“Try Your Best”: Parent Behaviors During Administration of an Online Language Assessment Tool for Bilingual Mandarin-English Children

Yao Du

University of California, Irvine
Irvine, CA, USA
yaod7@uci.edu

Li Sheng

University of Delaware
Newark, DE, USA
lsheng@udel.edu

Katie Salen Tekinbas

University of California, Irvine
Irvine, CA, USA
ksalen@uci.edu

ABSTRACT

The world is becoming increasingly multilingual. In the U.S., despite rapid growth in linguistic diversity, there is a complete lack of multilingual language assessment tools and a severe shortage of multilingual clinicians to detect language impairments among children who speak minority languages. To develop accessible child language assessment tools, we designed MECO-LAB, a web-based bilingual Mandarin-English assessment that uses parents as one of the potential groups of test administrators. We analyzed 16 videos of child-parent dyads and found that with minimal instructions, the majority (11 out of 16) of parents were capable of administering MECO-LAB to their children. We identified 296 interference and 381 support behaviors from parents that are influenced by linguistic, cognitive, emotional, and technical factors that researchers should consider when designing online language assessments. We proposed design recommendations for supporting child-parent interactions in similar applications that enable parents to administer online bilingual language assessments to their children.

Author Keywords

Empirical studies in HCI; user studies; parent child interaction; web-based language assessment.

CSS Concepts

• **Human-centered computing** → **Human computer interaction (HCI)** → **Web-based interaction**.

INTRODUCTION

Early identification of developmental language disorder, a prevalent but hidden disability that causes difficulties speaking and/or understanding language, is critical for young children. Failure to diagnose language impairments can negatively impact children’s overall communication abilities (e.g., listening, speaking, reading, and writing), academic achievement, and social relationships [6, 9, 49]. In the United

States, bilingual children who are simultaneously learning two or more languages comprise 27% of preschool children and 22% of school children [51]. Evidence-based practice guidelines stipulate that bilingual children should be assessed in both or all languages by trained bilingual or multilingual speech language pathologists to determine the presence of a language delay and/or impairment. However, standardized bilingual assessment tools are only available for Spanish-English speaking bilinguals; resulting in over-, under-, and misdiagnosis of many minority children [33].

Developing standardized bilingual language assessments is challenging because of the difficulty in obtaining a large sample of participants for minority languages. For instance, although Chinese (Mandarin) is the most spoken language in the world and the second most spoken minority language in the U.S. (after Spanish), there are currently no assessment tools available for Mandarin-English speaking children. Even when an assessment is developed, it can be difficult for parents to gain access to bilingual clinicians who can conduct the assessment. Most bilingual service providers reside in population-dense states (e.g., California, Texas, New York), which poses additional barriers in accessing interpretation services for children and families in rural areas [2]. These complex issues (e.g., lack of assessment tests and service providers) often result in delays and inaccuracy in diagnosis and treatment for bilingual children and perpetuate health disparities for bilingual families [20].

This paper focuses on the behaviors of parents, a potential group of test administrators, while they supervised their children who complete a bilingual language screening tool. Our main goal is to examine the feasibility of parent supervised language assessment, rather than the psychometric properties of the test. There are multiple benefits (e.g., convenience, easy administration) of using parents to administer bilingual language screening to their bilingual children, however, administering assessment requires following specific protocols to encourage children’s participation and prompt for responses. Given the fact that parents are not licensed clinicians who are trained for these procedures, it is unclear whether parents are prepared to follow these protocols. Furthermore, using parents to implement online language assessments for their children has not been investigated in applied language science, hence

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from Permissions@acm.org.

IDC '20, June 21–24, 2020, London, United Kingdom
© 2020 Association for Computing Machinery.
ACM ISBN 978-1-4503-7981-6/20/06 \$15.00
<https://doi.org/10.1145/3392063.3394441>

there is a lack of information on the type and frequency of parental behaviors.

The present study is one of the first works that attempt to investigate the feasibility of utilizing parents as administrators of online language assessment. By analyzing videos from 16 parent-child dyads, we summarized a total of 677 incidents of parental behaviors, including 381 support behaviors that can facilitate children's successful completion of MECO-LAB and 296 instances of parental interference that may hinder the validity of assessment. Our findings reveal a relatively high degree of parent adherence to assessment protocols in 11 out of 16 parents, suggesting that parents have the potential to aid clinicians and researchers in conducting online screening with bilingual children. We also identified areas for improving parental adherence to test administration protocols.

