepts present additional challenges for deaf individuals in accurately understanding ideas (Parvez et al., 2019), resulting in a cognitive burden (Bosch-Baliarda et al., 2019). When deaf signers recognize letters and words, they may not fully understand the concept itself; therefore, they have to deconstruct it into several simpler concepts in order to achieve comprehension. According to the experience of local interpreters, some of them are CODA and familiar with deaf culture; instead of utilizing the Internet or encyclopedias to ascertain the meaning of a sign, deaf signers generally seek clarification from their own social group, including friends or relatives. According to (Morere, 2012), the educational level of young adults who graduated high school is reported to be similar to that of fourth-grade students in the USA. Local sign language interpreters and representatives of organizations for the Deaf report a remarkably similar situation in Kazakhstan and the CIS countries.

It is noteworthy that prior research (decades ago) on sign languages was predominantly concentrated on Western sign languages (such as ASL LSF, and DGS), which have been thoroughly investigated, resulting in an abundance of resources. However, comprehensive studies of sign language used in Kazakhstan, which adhere to international standards, started only about a decade ago (Kudubayeva et al., 2016; Imashev, 2017), including data collection (Imashev et al., 2020) and sign language recognition (Kuznetsova et al., 2021; Duisenbek and Zhukabayeva, 2025), and only recently were the first evaluation studies also conducted (Imashev et al., 2022).

One of the primary obstacles to this work is the lack of consensus on the complexities of conducting evaluation studies with the deaf. A major challenge is the development of deaf-friendly survey metrics to maximize researchers' understanding of the responses of deaf participants. Thus, traditional textual questionnaires, commonly used to conduct surveys with hearing individuals, are often inappropriate for user evaluation studies involving the deaf. This approach can undermine the validity of the feedback obtained for several obvious reasons (Bosch-Baliarda et al., 2019).

This work prioritizes both the selection and design of evaluation instruments and the logistics of user studies, which include field studies with deaf participants.

2. Avatar Design

This section describes the iterative evolution of data-driven signing avatars designed for Kazakh-Russian Sign Language performance has undergone four significant modifications due to technological advancements, supported by two research-oriented grants over the past six years, with a focus on enhancing performance plausibility and visual representation (see Figure 1). The rationale for all modifications and enhancements was guided by a combination of feedback provided from the participants of each user study and was implemented incrementally from version to version. All user studies described in the subsequent Section 3 and their outputs are associated with each version of avatar.

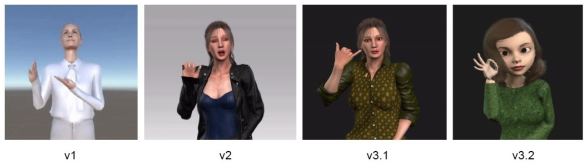

Figure 1: The evolution of Kazakh-Russian Sign Language Avatar development.

v1. The avatar used for the online user study (only flat hand configurations and no facial emotions were available for this version); v2. The avatar used for the first in-person user study (hand configurations, facial mimics, mouthing); v3.1 The updated avatar used for the second user study (more precise finger articulation, less shiver); v3.2 The latest version ended up with cartoon-like appearance because it allowed to obtain more stable motions.

2.1. Avatar 1 (v1)

In 2021, it was decided to conduct a user study online due to the COVID restrictions. The approach utilized for the online user study is described in (Martinez et al., 2017). It extracts human body keypoints from 2D videos by OpenPose. Then process depth estimation, which helps to reveal distance from the camera and convert them into 3D domain.

The motion models obtained can be imported into avatars. Unfortunately, it allowed us to use flat-hand configurations only, so it was necessary to construct sentences using flat, open-hand configurations only. Facial expressions are also not involved.

2.2. Avatar 2 (v2)

The improved approach used for the first in-person user study. It requires two additional techniques on the human pose sequence stage: namely LightTrack (Ning et al., 2020) and ExPOSE/SIMPL-X (Choutas et al., 2020). LightTrack is a framework developed by MIT for online human pose tracking, and ExPOSE/SIMPL-X recovers details of hands and faces thanks to its attention model. This improved version mimics the movements in a better and more natural (physiologically believable) way according to the feedback of deaf signers and interpreters.

2.3. Avatar 3 (v3)

This is the pipeline of how Agent 3 operates. Basically, it is almost the same as the avatar proposed above. Just another outer appearance, minimal hyperparameter-tuning, minimal fine-tuning, and less body shivering obtained by the iClone (McCallum, 2011; Georgiev et al., 2024) software (see Figure 2).

