The Effect of Handshape Complexity on M2 Lexical Acquisition for First-Time Learners in Chinese Sign Language

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Abstract: The influence of certain parameters of sign language phonology has long been under investigation. Sign language phonology mainly includes handshape and movement. Prior research has focused on the immediate reproduction of signs, with limited attention to long-term memorization. This gap necessitates examining how handshape complexity affects the retention and acquisition of sign language vocabulary over time. To address this gap, this study applied Boyes-Braem's ASL-based classification for handshape markedness to categorize CSL handshapes. Questionnaires were sent to over 200 participants, asking them to guess the meanings of our selected stimuli signs, and research members assessed iconicity using a systematic scoring method. Consequently, eight Mandarin-speaking and sign-naive participants aged 15-16 were recruited and randomly divided into control and experimental groups. The experimental group received reinforced learning sessions, while the control group did not. This study measured accuracy in sign reproduction across different stages of markedness, both short-term and long-term. Our findings indicate that handshape markedness negatively affects lexical acquisition while iconicity enhances it. Reinforced learning methods also significantly improved long-term retention. These results suggest that effective pedagogical strategies for CSL should account for handshape complexity and iconicity.

Keywords: M2 acquisition, Chinese Sign Language (CSL), Handshape Markedness, Iconicity, Lexical acquisition

1. Introduction

Learning a different language, especially in a different modality, like sign language, can present unique challenges. When learning sign languages, many learners find some signs easier to perform than others. Subsequently, people remember the signs to a different extent. Early studies on the sub-lexical structure, or phonology, of sign languages characterized signs using four main parameters: handshape, location, movement, and orientation. More recent theories have shown that while these parameters are practical, analyzing signs at a more detailed feature level provides deeper insights into the organization and complexity of sign phonology [1]. Much research has investigated how sign phonology affects the immediate reproduction of signs, but fewer studies have focused on long-term

memorization. This study aims to bridge this gap by exploring how handshape complexity, or markedness, impacts the long-term retention of Chinese Sign Language (CSL) signs among Mandarin-speaking learners with no prior sign language experience.

2. Literature Review

2.1. M1 and M2 Acquisition

This research examines the process of learning sign language as a second language (L2) in a different modality (M2). Specifically, it addresses learners whose first language (L1) is spoken and who are acquiring sign language as their L2 using a different communicative channel. M2 learners approach sign language acquisition differently from those learning it as an L2 within the same modality (M1), as they must adapt to expressing language in a novel way. Unlike M1 learners, who are already accustomed to using the visual-gestural modality, M2 learners face the challenge of learning an entirely new mode of expression [2].

M2 learners may find it more challenging to acquire sign language than M1 learners because they need to adjust to the visual-gestural modality, which involves using body language, facial expressions, gaze, and other non-verbal cues [3]. Their existing motor skills, particularly in their fingers, hands, and arms, are already established, but they need to learn how to use them differently to produce signs accurately.

Another aspect of learning is the role of gestures. In spoken languages, gestures often accompany speech as co-speech gestures, sometimes enhancing or replacing verbal communication [4]. Research suggests that this gestural knowledge from spoken languages can be advantageous for M2 learners in acquiring sign languages [5-8].

2.2. Sign Complexity

Markedness refers to the relative frequency and complexity of linguistic features [9]. In the context of sign language, marked handshapes are less common and more complex, while unmarked handshapes are more frequent and simpler. The classification of handshapes into marked and unmarked categories is supported by several studies [10-14].

Boyes-Braem categorized American Sign Language handshapes according to her proposed sequence of L1 sign acquisition [12]. She suggested that the first handshapes to be acquired by a Deaf infant are those that only involve movement of the hand as a whole, as well as those that only manipulate the index finger and thumb – the two most anatomically independent fingers, such as the signs “A” “S” and “L” in ASL. More complex handshapes are acquired further along the learning process. Considering the anatomical features of infants’ hands and their cognitive abilities, Boyes-Braem divided the sequence into stages numbered 1 to 4 (Table 1), with higher stage numbers representing increasing difficulty in L1 handshape acquisition and, thus, a higher degree of handshape markedness. Similarly, Ann studied markedness in Taiwan Sign Language using an algorithm based on five anatomical criteria [10]. Depending on the resulting scores, handshapes are classified into different categories based on ease of articulation. Ann’s 2006 studies on TSL handshape markedness largely aligned with Boyes-Braem’s 1990 ASL classification.