BACKGROUND AND RELATED WORK

A diverse body of prior research has examined the roles of parents in reporting on their children's language functioning and in implementing interventions, and potential promise of computerized assessment for children's speech and language skills. This multi-disciplinary project was informed by the applied language science literature that documents the benefits of involving parents in clinical assessment and intervention [6, 8, 19, 50] and highlights opportunities for web-based assessment for children [39, 42, 46]. In addition, relevant work within telemedicine [1, 16, 30], human computer interaction (HCI) [4, 22, 25, 31, 44, 47, 49, 52], and citizen science [13, 14, 38, 41] provided us guidelines for designing the MECO-LAB administration protocol.

Clinical Utility of Parents in Assessment and Intervention

Using parents as informants for surveys and questionnaires has been shown to be a cost-effective and representative way to evaluate a child's overall development and obtain additional information regarding family history and parenting practices [23, 50]. One of the most widely used parent-reported instruments for young children is the MacArthur-Bates Communicative Development Inventories (MBCDI) [18], which utilizes parents to report on children's early language skills between 8-30 months across multiple languages (e.g., English, Spanish, Mandarin, French). It is an effective measure for families from various socioeconomic backgrounds and different geographic areas. Although parents may over- and under-report children's level of functioning on the MBCDI due to memory lapse, the tool in general has a strong correlation with other language measures (e.g., spontaneous speech, verbal IQ) [26].

Parents can also act as implementers of intervention strategies in the home and community settings [34]. Parent-implemented interventions such as the Hanen program and joint storybook reading programs [10, 40] have been extensively investigated and demonstrated promising results for clinical efficacy and effectiveness. Brown & Woods [6] studied the use of parent-implemented communication interventions with children who have Down Syndrome,

autism spectrum disorders, and developmental delays. They found a positive change in children's communication outcomes through a collaborative parent-coaching approach using natural location (e.g., home and community) and family routines to enhance parent participation in the intervention process. Despite these, to our knowledge, no empirical studies have examined the feasibility of using parents as test agents to administer computerized language assessments to bilingual children.

Application of Computer-Assisted Testing

In recent years, computerized speech and language assessments have begun to emerge to address barriers in service delivery mentioned earlier [16, 43]. Polišenská and Kapalková [39] developed a quick, inexpensive, and easy-to-administer computer-based nonword repetition task for children (aged 2-6) using visual pictures and audio recordings. In a feasibility evaluation, 85.7% of children successfully followed the assessment procedure and completed the task under the supervision of researchers.

Automated administration of assessment using pre-recorded audio and visual stimuli not only increases consistency of assessment procedures that are previously delivered by clinicians who may have different speech accents but also reduces clinician's time needed for test preparation and scoring [21]. The Quick Interactive Language Screener: English - Spanish (QUILS:ES) is, to our knowledge, the first automated bilingual Spanish-English language screener that allows children between 3 and 5 years old to complete the assessment via a tablet or touchscreen computer under adult supervision [23]. The QUILS:ES assessment does not require special training, therefore, a wide range of professionals (e.g., teachers, classroom volunteers) can supervise the children's test administration process. However, this tool is only available in English and Spanish, leaving speakers of the other 350+ minority languages in the U.S. with no assessment options.

These prior studies indicate the feasibility of computerized assessment. Given the ubiquity of computers and internet in modern households, new opportunities for assessment tool development exist for smaller populations if parents can be involved in the data collection process to generate adequate sample sizes for norming purpose [3, 7]. If parents prove to be capable of administering standardized tests, they can be further involved as agents of screening at home, which may lead to much earlier identification of language impairments.

Designing for Parent Adherence in the Online Space

In clinical and medical research, adherence is defined as the "extent to which a patient's behavior coincides with medical or health advice", whereas in eHealth and Internet intervention research, adherence refers to "the extent to which individuals experience the content of the internet intervention" [31]. To examine users' adherence to web-based interventions for weight control, Kelders et al. [31] found overall adherence to these interventions across different studies ranged from less than 33% to 77%.