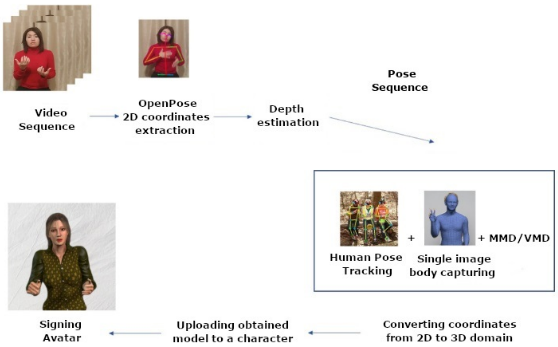

Figure 2: The updated approach used for signing avatar involved in the second user study.

2.4. Avatar 4 (v4)

The latest version of the proposed K-RSL signing avatar is depicted in Figure 3. The architecture remains the same as the previous version; however, the body shiver was quite bothersome for participants in the previous user survey. Consequently, experimenting with various body proportions supposedly enhanced motion stability and rendered a more cartoon-like appearance. Despite the fact that (Adamo-Villani and Anasingaraju, 2016) experimentally rejected their hypothesis that avatar stylization could significantly influence participants' perception of signing avatars, they had a relatively small sample size. There is a probability that the stylization of avatars in a manner that is reminiscent of cartoons could be more functional, welcoming, and engaging for the purpose of education and advertising in the context of sign language and avoid potential uncanny valley effect (McDonald, 2025).

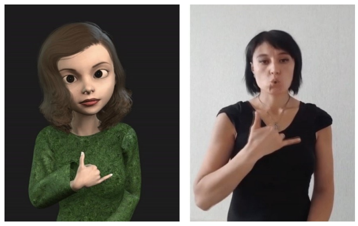

Figure 3: The updated approach (v3.2) used for signing avatar was demonstrated in the second in-person user study compared to a human signer.

3. Comparison of the proposed avatar with other existing signing avatars

This section showcases a list of seven well-known state-of-the-art and reputable available 3D signing avatars created for sign language production (generative or pre-recorded) and provides brief comparisons of their merits and demerits:

The first approach is based on the SiGML[1] (Ebling and Glauert, 2016) agents (see Figure 4). It utilizes the HamNoSys (Hanke, 2004) notation system, which encodes the manual features of sign languages. This approach is widely recognized. However, it is rule-based and always requires expert approval.

Figure 4: SiGML avatars

The authors (Yang et al., 2022) of the second signing avatar have used motion capture technologies to record college lessons and import them into mixed reality (see Figure 5 a). This approach is time-consuming and requires expensive technologies with interpreter approval to film each lesson.

The third avatar (see Figure 5 b) is designed to produce German Sign Language (Nguyen et al., 2021). It converts coordinates from 2D videos to 3D domain using Mediapipe and uploads motion models to a Blender avatar. Unfortunately, the eyes of the avatar do not have pupils or iris. As we understood, head position and eye gaze motions are crucial for interaction between deaf signers. In our case, when participants watched the SiGML avatar ANNA, they mentioned that her eyes seemed to look a bit down, and simultaneous head motions from side to side may be perceived as avoiding conversation or even disrespect in local deaf culture.

[1] https://vh.cmp.uea.ac.uk/index.php/SiGML

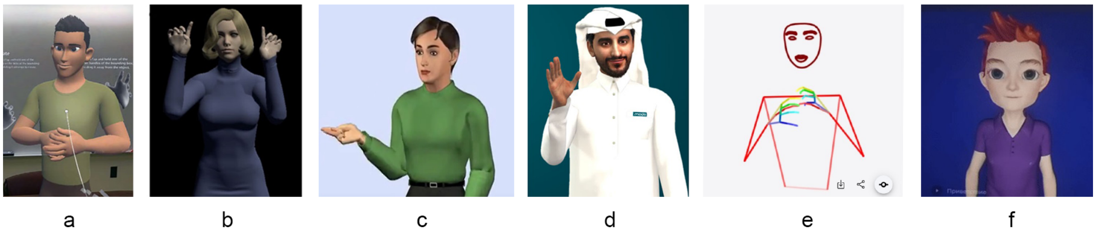

Figure 5: a) The mixed-reality avatar of (Yang et al., 2022); b) the 3D avatar of (Nguyen et al., 2021); c) the avatar Paula from DePaul university; d) BuHammad; e) SignMT's stick-figure avatar; f) Project Adaptis.