Each sign language has its inventory of occurring handshapes, which varies across sign languages [15-18]. However, the set of hand configurations based on human anatomy, as identified previously, potentially occurs universally across sign languages [12, 19-24]. As a result, this study uses the metric for handshape markedness originally designed for ASL to choose our signs in CSL.

Table 1: Boyes-Braem Hierarchy of Handshape Markedness [12]

Markedness	ASL Signs	Handshape Description
Stage I	A, S, L, bO, G, 5, C	Beginning with unmarked A, the extension of the hand as a whole and independent manipulation of the radial finger group are developed.
Stage II	B, F, O	The extension is applied to the ulnar finger group; the thumb contacts other fingers or is the only unselected finger.
Stage III	I, Y, D, P, 3, V, H, W	Individual fingers in the ulnar group are manipulated.
Stage IV	(8, 7), X, R, (T, M, N)	Ulnar fingers are activated and inhibited independently; 2° features cross and insertion are applied. [25]

2.3. Iconicity and Transparency

Iconicity, the resemblance of a sign and its representations of the form, shape, or action of reality, is a prominent feature in sign languages. It is found to have both positive and negative effects on M2 learners. Ortega and Morgan identified both the benefits and drawbacks of iconicity for M2 learners of British Sign Language (BSL) [26,27]. The iconic nature of the signs facilitated easier comprehension and memorization of signs by associating them with real-world concepts [28]. However, iconicity tended to lead learners to overlook the correct phonological execution of signs, likely because they perceived the signs as "easy." Further studies have also confirmed these effects of iconicity [29]. The prior analysis indicated that while iconicity enhances the conceptual-semantic understanding of signs, it does not improve their linguistic structure.

Transparency refers to one's ability to infer the meaning of a sign solely based on its form [21]. Studies have found positive correlations between iconicity and transparency, though in some signs, this association is only modest [30].

2.4. Lexical Acquisition

Lexical acquisition, also known as vocabulary learning, is part of language acquisition that involves acquiring the connection between a word or sign and its meaning. It is distinct from imitation, which does not involve learning and memorizing the meaning. Lexical acquisition can be divided into two types: incidental and deliberate. The former occurs in casual communication and depends on context, while the latter occurs in explicit vocabulary learning [31,32]. Gu also identified multiple strategies for lexical acquisition, including consulting dictionaries, note-taking, and rote rehearsing.

Namy et al. tested infants' symbol-to-referent mapping by gesturing a representation of a toy and instructing participants to pick out the specific toy afterward [33]. Morett assessed ASL lexical acquisition by instructing participants to reproduce previously learned signs upon hearing the verbal translations [34]. She also investigated short-term and long-term retention by conducting experiments at different times. This study draws on these studies and Pichler's 2011 research on sign imitation [25] to examine deliberate lexical acquisition.

2.5. The Current CSL Study

Chinese Sign Language (CSL) encompasses all sign language variants used by the ethnically diverse deaf communities in mainland China, excluding Tibetan Sign Language. The two main dialects are Northern CSL and Southern CSL, which were directly influenced by American Sign Language (ASL) and French Sign Language (LSF), respectively [35]. CSL incorporates fingerspelling and tracing Chinese characters strokes in the air, reflecting various cultural influences on the language.

Defining a standard "Chinese National Sign Language (CNSL)" has been a long-term challenge [36,37]. Introduced in 2018 by the Ministry of Education and the China Disabled Persons Federation, the most recent language standard replaced the 2003 version [38], which did not satisfy the needs of the deaf communities [39]. This study uses the new 2018 standard.

Sign language research in mainland China started relatively late, focusing on phonology, morphology, syntax [40], and language technology (e.g., [41]). Language acquisition has been somewhat overlooked in the CSL context. Similarly, though previous studies on language acquisition have explored its various aspects, there is limited understanding of how handshape complexity affects lexical acquisition in an M2 context. This study aims to fill this gap by investigating the impact of handshape complexity on deliberate lexical acquisition of CSL signs among Mandarin-speaking first-time learners.