Researchers argue that adherence to interventions requires some forms of behavioral change and positive user experiences with computer-based systems [22]. Van der Lubbe et al. [52] designed and evaluated a touch-based application to promote diet adherence and found that designing persuasive communication using messages that are authoritative can be an effective method.

There is limited prior work in HCI related to designing for parent adherence. Chan et al. [10] and Song et al. [49] explored system designs towards improving parent-child interaction by teaching parents to increase the use of communication strategies for daily routines and language intervention. However, design goals and approaches in these prior works are inherently different from those of the current study. To obtain valid results, an assessment tool, regardless of the test administrator, needs to encourage children's independent participation in complex linguistic tasks, while minimizing the test administrator's communications that may interfere with the tasks. Language assessment tools such as the MECO-LAB are unique because they are not medical devices or interventions for repeated use, but rather assessments that can only be administered to children with limited frequency to ensure validity and novelty.

In a citizen science project, Scott and colleagues [46] studied how parents use web browsers to self-administer behavioral studies with their toddlers and young children at home through an online data collection tool called "LookIt." This tool has been successfully utilized to increase the diversity of participants in developmental research, a field dominated by participants from WEIRD (Western, Educated, Industrial, Rich, Democratic) background [38]. Scott et al. found that parents interfered in 8% of trials during preschoolers' forced-choice selection by repeating the options or answering the questions for their children. Finally, previous qualitative analyses work [47] on children's collaborative interaction using shared computers in the classroom showed that some children may have difficulty reaching a shared understanding of the workspace. This suggests that parent involvement is necessary for young children who may not have enough experience with computers.

CURRENT STUDY OBJECTIVES

This paper describes the evaluation of parent behaviors during administration of MECO-LAB, a web-based Mandarin-English language assessment for bilingual children between 3 and 8 years old. The study aims to examine characteristics of parent behaviors and identify incidents that are supportive of and/or disruptive to the assessment procedure. We anticipate that parents will offer help and support because of the children's young age, lack of motor dexterity, lack of technical knowledge, flaws in our initial design, and/or their inherent interest in demonstrating their children's best performance. Analyzing how parents and children engage in these behaviors may lead to a better understanding of effective design strategies to reduce parent interferences during assessment and increase the child's

independent use of our tool. We then propose design recommendations to guide child-centered parent-administered interaction in online language assessment tools. The following research questions are addressed:

1. What are the types and frequencies of parent behaviors?
2. What are the characteristics and contexts of these parent behaviors?
3. How can the MECO-LAB administration instructional protocol be improved to increase parents' adherence?

DESIGNING MECO-LAB

Designing Assessment Items

The pilot version of the MECO-LAB has a Mandarin module (44 items) and an English module (36 items) that assesses Mandarin-English speaking children's comprehension of specific linguistic constructs using pictures and audio stimuli. All items have one correct answer from two to four options, and each item weights one point within each module. Based on prior research on clinical diagnostic markers, we designed English items that assess plurals, prepositions, quantifiers, passive sentences, and relative clauses [23, 37] and the Mandarin items that assess prepositions, classifiers, quantifiers, passive sentences, and relative clauses [17, 28, 29, 48, 55, 56].

Initial Web Usability Evaluation

Prior to evaluating joint parent-child interaction, we recruited 19 adult participants (mean age: 23 years old; 14 females, 3 males, 2 nonbinary) to evaluate the usability of the English portion of MECO-LAB using their personal computers. After completing the assessment, Participants were invited to provide a rating between 1 (strongly disagree) to 5 (strongly agree) on 10 Likert scale questions from the System Usability Scale (SUS) by Brooke [5]. Using the same method by McLellan et al. [35] to calculate average rating, participants reported excellent usability for the MECO-LAB website, with an 88-point average score (see supplementary materials for a summary of all participants' scores using the SUS).

Designing Parent Instruction

Prior work by Scott & Schulz [45] recommended several design features for parent instruction. These included adding clear and simple explanations regarding why it is necessary for parents to follow research protocol and not to interfere during assessment and providing onscreen instructions to guide parents through procedures (e.g., replay experiment questions, prompt the child without repeating object labels). Drawing on these recommendations, we designed a set of short parent instructions available in both English and Mandarin. The design of the parent instruction page focused on explaining the importance of not interfering (e.g., repeating questions or correcting children's mistakes) and describing browser requirements and the test environment. After reading the instruction, the parent is invited to select

either the English or Mandarin module to begin assessment for their children. The instructions are written in short, direct sentences in an authoritative tone to reduce information overload and encourage compliance.