Next, DePaul University's Paula avatar (see Figure 5 c) demonstrates all ASL linguistic parameters, including hand movements, facial expressions, and body gestures, for clear and natural signing (Davidson, 2006; McDonald et al., 2024). She has been used in practical and instructional settings, including interpreter training at the Jack Mabley Developmental Center in Dixon, Illinois, for the Illinois Department of Human Services.

The avatar named BuHammad (see Figure 5 d) was created for Qatari Sign Language (El Ghoul and Othman, 2022); although it performs convincing signs and facial expressions, the website presents a limited vocabulary for now.

The 6th avatar is cutting-edge technology called SignMT (see Figure 5 e), which supports several sign languages, produces a Skeleton Viewer (stick-figured agent), a Human GAN model for signing videos, and a 3D Avatar; and operates like the Google Translate service (Moryossef, 2023).

The last avatar (see Figure 5 f) is the avatar related to the RSL Adaptis project [2]. It has limited vocabulary on the website and a disproportionately large head, making some signs inaccurate (see Figure 15 in Appendix A, Adaptis performs DAD (in RSL) starting from the area of the intermediate nasal bones instead of the area of the forehead).

4. Questionnaire iterative development

Creating sign language interpreting systems emphasizes stakeholder review to determine usability before deployment by end-users. Numerous research studies have explored approaches for empirical evaluation of deaf individuals, including metrics and instruments for critical feedback (Berke et al., 2018). In user studies of sign language interpreting systems, questionnaires are commonly used to obtain subjective feedback (Huenerfauth et al., 2015; Berke et al., 2018).

In addition, the design of deaf-friendly survey elements is also critically important (Schnepp et al., 2011). Researchers are started acknowledging the importance of deaf-friendly questionnaire design and how accessibility, design, and delivery may affect respondents' critical judgments less than a decade ago. In Bosch-Baliarda et al. (2019), authors emphasized the necessity of ensuring full questionnaire accessibility for reliable research and legitimate outcomes.

Recent technology breakthroughs provide varied data collection techniques. Videos, photos, and picture books have helped deaf and hard of hearing research populations, but data gathering is challenging. Prior study has identified effective methods for employing signing avatars with deaf and hard-of-hearing individuals (Huenerfauth et al., 2015).

A key concern is creating deaf-friendly survey metrics to maximize the benefit of responses. The proposed questionnaire has gone through several user studies as an iterative development stage.

4.1. Online user study

For the online study, 18 respondents took part in the study (12 were native deaf signers and six were certified hearing interpreters). The ages ranged from 18 to 57 years (mean: 33 years), with a gender distribution of 4 males and 14 females. Education levels distribution: one person completed 9th grade, one 11th grade; four completed a bachelor's degree (1 deaf); the others completed a college degree. Both groups (deaf participants and interpreter) were evaluated separately to figure out if their opinions about signing avatars coincide or not.

It has been decided to compose 5 generic questions aimed at understanding deaf signers' opinion about the challenges they experienced, usability and perception in general, providing them 1-5 Likert scales with range from "Not at all" to "Yes" as options to reply: 1) Was it hard to understand separate signs without facial expressions?; 2) Do you think such an agent would be useful in the case of proficient interpreter absence?; 3) Do you find such a system interesting to use?; 4) Would such a system be useful for displaying ads?; 5) Would such a system be useful for announcing an alarm or emergency?

[2] https://adaptis.pro/en/

Questions composed to obtain the general feedback
1. Did you understand the meaning of the sentences right away?
2. Do you think you understood correctly what the character is showing?
3. Did you have to think out the meaning of the sentence because of the character's movement style?
4. Do you consider such a system suitable for use?
5. Do you find this type of interaction exciting?
6. Would you trust such a character?
7. Would you trust such a character to translate into SL?
8. Will a similar character be useful for translation when there is no sign language interpreter?
9. Was this communication effective?
10. Would such a system be useful for advertising or entertainment content?
11. Will such a system be useful for announcing important information at the PSC, Railway Station /Airport?
12. Would such a system be useful for declaring an alert or emergency?
13. Would you like to interact with such characters in the future?

Table 1: Generic questions utilized for the first in-person user study.