3. Method

3.1. Materials

This study applied Boyes-Braem's ASL-based classification methodology to CSL handshapes for experiment stimuli. The stimuli set was narrowed down to 12 CSL signs, which can be divided into four balanced groups of 3 signs concerning the markedness of its handshape (see Table 3, Page 8). For other parameters of sign language [42] to be controlled, this study limited the location of selected signs to the neutral space, the movement to linear or shaking movements, and non-manual markers to none or inconspicuous. Iconicity was initially controlled by ensuring that six signs were relatively iconic and the other half were un-iconic.

Twelve videos of each stimuli sign were extracted from the official CSL dictionary application by screen recording. All twelve videos had the same composition format, and each video consisted of one demonstration at 1x speed and another in slow-motion playback by the same signer. At the beginning of the video, all possible definitions of the sign were displayed on the side in Simplified Chinese and read out in Mandarin Chinese.

As "fillers," three podcasts [43], [44], [45] and one video [46] were chosen. They discussed the deaf community's status quo, personal experiences, and different perspectives on sign language.

3.2. Questionnaire

3.2.1. Participants

To accurately determine and control the iconicity of stimuli signs, a word-guessing Wenjuanxing questionnaire (https://www.wjx.cn/vm/Q0UX2gH.aspx) was sent via WeChat. The only criterion for participants was not having any previous knowledge of sign language. In limiting their experience, this study elicited and examined their first-time sign-referent associations in an M2 language. 236 valid responses were recorded. Participants ranged from 15 to 65 years of age (M_{age} = 44.48, SD_{age} = 12.26) with mixed experiences living in different countries and no previous experience in sign language. This study allowed such an expansive demographic to determine iconicity comprehensively.

3.2.2. Stimuli & Procedure

The twelve CSL videos were edited to crop out the definitions and were converted to GIF format. Each GIF was included in the questionnaire, and an open-ended answer box was provided below. Participants were asked to guess the meaning of each sign and type their best guess into the answer box.

3.2.3. Coding

To statistically analyze the data on iconicity, this study employed a systematic scoring method for each participant's response. Specifically, answers that directly included the keyword were assigned 2 points (e.g., "注意看 (to look attentively)" for the keyword "看 (to look)"). Responses that required some associative thinking to link to the keyword were given 1 point (e.g., "瓶子里面空了 (the bottle is empty)" for the keyword "没有 (nothing)"). Answers that bore no relation to the keyword were assigned 0 points. Both researchers independently examined and scored the responses. The cumulative scores from both researchers were again tallied for each word to determine whether they could be classified as iconic or un-iconic.

3.3. Experiment

3.3.1. Participants

Experiment participants were required to be in the 14-18 age range, considering any effects of age on motor control and lexical acquisition skills. Through another Wenjuanxing questionnaire (https://www.wjx.cn/vm/exe7REY.aspx) sent in WeChat, eight Mandarin-speaking participants (six females) were recruited, 7 of whom were 16, and one was 15. All participants were from a Chinese background and had no experience living outside mainland China, so the effect of transfer from conventional gestures was similar across participants. Moreover, all participants were right-handed and had no physical or mental disorders. Importantly, this study ensured that none had participated in the iconicity questionnaire and had no previous knowledge of sign language to replicate the early stages of M2 acquisition. This selection enabled us to draw conclusions based on the perceptual processing of signs without interacting with already established lexical items.

Participants were equally and randomly divided into two groups: the experimental group, which reflected memory retention with the typical rote rehearsal technique, and the control group, which reflected pure long-term memory retention without reinforcement.

3.3.2. Procedures

The three-day experiment procedure (Figure 1) consisted of five Tencent Meeting sessions scheduled with each participant individually. In teaching sessions, participants engaged in deliberate lexical acquisition of all twelve signs. They were required to reproduce a sign after being shown the corresponding video, and the researchers corrected them until their reproduction was deemed accurate. In testing sessions, participants were required to accurately reproduce a sign based on memory upon hearing its Chinese definition; mistakes were also corrected afterward. The order of signs being taught or tested was randomized every session by ChatGPT. In interview sessions, participants were asked the same questions about the same materials sent in session intervals. Each participant had their first session and last test at the same time of day.