Designing Assessment Interaction for Children

To participate in MECO-LAB, the child is asked to select one correct answer from 2 to 4 picture choices by listening to the audio clip of recorded sentences, which are automatically played twice. Following recommendations of standardized assessment protocols [15, 23], there is a 3-second wait time before the initial audio plays, and 15 seconds before the replay. If no selection is made 15 seconds after the replay, the web page automatically advances to the next item. After picture selection, the website automatically registers the response and advances to the next question. Users cannot go back to the previous screen; this prevents learning and priming effects during assessment. Integrating recommendations from Scott et al. [46], new functions were added (Figure 1), such as practice trials in the beginning of each language module for the child to learn the assessment task, an audio button to pause the task, built-in constraints for timing and number of allowable repeated audio plays, and a completion progress bar.

Figure 1. An example of English item “The picture is on the bed.”

EVALUATING PARENT-CHILD INTERACTION

Selection and Participation of Children

We recruited 16 bilingual Mandarin-English speaking parent-child dyads (Table 1) from Delaware, United States via local events and social media posts. Testing sessions were conducted in the home ($n = 10$) and the university laboratory ($n = 6$). Participating parents (mean age = 37.6 years old; 11 females, 5 males) were all native speakers of Mandarin born and raised in Mainland China and had English reading proficiency demonstrated by an understanding of the test procedures during initial screening. Participating children (11 males, 5 females; age range: 3 to 8 years old; mean age: 5 years 7 month) were all born and/or raised in the United States. Per parent report, all children have normal hearing, normal or corrected-to-normal vision with no genetic, neurological, or psychiatric disorders. Per

parent report, these children also used both Mandarin and English for at least 20% of the time on a daily basis.

A trained research assistant explained the study purpose, obtained written consent for video recording from parents, and set up the touchscreen laptop (Dell Inspiron 15, 7000 Series), which allowed participants to make selections using both the computer touchpad and the touchscreen. Parent interactions with their children using MECO-LAB were video-recorded with the camera placed behind the parent-child dyad facing the laptop. This allowed researchers to capture activities on the screen, protect the privacy, and reduce potential distraction. Parents also filled out a paper questionnaire that collected their personal information (age, gender, and level of education) and ratings of language proficiency for themselves and their children in both English and Mandarin. Before the testing started, the research assistant asked parents to read the instructions of MECO-LAB and explain the test procedure to their children prior to administering MECO-LAB.

Video Analysis

Sixteen parent-administered assessment videos in English and Mandarin (approximately 5 hours) were transcribed, coded, and analyzed by two bilingual Mandarin-English speaking researchers using a Windows media player and Excel spreadsheet. Transcription started when the parent began the MECO-LAB instruction page and concluded when the child completed the last test item of MECO-LAB for both the Mandarin and English modules. All observable parent behaviors, including both support and interference behaviors were coded, calculated, and represented in the last two columns along with participating dyads’ demographic information (gender, age, and parent education) in Table 1.

ID	Child	Parent	Parent Edu	Support	Interference
1	M (5;9)	F (34)	Masters	22	9
2	F (5;5)	M (43)	Masters	96	50
3	F (5;11)	F (37)	Masters	13	0
4	M (6;7)	M (37)	PhD	8	0
5	M (8;6)	M (37)	PhD	11	0
6	F (6;4)	F (46)	Masters	29	2
7	M (3;8)	F (41)	PhD	33	51
8	M (6;1)	F (41)	PhD	22	1
9	M (6;6)	M (34)	PhD	9	0
10	M (6;1)	F (40)	Masters	39	72
11	F (4;1)	F (39)	PhD	38	77
12	M (6;7)	F (41)	PhD	29	3
13	M (6;3)	M (43)	PhD	6	1
14	M (7;9)	F (35)	Vocational	10	30
15	F (3;8)	F (37)	PhD	9	0
16	M (8;2)	F (28)	Bachelor	7	0

Table 1. Demographic information (gender, age, and parent education) and parent behaviors of the 16 dyads.