Section	Items		
Anthropomorphism	Fake	-	Natural
	Machinelike	-	Humanlike
	Unconscious	-	Conscious
	Artificial	-	Lifelike
	Moving rigidly	-	Moving elegant
Animacy	Dead	-	Alive
	Stagnant	-	Lively
	Mechanical	-	Organic
	Artificial	-	Lifelike
	Inert	-	Interactive
	Apathetic	-	Responsive
Likeability	Dislike	-	Like
	Unfriendly	-	Friendly
	Unkind	-	Kind
	Unpleasant	-	Pleasant
	Awful	-	Nice
Perceived Intelligence	Incompetent	-	Competent
	Ignorant	-	Knowledgeable
	Irresponsible	-	Responsible
	Unintelligent	-	Intelligent
	Foolish	-	Sensible

Figure 6: Four sections taken from Godspeed questionnaire

In conjunction with this, it was also decided to use sections of the Godspeed questionnaire (Bartneck et al., 2009). All these questions including Godspeed inquiries (see Figure 6) have been reformulated as questions and translated into K-RSL with slight elaborations and recorded as videos.

Unfortunately, such minimal elaborations revealed that participants were confused, and it has also become evident that several Godspeed items seem very similar in sign language: for example, "competent" and "intelligent" or "natural" and "organic" utilized the same signs with slightly different additional elaborations that ended up confusing and still seemed very similar for participants; therefore, the inclusion of elaborations used for translations became insufficient. So, further, more extensive elaborations are required to differentiate them. Participants also agreed that recognizing signs without facial expressions is extremely challenging and that these facial expressions are crucial not only for human-to-human sign communication, but also for comprehension in general.

An important finding of the online research is that each participant made several video calls to the separate interpreter, who was not involved as a participant, and helped with question translations into K-RSL before the user study and supported them during the user study to clarify inquiries throughout interactions with the signing avatars. It was allowed since it was online, while generally deaf signers come with interpreters. Thus, the presence of a human interpreter is essential for subjects' comfort and the assurance of being on the correct path. More information on the agents utilized, the questions, and the outputs obtained (including statistics) is described in Imashev et al. (2025b).

4.2. First in-person user study

Ten native deaf signers between the ages of 25 and 59 (mean age: 31.5; 4 male and 6 female participants) took part this time. Their educational background varied, and the majority of the participants had a college degree. The list of generic questions was improved and contained 13 of them (see Table 1). It is important to note that the selection of questions was not random and was based on a previous user study, where some subjects specifically indicated that they were not currently considering avatars for important tasks such as assisting with translations at the police or medical facilities, but rather for advertising or other more common purposes. All these questions were translated into K-RSL videos. Ten items from the Godspeed questionnaire were taken again, with elaborations to a greater extent since, for example, "Machinelike" might be understood as "Looks like a car", so this response option was formulated as "Looks like a robot". In order to reveal eye gaze motion patterns during the interaction with signing avatars, Tobii Pro 2 eyeglasses were used in this study.

This study revealed that: 1) the movements of the data-driven avatar exhibited a higher degree of physical credibility, which may elucidate why participants expressed a preference for its facial expressions over those of the manually animated counterpart, characterized by rigid articulations. Besides, participants demonstrated greater precision in their translations while engaging with the manually animated avatar (see Figure 10 A2), as opposed to the data-driven avatar, and exhibited the least fluctuation in mood throughout the interaction. The motions of this manually animated avatar were animated by a team of the research team under supervision of professional interpreter using iClone software; 2) the inclusion of tangible items for comparison, such as a genuine edible apple with a prop apple that is typically utilized in art schools or film production, should be used to provide a more profound comprehension than the abstract concepts of "artificial" and "realistic", and others. More detailed information on the user study and statistics is available in Imashev et al. (2025b).

4.3. Second in-person user study

In total, for this user study we recruited 12 deaf signers aged 27–53: six male and six female, their mean age was 36.33. Four agents performed three different sentences in K-RSL (similar to the previous user study 12 sentences in total were composed: three distinct signing phrases in K-RSL for each agent, ensuring that the phrases were uniformly balanced with respect to the handshapes utilized and the complexity of the sentence structures and concepts articulated). After numerous trials of formulating proper elaborations for Godspeed items, it has been decided to propose a visual scale with not 1 to 5 or 1 to 10 range as response, but a thermometer-like 100-point scale that could become more suitable for participants to evaluate and for researchers to use especially in cases of small number of participants. Generic questions and sorting tasks were also utilized for the assessments. Several proposed scales are depicted in Figure 7, such as scales for Dead-Alive, Inert-Interactive, Ignorant-Knowledgeable.

In addition to images, tangible artifacts were also used as boundaries for the various ranges for better clarity (see Figure 8) and the Tobii Pro 2 kit to track eye trajectories, but this time in front of a big screen and a fixed distance.

Together with them a Funometer scale (Read et al., 2002) was also incorporated before and after interactions with each agent (see Figure 9).

More detailed information on the perceptions of agents by participants and statistical outputs available in Imashev et al. (2025a).