Considering the effect of idiosyncratic revision habits, this study refrained from informing participants of any impending tests. The participants received instructions (see Appendix) which intentionally provided misleading and corroborating information. As shown in Fig. 1, expected and unexpected tasks were spread out in both groups' agendas. Ideally, this pattern confused them about the actual procedure and discouraged them from practicing after sessions, thereby minimizing the influence of idiosyncratic revision habits on participants' performance. In addition, the "filler" podcasts acted as distractions from potential revisions in session intervals. We ensured that the participants would pay attention to the "fillers" by informing them that there would be questions during the interviews.

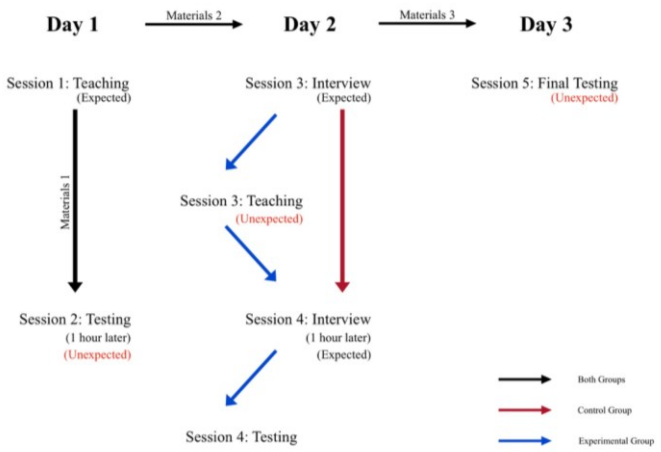


Figure 1: Experiment Procedure Chart

3.3.3. Coding

In the analysis, accuracy was measured solely based on handshape. Participants' attempts were classified as "Accurate" if the handshape was precisely correct or allophonically the same, as "Erroneous" if there were errors in finger selection and finger position that were not allowable allophonic errors, and as "Forgotten" if the participant failed to reproduce anything. The Accuracy Percentage is calculated as the number of accurate attempts divided by the total number of attempts.

4. Results

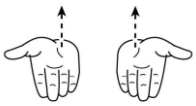
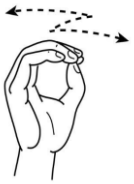
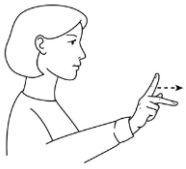
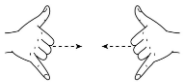
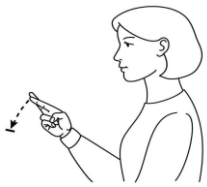
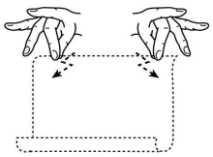
4.1. Questionnaire

The summed iconicity scores from 236 questionnaire responses are shown in Table 2. The stimuli set with the iconicity is shown in Table 3.

Table 2: Iconicity score

Iconic		Un-iconic	
Sign Meaning	Score	Sign Meaning	Score
TO LOOK	789	TO BE	67
TO GET UP	699	SWALLOW, bird	6
TO WASH	679	PENCIL	4
NOTHING	182	PAPER	4
CAT	177	TO BORROW / TO LEND	3
TO MEET	108	SIDE BY SIDE	0

Table 3: Stimuli Set with Iconicity

Markedness	Stimuli Signs		
Stage I	并排 (SIDE BY SIDE)	铅笔 (PENCIL)	洗 (TO WASH)
			
Stage II	起来 (TO GET UP)	没有 (NOTHING)	猫 (CAT)
			
Stage III	借/租 (TO BORROW / TO LEND)	看 (TO LOOK)	相遇 (TO MEET)
			
Stage IV	是 (TO BE)	燕子 (SWALLOW, bird)	纸张 (PAPER)
			

Note. Red text indicates iconic signs, and black text indicates un-iconic signs. Sign pictographs are from the CSL dictionary application [47].

4.2. Experiment

Each participant's performance was measured in their accuracy in the reproduction of signs one hour after first-time learning and on the final day, respectively.