We identified four types of interference behaviors - repeating questions, answering questions, analyzing items, and judging

of correctness, and four supporting behaviors - encouragement, technical support, broadcasting, and miscellaneous (Table 2). The coding categories were adapted from an examination of literatures on parent-child intervention, child language assessment, conversation analysis, and clinical discourse analysis [6, 15, 12, 19, 35]. The coding definitions were developed using both inductive and deductive approaches, based on identified behaviors from video analysis and from instructions in standardized test manuals [15] which illustrate specific test administrator behaviors that are acceptable (e.g., praising for efforts) and prohibited (e.g., judging accuracy of responses). To ensure the reliability of coding, each researcher independently coded all 16 videos. The percent agreement level across two coders was 97%.

Codes	Definitions
Repeating Questions (RQ)	Repeating the pre-recorded audio questions before and/or during the process of a child initiating a response
Answering Questions (AQ)	Using verbal, gestural, and tactile cues to suggest or select a correct answer for the child
Analyzing Items (AI)	Elaborating on the critical linguistic components by labeling objects and actions, emphasizing on prosodic cues, or breaking down complex sentences from the audio stimuli
Judging of Correctness (JC)	Verbally evaluating the child's response as "correct" or "incorrect"
Encouragement (E)	Showing verbal and/physical support for the child to continue, saying "good job/excellent" to reinforce the child's selection, expressing empathy (e.g., "it's okay") on struggled items
Technical Support (TS)	Offering verbal and/or physical assistance related to interacting with the MECO-LAB website and the testing computer
Broadcasting (B)	After the child made a selection, describing the selection via a word, a phrase, or a sentence
Miscellaneous (M)	Initiating and/or responding to events that redirected a child's attention, sharing opinions about test procedures and stimuli, nonverbal behaviors that were out of the child's view

Table 2. Coding categories and definitions for parent behaviors (see supplementary files for transcript examples).

RESULTS & DISCUSSION

Type & Frequency of Parent Behaviors

All 16 parent-child dyads completed the task. Out of the 16 videos, a total of 677 observed parent behaviors were identified, including 381 incidents of support behaviors and 296 incidents of inference behaviors. Figure 2 illustrated individual behavior breakdowns in percentages.

Eleven out of 16 parents (dyads D1, D3, D4, D5, D6, D8, D9, D12, D13, D15, D16) demonstrated no more than 10 incidents of parent interference behaviors during administration of both Mandarin and English modules combined. Because there is no existing research that investigates the level of adherence to assessment protocols among trained professionals, we operationally defined "adherence to assessment protocol" in the current study as less than 10 incidents of interference. We considered this frequency to be within acceptable limits due to the minimal instructional training given to the parents who had no prior experience administering formal assessments. Nearly 95% of parent interference behaviors (280 out of 296) were observed from the five dyads who showed low adherence (D2, D7, D10, D11, D14).

Figure 2. Percentage of eight coded categories of parent support and interference behaviors.

Characterizing Parent Support Behaviors

In-depth analyses of the 381 parent support behaviors indicated that 35.96% of (137 out of 381) incidents were to provide verbal and physical encouragement for their children. We noticed that parents may have different levels of expectations for children's language ability and can be emotionally invested in their children's success, thus, dedicated different efforts in supporting their children.

The parent in D11 was observed using support behaviors for a total of 28 times through verbal encouragements (14 times each for Mandarin and English) such as: "Don't know? Hurry up, if you don't click you will miss it, if you click you still *have a 25% chance*." In another child-parent dyad, the parent encouraged the child by saying: "Try your best, *you can get it correct*, why aren't you paying attention? If you thought of anything, just click." These contextualized parent support behaviors revealed a special emphasis on achievement by asking their children to take the most optimal chance to get the answer correct, rather than on assessment completion. It is important to note that even though these behaviors were labeled as support behaviors, we noticed that excessive verbal encouragements can distract children from thinking and completing assessment tasks. For example, when the child was hesitating to provide an answer,

the parent in D6 provided multiple verbal encouragements on four specific Mandarin items (Table 3). The hesitation behavior from the child could be interpreted by the parent as an act of refusing to participate, but in reality, the child may be carefully processing the sentence and making decisions from available choices.