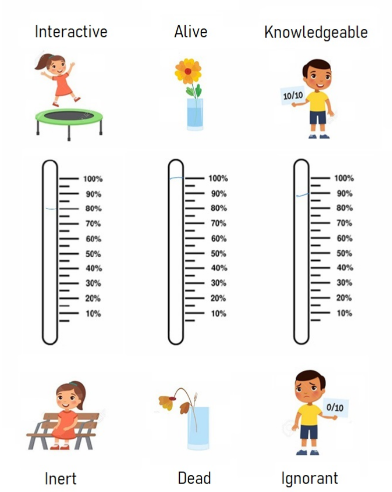

Figure 7: Godspeed questionnaire as visual thermometer scale provided with iPad tablet and stylus

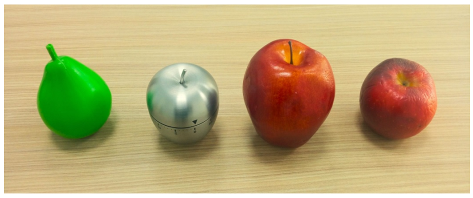

Figure 8: Tangible artifacts

Figure 9: Funometer used for mood pre- and post-evaluations before and after interaction with signing agents (SignMT, SiGML, proposed and human)

5. EASIER evaluation tool

The EASIER project (Picron et al., 2024; Dimou et al., 2022a,b) underscores the importance of engaging deaf people in the creation and assessment of signing avatars to improve their clarity and cultivate confidence among users of synthetic signing technology. The project seeks to establish a collaborative environment in which sign language users can offer comments during the avatar development process. The fundamental element of this initiative is a questionnaire-based methodology aimed at collecting insights from various sign language groups, notably focusing on users of Greek Sign Language (GSL), French Sign Language (LSF), German Sign Language (DGS), and Swiss German Sign Language (DSGS).

The technique comprises a systematic online questionnaire that evaluates essential performance factors, including the naturalness and comprehensibility of the signings performed by avatars. The questionnaire was based on the SUS questionnaire (Brooke, 2013) (with a 1 to 5 Likert scale from "Strongly disagree" to "Strongly agree") and has been designed to be user-friendly and accessible, allowing participants to offer feedback on different aspects and components of avatar performance. The preliminary pilot study (Dimou et al., 2022b) with GSL signers indicated a preference for the avatar "PAULA" over "FRANÇOISE" (Jennings et al., 2010), suggesting that PAULA's signing was regarded more natural and intelligible. The findings underscored the necessity for continuous user participation to further enhance avatars.

The results of the pilot user study indicate that although both L1 (native) and L2 (non-native) signers evaluated PAULA in a quite similar way, significant discrepancies were observed in their evaluations of FRANÇOISE. This suggests that L2 signers may have a more permissive perspective on average signing performance compared to L1 signers.

6. Results

The iterative outputs of the signing avatar evaluation methodology revealed that:

6.1. Online User Study

This subsection describes the results obtained in 4.1 conducted with avatar v1 (2.1).

All four agents executed sequences of sign language that exclusively incorporated open-palm signs, thereby facilitating a focused analysis of the effectiveness and reception of data-driven sign language representation. Specifically, Avatar 1 demonstrated the sign sequence "NOTHING NEW", Avatar 2 performed the "HELLO" sign twice, Avatar 3 communicated "IWILL STOP", and Avatar 4 conveyed "ILIKE FISH". Hearing interpreters acknowledged Agent 4 (see Figure 12 in Appendix A), the human interpreter, as the most adept in local sign language, while Agent 1 was seen as the least skilled in local sign language. Simultaneously, the deaf participants determined that Agent 4's sign language skill is marginally better than that of the other agents. This gap is speculated to arise from the fact that deaf users consider more than just hand configurations for communication (including non-manual markers); they may perceive that Agent 4 likely lacks expertise for particular signs she performed.

Table 2: Friedman test results over four agents, significant findings are in bold.

Measurement	Friedman test output
Fake - Natural	$\chi^2(3) = 43.795; p = 0.000.$
Machinelike - Humanlike	$\chi^2(3) = 39.281; p = 0.000.$
Moving elegantly - rigidly	$\chi^2(3) = 6.614; p = 0.085.$
Stagnant - Lively	$\chi^2(3) = 40.452; p = 0.000.$
Lifelike - Artificial	$\chi^2(3) = 8.955; p = 0.03.$
Mechanical - Organic	$\chi^2(3) = 42.022; p = 0.000.$
Like-Dislike	$\chi^2(3) = 6.060; p = 0.109.$
Competent - Incompetent	$\chi^2(3) = 6.944; p = 0.074.$
Pleasant - Unpleasant	$\chi^2(3) = 3.358p = 0.340.$
Unintelligent - Intelligent	$\chi^2(3) = 30.163; p = 0.000.$

Furthermore, a significant discovery from the online user study indicated that deaf natives had less optimism about avatar technology in contrast to hearing interpreters for live face-to-face translation, and they prefer the involvement of a human sign language agent-interpreter.