4.2.1. One Hour After First-Time Learning

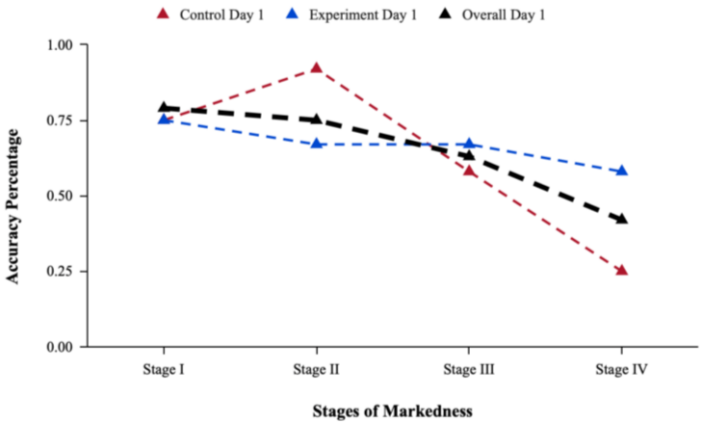


Figure 2: Accuracy Percentage on Day 1, Session 2

From the graph, it is clear that there is a downward trend for accuracy as the stages of markedness increase. As the level of markedness goes up, people remember the signs less accurately, which preliminarily proves our hypothesis that the markedness of handshape negatively affects the acquisition of these vocabularies. However, there is a dent in Stage II for both the control group and overall performance, which will be explained further in the paper.

4.2.2. Final Testing

Data on participants' attempts was again collected on the final day. The combined accuracy of the control and experimental groups on Day 3 was not studied since they did not receive the same treatment.

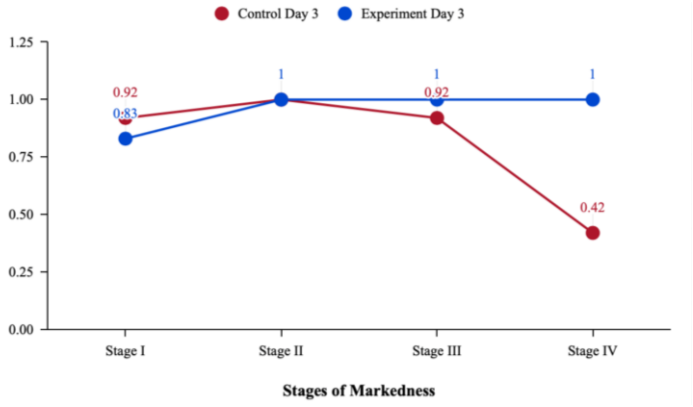


Figure 3: Accuracy Percentage on Day 3, Session 5

The data from the control group performed similarly to the data obtained on Day 1, indicating that it is harder for people to retain the vocabulary as handshape complexity increases. However, a different trend was observed for the experimental group that received rote rehearsal reinforcement. The participants remembered the signs from Stages II-IV perfectly and made few mistakes in Stage I. This is probably because the participants repeatedly learned the signs, which caused a ceiling effect where the stages of markedness no longer affected their accuracy in performing the signs.

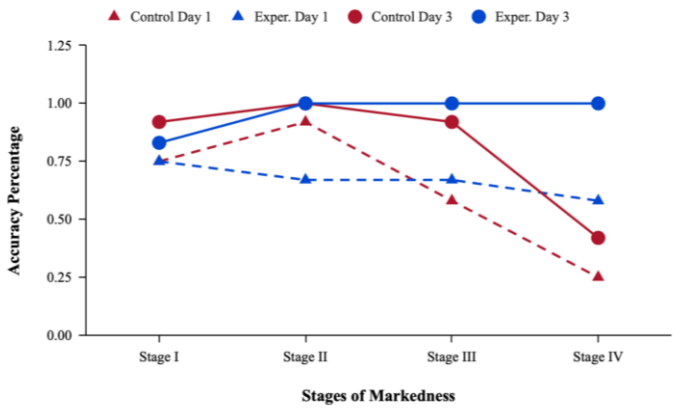


Figure 4: Accuracy Percentage across Days 1 & 3

The graph compares accurate attempts between the first and last days of this study, focusing on the percentage of accurate attempts across different stages of markedness for both control and experimental groups. The graph shows that both groups demonstrated a relatively higher Accuracy Percentage on the third day than on the first. This trend indicates that participants improved their retention and recall of signs over time.

Participants were not informed about impending tests, which likely discouraged intentional memorization. However, once they were aware of the testing, they subconsciously prepared for it, including those in the control group who did not receive additional study sessions. The testing itself also acted as a reinforcement tool, as participants were corrected during the process. After final testing, many participants revealed that they had reviewed the signs independently, contributing to the higher Accuracy Percentage observed. This finding aligns with our research question by demonstrating the impact of reinforced learning and self-study on the lexical acquisition of CSL signs.