Mandarin Items	Parent Behaviors
有的小朋友在吃苹果。 / Some children are eating apples.	"Can you choose? Can you choose?" "Do you understand? Just choose one that you think is right."
有的小狗在啃骨头。 / Some dogs are chewing bones.	"Can you choose? Which one?" <Tap on the child's back> "Can you make a selection? Just choose one of the three. Do you understand me? Can you choose?"
有的动物举着一面旗。 / Some animals are waving a flag.	"Can you choose? Just choose one of the three. Doesn't matter whether it's right or wrong. Are you okay?"
有的小男孩在吃香蕉。 / Some boys are eating bananas.	"Can you choose? Go ahead." <Tap on shoulder> "Please choose one out of the three. Are you okay? Nobody will see. Just make your choice. Either one." "Hurry up and choose. No. Do you understand what it's saying? No? Okay."

Table 3. Examples of D6 parent verbal encouragements.

In addition to the encouragement behaviors, we also found that a majority of parent support behaviors (38.48%; 147 out of 381 incidents) were related to providing technical support. Table 4 summarizes these 381 multimodal parent support behaviors, which were related to a range of usability issues including item selection, web navigation, and physical access. This is reasonable because we anticipate that providing technical support is a critical component of parent assistance due to children's emerging computer literacy and motor skills to interact with the assessment via a touchscreen computer. However, this high rate of technical support provided by parents indicated that the MECO-LAB website and/or the laptop should be properly configured prior to assessment to avoid potential usability and/or functionality issues.

In our video analysis, 14 out of 16 participating children (all except children in D2 and D10, in which their parents completed the tasks via the touchpad for them) demonstrated the ability to independently make selections during testing using either the touchscreen or touchpad with minimal assistance from parents. This is consistent with prior work by Fisch et al. [19], who investigated the parent-child behaviors while using computers for joint reading of online storybooks. They found that six out of the seven participating preschoolers held and physically controlled the mouse at least 50% of the time, four children controlled the mouse all

the time, and two shared control with parents; in only one case did the parent do all of the clicking.

Supports	Description of Parent Behaviors
Item Selection	Asked the child to point to the answer more clearly, confirmed with the child that the audio will be repeated
Navigation	Sought advice from the researcher about auto-advance/whether the tasks can go back, explained to the child that he/she cannot go back to previous assessment questions, clicked or scrolled down the page so that all the choices were clearly visible
Access	Advised the child to click slower in order to avoid skipping items or click harder and/or longer to select the picture, pointed to show the replay button on the screen, used the touchpad for picture selection and to exit modules, helped the child to make a selection when the child's first attempt was not registered by the touchscreen
Reminder	Stopped the child from rushing to make answer choices before the audio play was finished
Proximity	Adjusted the physical environment (e.g., seating and device position) for the child

Table 4. A summary of technical support by all 16 parents.

Characterizing Parent Interference Behaviors

Several key characteristics were observed from videos of the five parents (D2, D7, D10, D11, D14) who exhibited exceptionally high interference behaviors. These five parents had children from a diverse age range, including the youngest child in D7 (3 years old) and the oldest child in D14 (7 years old). Some of the parents did not spend time thoroughly reading through the assessment instructions, and they also did not carefully explain the test procedures to their children. As a result, although the parent instruction prohibited "repeating sentences" and "helping the child," these parents did not adhere to instructions, and repeated and answered questions and analyzed items for their children.

When parents repeated questions themselves rather than waiting for the audio replay, their linguistic variations can significantly impact the validity of test items. For example, the parent in D10 repeated portions of the recorded sentences, switched the grammatical structure of the sentences, translated tasks between English and Mandarin, and used variable speech rate during sentence repetition. These behaviors were meant to simplify the recorded stimuli and differentiate the correct picture from other potential picture choices. However, these behaviors may have left the child with less processing time to comprehend the sentence. Additionally, when parents switched between English and Mandarin, it forced children to switch between two languages when listening to parent repetitions, which may have increased the demand for executive function [27]. Although code-switching is common between bilingual parents and children [24], these parent interference behaviors violated the purpose of the assessment protocol, which seeks

to test children’s comprehension separately in either Mandarin or English language modules.