Additionally, Table 2 showed notable differences in six out of ten categories, which indicates that Agent 4 was perceived to be significantly more intelligent and realistic. These results revealed that significant advancements are necessary for our data-driven avatar to potentially compete with human agents in the future. This is how the iterative improvement started.

6.2. In-person User Study #1

This subsection describes the results obtained in 4.2 conducted with avatar v2 (2.2). For the first in-person user study, we compared a data-driven avatar (A1) with a manually animated avatar (A2) and a human agent (A3) (refer to Figure 10), which was comparable to the online study.

Figure 10: Signing agents used for this study from left to right: A1 - Data-driven avatar, A2 - manually animated avatar, and a novice human agent (A3).

In this instance, a novice human signer was involved and the decision is influenced by the lack of smoothness in the motions of both the data-driven and manually animated avatars, which appeared somewhat constrained. A comparison with a professional human signer may yield an unfair assessment, favoring the human signer significantly. They performed 12 different signing phrases (see Table 3). These phrases were designed to attain balance in handshapes, the number of signs used in each sentence, and the cumulative complexity of the phrases.

Table 3: Sign sentences (as gloss sequences) performed by characters.

Level	Avatar 1 (data-driven)	Avatar 2 (manually animated)	Human Agent
Easy1	YOU HUNGER	YOU WORRY	YOU GLAD
Easy2	YOU LIKE FISH	YOU BORN EARLY	YOU WANT WALK
Med.	YOU LIKE RAIN	WHERE YOU HOUSE	YOU HOUSE KEEPER
Hard	WHICH YOU NUMBER PHONE	YOU HAVE DEAF RELATIVES	YOU DO SEW FACTORY

Cronbach's Alpha for the Human agent did not result in excellent internal consistency, as seen in Table 4, suggesting that individuals exhibited variability in their evaluations of the human agent.

Table 4: Godspeed Questionnaire mean and Cr.α valued (in brackets).

	A1	A2	Human agent
Anthropom.	**0.75** (1.4)	**0.71**(1.5)	0.6 (3.9)
Animacy	0.59 (1.4)	**0.82** (1.5)	0.53 (3.9)
Intelligence	**0.87** (1.9)	**0.77** (2.2)	0.45 (3)
Likeability	**0.99** (3.85)	**0.89** (3.5)	**0.78** (2.9)

Anthropomorphism and Animacy received a score of 3.9 out of 5, intelligence was scored at 3 out of 5, and likability was assessed at 2.9 out of 5. The phenomenon may arise because participants still needed further elaborations for enhanced explanations of closely related concepts, possibly interpreting knowledge of sign language as general intelligence or realism as questioning whether an individual is an actual interpreter rather than inquiring about being human.

The agents were shown on a laptop screen, and some participants recommended moving the screen's location to improve accessibility. Instances occurred when the screen size limited the participants' capacity to scrutinize the entire agent in depth, resulting in a focused concentration on the agent's center (see Figure 13 a and b in Appendix A) with little eye movement.

Presbyopia or age-related farsightedness was not expected. It caused a challenge twice when calibrating the glasses before the experiment began. This problem became apparent when the tracker's trajectory reflected the movements of agents' hands, despite being located in vacant areas of the screen. The participant's attention on the agents' hands is definitely apparent, but their focus on the agents' faces lacks comparable clarity (see Figure 13 c in Appendix A). Two instances of presbyopia were observed and subsequently excluded from the average heatmap composition; despite this, the questionnaire responses of the corresponding participants were included in the analysis.

6.3. In-person User Study #2

This subsection describes the results obtained in 4.3 conducted with avatar v3.1 (2.3). For the user study #3 (second in-person user study), the proposed signing avatar was compared with two existing solutions and the professional human CODA signer, the sentences performed are listed in Table 7 in Appendix A. One of the questionnaire sections was dedicated to asking participants how they understood the signings performance of agents. The numbers revealed that the participants understood the SiGML avatar slightly (non-significantly) (see Table 5): the results of the Dependent T-test indicated that there is a non-significant difference between comprehension of SiGML and aiSL-a: $t = -1.2, p = 0.268$.