4.2.3. The Role of Iconicity

Even though the number of iconic signs was slightly balanced in the selected set, iconicity still played a significant role in sign acquisition. The previous graphs revealed an interesting dent where the Accuracy Percentage of the reproduction of Stage II signs appears to be higher than that of Stage I, which, according to our hypothesis that states it is harder to remember when handshape complexity increases, should be impossible. This anomaly can be explained by the varying iconicity between the stages. Stage I contained more un-iconic signs than Stage II, which could have made these signs harder to remember [27]. As a result, even though the number of iconic signs was controlled, the higher proportion of iconic signs in Stage II likely contributed to better retention and recall, overshadowing the expected ease of learning unmarked handshapes in Stage I.

The low Accuracy Percentage of Stage IV can also be explained by its complex handshape and because all the signs are considered un-iconic, making them harder to remember.

Our experiment also indicates that people remember iconic signs better, as the Accuracy Percentage for iconic signs is higher than for non-iconic signs.

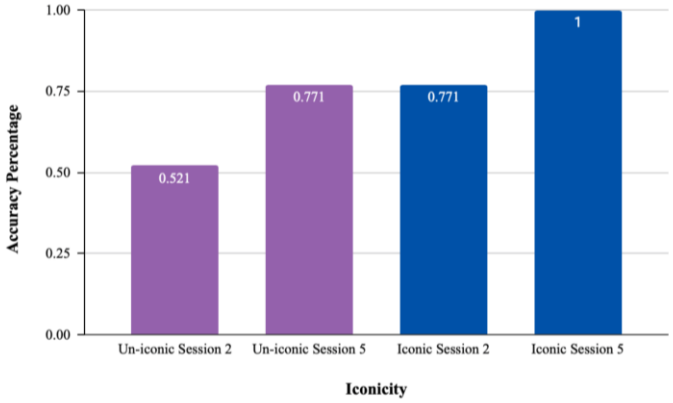


Figure 5: Overall Accuracy Percentage regarding Iconicity

This finding underscores the importance of iconicity in the acquisition of sign languages, suggesting that the visual-semantic relationship of signs can significantly enhance learning outcomes, particularly for first-time M2 learners.

5. Conclusion

5.1. Critiques

This study recognizes some shortcomings that should be improved in future studies. Firstly, stimuli signs differed in iconicity, which influenced participants' performance. Sign language parameters were also inconsistent across stimuli. Movement differed in certain signs, orientation changed in "SWALLOW," and non-manual markers were involved in "CAT." Consequently, the results cannot conclusively determine the sole effect of handshape complexity on deliberate lexical acquisition.

Secondly, our questionnaire measured the transparency of signs rather than their iconicity, which is more relevant to the experiment. Although these two measurements have been proven to be positively correlated in a large data set, the same situation cannot be guaranteed for our 12 stimuli.

Thirdly, this study recruited only a limited number of 8 participants due to the highly selective criteria. Any widely idiosyncratic learning habits or skills could render our statistical data, especially the overall Accuracy Percentage, unrepresentative of the general situation. The participant demographic was also too restricted for a generalization across all M2 learners.

Finally, this study observed that participants gestured number 10 differently despite being from similar cultural backgrounds; one of these gestures was the same as the handshape of "IS" in our stimuli set. Hence, different transfer effects potentially occurred across participants.

5.2. Conclusion

This study demonstrated the effect of handshape complexity on M2 lexical acquisition in first-time CSL learners, identifying iconicity as another significant contributing factor.

Our questionnaire found that our stimuli signs exhibited varying degrees of iconicity and transparency, which aligns with previous research.

In our experiment, conclusions can be made regarding handshape complexity and deliberate lexical acquisition methods. Experiment data from the testing sessions consistently showed a negative correlation between handshape complexity, measured by stages of markedness, and the overall percentage of accurate sign reproduction attempts. This suggests that markedness inhibits the precise acquisition of signs, also implying that Boyes-Braem's 1990 anatomy-based hierarchy also applies to M2 acquisition though initially backed by observations in L1 acquisition. Of particular interest was

an upward dent seen in two data sets: as the number of iconic signs in the group increased from markedness Stage I to II, the Accuracy Percentage also rose despite the handshape becoming harder to articulate. This reflects the significant role iconicity played in participants' lexical acquisition. The positive effects of iconicity observed in this study align with the findings of Ortega and Morgan [26-27] and Baus et al. Moreover, in comparing data of the experimental control groups from the last testing, this study determined that the commonly used rote rehearsal technique has an efficacious reinforcement effect on deliberate lexical acquisition, highlighted by the single inconsistent data where the ceiling effect in accuracy was observed in the experimental group after two teaching sessions, meaning that complexity no longer affected their high-level performance.