Despite the fact that initial parent instruction on the website indicated “do not help your child or correct their mistakes,” the parent in D14 parent offered 16 verbal (“对/correct”) and nonverbal cues (e.g., nodding) to confirm an accurate selection from the child. This parent did not correct or acknowledge any wrong answer choices that the child selected, but likely interpreted that “confirming the correct answer” for the child was acceptable. This behavior is potentially due to this particular child’s low proficiency in Mandarin and/or the pressure and anxiety to correctly answer questions. This parent behavior could be one factor influencing the child to become more dependent on parents. For instance, the child in D14 consistently ask “this one, right?” for a total of 14 times in the Mandarin module and 2 times in the English module. As a result, the answer from parent may affect children’s final response selection and impact children’s performance.

As shown in Table 5, parent exhibited more support and inference behaviors in the Mandarin task than the English task. On average, 16 parents interfered in approximately 10 items in Mandarin and 5 items in English and offered support to 11 items in Mandarin and 6 items in English. The higher interference and support behaviors in Mandarin tasks may be attributed to that parents were more comfortable or felt more compelled to interfere when the language of the home environment was tested.

	Support (n = 381)				Interference (n = 296)			
Types	E	TS	B	M	RQ	AQ	AI	JC
MAN	85	106	44	20	102	12	71	32
ENG	51	42	16	17	42	0	18	19
Total	136	148	60	37	144	12	89	51

Table 5. A summary of parent interference and support behaviors in Mandarin (MAN) and English (ENG).

During data collection, 13 out of 16 parents started with the Mandarin module first; it is likely they therefore became more familiar with the mechanics of the testing procedure first before their children did. This suggests that for future design, rather than allowing parents to choose their preferred language to start, it might be appropriate to complete the assessment in children’s more proficient language, so that children can learn the assessment procedure using a more comfortable language without necessarily eliciting potential parent interference behaviors that may impact the validity of the assessment.

Other parent interference behaviors pointed to differences in how parents’ interpretation of the instruction may deviate from the researcher’s original intent of the instruction. After children made a selection for a question, multiple parents verbally offered judgment to their answers by saying “yes” or “correct.” By confirming that their children answered a question correctly, parents acknowledged the mastery of specific task knowledge during the assessment, making children more motivated and confident about the ongoing

tasks [53]. In sum, analyses of the 296 parent interference behaviors revealed multiple areas of needs to redesign both the assessment instruction and interaction to reduce parent interferences and increase children’s independence.

REDESIGNING MECO-LAB

Investigating the parent-child computer interaction during the MECO-LAB administration not only sheds light on multiple usability issues but also points to future design needs for both children and parents as users of this collaborative assessment environment. The 677 observed parent behaviors were motivated by cognitive, linguistic, emotional, and technical factors to assist and support their children during assessments. These factors must all be carefully considered during the future development of online language assessment tools.

Analyzing specific instances of parent interference and support behaviors helped us learn from naturalistic multimodal interactions between parents and children, and revealed ongoing needs to redesign auditory, visual, and tactile support to increase parent adherence to assessment protocol. The MECO-LAB instructional redesign focuses on two primary goals: (1) revising parent instruction to clarify assessment protocol, and (2) adapting multimodal supports from parents to web interface design to improve children’s independence during the assessment.

Our video analysis points to specific web redesign suggestions regarding information clarity and functionality on the parent instruction page of MECO-LAB. These ongoing areas of improvement (e.g., clarifying specific website functions, listing prohibited parent behaviors) were consistent with prior literature by Gloyd [22]. While analyzing the five parents (in D2, D7, D10, D11, and D14) who demonstrated an exceptionally high frequency of interferences, we found these parents did not carefully read assessment protocols and presented interference behaviors within the first 30% of the testing session. These findings suggest that parent interference behaviors can be prominent and evident at the start of the assessment, and it is critical to instruct parents to minimize different types of parent interference behaviors before administering the assessment.

Prior work by Alexandru [1] found users who interacted with telemedicine websites were not all equally aware of the usefulness of the training and documentation on the website, as a result, web usability was compromised. Our redesign should focus on increasing the clarity of parent instruction messages by communicating both the emotional (e.g., parents’ natural tendency to want their children to do well) and cognitive context (e.g., parents’ interpretation of prohibited behaviors). The revised instruction needs to prepare parents for their role as supervisory, not facilitative.