Table 5: Evaluation on how participants understood agents.

Agent	**Mean (SD)**	**Shapiro-Wilk test**
SignMT	37.59 (15.61)	$W = 0.897, p = 0.243$
SiGML	89.70 (7.28)	$W = 0.9194, p = 0.4142$
aiSL-a	84.56 (9.02)	$W = 0.9439, p = 0.683$
Human	98.78 (3.67)	$W = 0.39, p < .001$

Despite the fact that the proposed avatar looked and performed more natural and less robotic (see Table 6).

Table 6: Mean values(SDs) for Sorting Task

Measure	**SignMT**	**SiGML**	**aiSL-a**	**Human**
Anthrop.	1,09(0.17)	2,2(0.28)	2,71(0.36)	4(0.0)
Animacy	1,22(0.3)	2,11(0.4)	2,78(0.32)	3,83(0.3)
Likeability	1,69(0.77)	1,89(0.58)	2,53(0.52)	3,89(0.23)
Intelligence	1,13(0.22)	2,18(0.40)	2,71(0.41)	4(0.0)

Based on heatmaps of interactions, more natural signings led deaf signers to focus on the interlocutor's head, meaning this effect may take place not only when deaf signers are communicating with human agents (which has been proven by Emmorey et al. (2009)), but with signing characters, too. In contrast, the less natural-looking Agent 1 had been watched mainly on hands (see Figure 14 in Appendix A).

Regarding the evaluation scales, both the Sorting Task and the Thermometer scale presented distinct advantages as assessment tools for signing agents. The Thermometer scale (0 - 100) revealed significant disparities between the human agent and other avatars in all categories, while the Sorting Task (which ended up conceptually similar to 1 - 5 Likert-scale) results offered a more readily apparent preference ranking among the signing agents (see Figure 11).

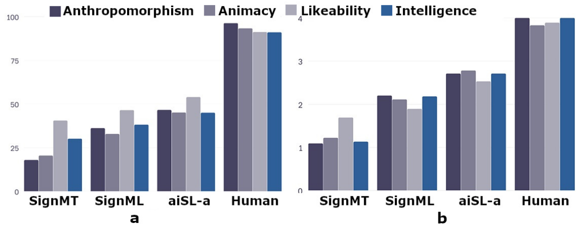

Figure 11: Visual comparison of Godspeed Thermometer(a) and Godspeed (b) Sorting Task means.

7. Limitations

It is highly preferable to conduct user studies with a larger number of people. Recruiting 30 or more participants (as stipulated by the Central Limit Theorem) to utilize the statistical methods allowed for normal distribution is still consistently problematic.

In our cases, native deaf female and younger signers often exhibited a greater willingness to participate in user studies, which influenced the imbalance. Each time we recruited different participants to avoid bias from previous interactions, it was quite challenging to involve participants due to the insular nature of the deaf community; establishing trust is also a long-lasting process. We hope that future familiarity with the research team and the participation of native deaf signers in the research will increase the interest and motivate more people to provide their feedback.

The results of three studies indicate the necessity of establishing a section titled “Perceived SL Expertise” in lieu of “Perceived Safety” from the Godspeed questionnaire, as the two questions pertaining to this subject in one particular case are insufficient to warrant a separate section of the questionnaire.

8. Conclusions and Future Work

Despite the fact that the proposed avatars already perform quite understandably and cover the demerits of other solutions, such as finger articulation, natural eye blink, mouthing, and smooth motions, and the aforementioned methodological explorations have already been appreciated in (Chemnad and Othman, 2025). The entire outcomes suggest the following for further improvement:

- A separate section for exterior attributes might be required. It is essential to consider including characteristics such as charisma and outfits, as shown in (Kipp et al., 2011b), to evaluate the likability of avatars.

- To formulate inquiries for the newly designated area titled Perceived SL Expertise.

- Concise phrases fail to convey a comprehensive understanding of signing avatars’ technical capabilities; hence, short tales, fairytales, or historical essays are more suitable for being performed by signing avatars.

- To provide additional artifacts or concepts in the central sections for all 100-point scales in the questionnaire.

- It is highly recommended to conduct follow-up research using more signing avatars and a larger pool of participants.

- The participation of a deaf interpreter as a member of the research team throughout the preparatory stages and the user studies itself will also be advantageous.

- A Text-To-Gloss LLM model trained to convert written text to proper word order gloss sequences, which will be comprehensible by native deaf signers, is needed for natural signing performance production by avatars.