5.3. Applications

The deaf communities are large, yet they are still obscure to the general public. We believe any sign language research has the potential to shed light on and raise awareness of the deaf communities.

This study increased the deaf awareness of our participants through teaching stimuli signs and recommending podcasts. During interviews, participants recognized some implicit biases, reported closer psychological distance to the deaf communities, and indicated a willingness to continue learning sign language. Additionally, the results of this study provide insights into the effect of handshape complexity on M2 lexical acquisition from the CSL perspective. They can also contribute to refining pedagogical approaches for the education of hearing sign language learners. As a last note, we hope this study can inspire and propel further research in CSL and M2 sign language learning to improve accessibility and inclusivity for the deaf communities in China.

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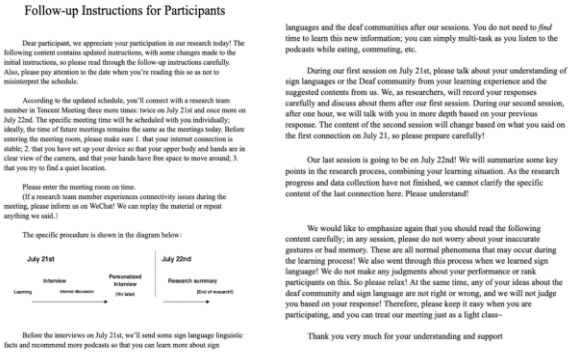
Appendix

Participant Instructions



Follow-up Instructions for Participants

Dear participant, we appreciate your participation in our research today! The following content contains updated instructions, with some changes made to the initial instructions, so please read through the follow-up instructions carefully. Also, please pay attention to the date when you're reading this so as not to misinterpret the schedule.

According to the updated schedule, you'll connect with a research team member in Tencent Meeting three more times: twice on July 21st and once more on July 22nd. The specific meeting time will be scheduled with you individually; ideally, the time of future meetings remains the same as the meetings today. Before entering the meeting room, please make sure 1. that your internet connection is stable; 2. that you have set up your device so that your upper body and hands are in clear view of the camera, and that your hands have free space to move around; 3. that you try to find a quiet location.

Please enter the meeting room on time.
(If a research team member experiences connectivity issues during the meeting, please inform us on WeChat! We can replay the material or repeat anything we said.)

The specific procedure is shown in the diagram below:

July 21st
Interview
Learning
Internal discussion
Personalized Interview
(1hr sited)
July 22nd
Research summary
(End of research)

Before the interviews on July 21st, we'll send some sign language linguistic facts and recommend more podcasts so that you can learn more about sign languages and the deaf communities after our sessions. You do not need to *find* time to learn this new information; you can simply multi-task as you listen to the podcasts while eating, commuting, etc.

During our first session on July 21st, please talk about your understanding of sign languages or the Deaf community from your learning experience and the suggested contents from us. We, as researchers, will record your responses carefully and discuss about them after our first session. During our second session, after one hour, we will talk with you in more depth based on your previous response. The content of the second session will change based on what you said on the first connection on July 21, so please prepare carefully!

Our last session is going to be on July 22nd! We will summarize some key points in the research process, combining your learning situation. As the research progress and data collection have not finished, we cannot clarify the specific content of the last connection here. Please understand!

We would like to emphasize again that you should read the following content carefully; in any session, please do not worry about your inaccurate gestures or bad memory. These are all normal phenomena that may occur during the learning process! We also went through this process when we learned sign language! We do not make any judgments about your performance or rank participants on this. So please relax! At the same time, any of your ideas about the deaf community and sign language are not right or wrong, and we will not judge you based on your response! Therefore, please keep it easy when you are participating, and you can treat our meeting just as a light class~

Thank you very much for your understanding and support

Note. The Initial Instructions for Participants document is similar to the Follow-up Instructions for Participants document and has been purposely omitted.