Compared with the proposed questionnaire, EASIER online evaluation tool required about 20 minutes vs. 40 minutes in Online User Study, making it easier to follow and less oppressive for the participants. Moreover, despite the methodological similarities with the user studies performed, substantial discrepancies were overlooked in the conceptualization of these studies contrasted to EASIER, wherein participants were tasked with assessing fingerspelling, individually chosen lemmas, brief signing sequences incorporating the selected lemmas, and static visuals representing emotions, all of which offer a more nuanced understanding of the possible disadvantages of avatars to be assessed.

The implementation of 100-point scales in the proposed questionnaire allowed for a more nuanced and sensitive evaluation compared to the 1-5 Likert scale (see Figure 11). Although a 5-point scale is appropriate for a larger sample size with normally distributed data (Westland, 2022), some methodological adjustments are required for small groups (Gaworski and Dańko, 2026); a higher number of points may allow the capture of subtle differences in opinions and experiences that a simpler scale may overlook (Preston and Colman, 2000; Finstad, 2010; Diefenbach et al., 1993).

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A. Supplementary materials

Figure 12: Signing agents used for online user study: Agent 1 and Agent 2 are two options of the v1, Agent 3 is a manually programmed avatar created CUNY ASL program, signs that have meaning on KRSL were trimmed from a pre-recorded video, Agent 4 is an apprentice local sign language user

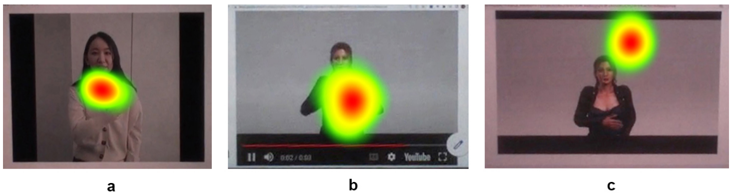

Figure 13: Examples of when image size is small enough to cover whole agent by eyes (a and b); Eye gaze shifted due to presbyopia (c).

Table 7: Sign sentences (as gloss sequences) performed by characters.

Stick Figure Agent (SignMT)	SiGML avatar Anna	aiSL-a (proposed Data-Driven Avatar)	Human Agent
BIG AND GREY ELEPHANT	NEED LAW DOCUMENT/PAPER	I LIKE RAIN	YOU WATCH YOUTUBE
I AFRAID WOLF	DO SEWING STAFF	WHICH YOUR TELEPHONE NUMBER	WEATHER TODAY HUMID
BEAR EAT BERRIES	I DRINK COFFEE	I HOUSE KEEPER	WHICH YOUR FAVOURITE MOVIE

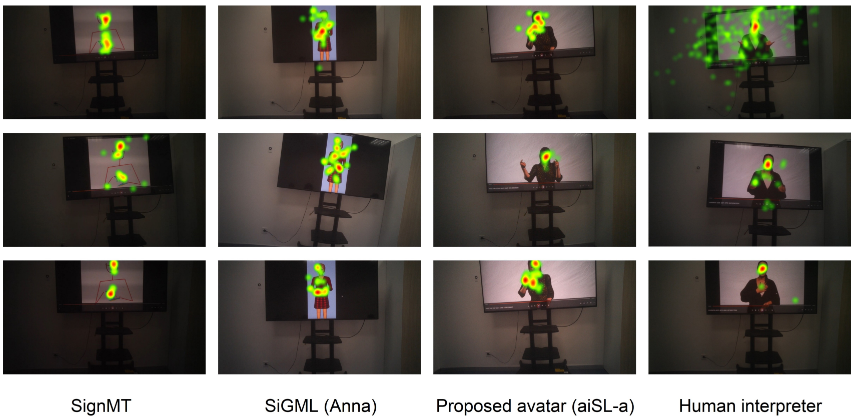

Figure 14: Averaged eye-tracking visualizations of participants' interaction with each agent.

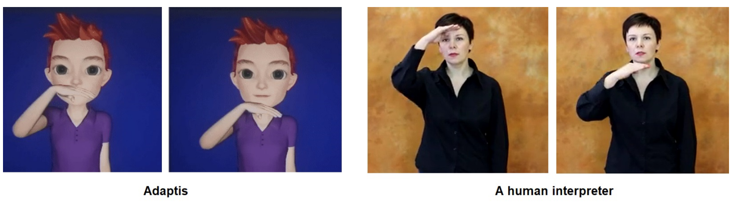

Figure 15: Comparison of the sign DAD of RSL is performed by Adaptis avatar and a human interpreter