Additionally, we found that the parents’ excessive verbal reminders could negatively impact children’s interaction with MECO-LAB. Video analyses from participant videos revealed that when acting as assessment administrators, five

out of 16 parents struggled to remain observant and neutral about their children's participation. If interjected simultaneously with an audio replay, these verbal reminders can potentially hinder children's attention and motivation. Some relatively lengthy and frequent verbal encouragements were provided by parents during the 15 seconds gap before the task items automatically advance to the next audio clip, which is a critical time window for their children to process the linguistic task and make a decision for selection. These types of parent behaviors can interrupt children's attention to assessment stimuli and force children to choose answers without adequate response time. These observations suggest that we need to clearly define acceptable and prohibited behaviors for parents and make this information salient in the instructional protocol.

A list of redesign recommendations to the parent instruction (Figure 3) and assessment include the following:

- **Informing parents that children should be the primary users:** parents are advised that only their children are being tested (not parents themselves) and they should not help children for judging the correctness of an answer. A parent education video will be added in the future.
- **Reminding parents to evaluate the child's technology access methods:** depending on children's level of linguistic and physical ability, parents will be prompted to discuss with their children regarding what is the most accessible way to provide an answer selection (e.g., should the selection be made by children themselves or by parents), and using what means (e.g., distance pointing, touchscreen, touchpad, mouse).
- **Providing examples of acceptable and prohibited parent behaviors:** a table was added to the parent instruction, describing accepted and prohibited behaviors. Simple and concrete examples of acceptable and prohibited parent behaviors can ensure the child-parent dyad both understand their individual roles before beginning the assessment.
- **Adding parent assessment questions:** in addition to reading instruction, parents must complete six assessment questions regarding their roles and behaviors prior to beginning MECO-LAB for their children.
- **Visualizing the audio replay and countdown features:** added textual cues for parents (e.g., "Audio will replay in __ seconds", "Next trial starts in __ seconds.") in both Mandarin and English to ensure procedural information are accessible for different levels of proficiency.

Figure 3. The revised parent instruction page

IMPLICATIONS

This feasibility study leads to several lessons for design. First, using parents rather than trained clinical specialists as test agents for administering computerized assessment entails different considerations when designing assessment protocols. Our video analysis revealed that parents' interpretation of assessment procedures might influence the overall validity of assessment. Designers should consider multiple sociotechnical factors (e.g., language and technical proficiency, socioeconomic status) and provide parents and children with clear goals and instructions.

Both clinical providers and parents need to offer encouragement and reinforcements when children lack the motivation to proceed through the assessment. When creating computerized assessments, designers should support children's task completion by providing positive reinforcement and rewards for compliance and good behaviors [10, 44] in specific intervals to ensure sustained engagement and participation.

Looking beyond assessment protocols and test items, researchers must acknowledge the importance of developmentally appropriate design children's assessment experience. For instance, children with a diverse age range may have different abilities when manipulating a mouse and completing tasks on the computer [7], and therefore, will require different levels of assistance from parents. Any computerized assessment tools should not only meet psychometric property requirements, but also address issues related to child-computer interaction through iterative usability testing with a diverse age group of child users. Doing so will ensure optimal performance with the software program and hardware device, which is essential to determining the test validity of any computer-mediated assessment.

LIMITATIONS & FUTURE WORK

The current study has several limitations. First, our sample includes a wide age range of child participants, leading to

differences in both developmental and experience factors that impact the usability of mouse and computer interface [7]. We did not conduct a pre-screening of technology proficiency skills for children and parents, but such a procedure should be integrated into future development of assessment protocols.

Second, our sample also has a significant portion of parents with a relatively high level of education. Prior work by Lane et al. [33] suggests that parents' socioeconomic and racial backgrounds may further impact children's access to computers and the frequency of computer use. It is unclear whether parents' ability to administer MECO-LAB might change with education levels; thus, our findings should not be generalized to parents from other educational and socioeconomic backgrounds. Future work may continue to investigate whether parent education levels and family computer use impact families' participation with online assessment.

Third, due to the lack of existing guidelines in interpreting and evaluating parent behaviors, we designed our own coding protocol using iterative processes. Clearly, revisions and fine-tuning of the coding protocol are warranted. For example, approximately 5% (37 incidents) of parent behaviors were categorized as "miscellaneous" and subsumed under supporting behaviors. Closer analyses of the miscellaneous category should be conducted to see if they should be further categorized or relabeled.

Fourth, to the best of our knowledge, clinician's adherence to testing protocols have not been investigated. Therefore, we do not have a reference group of trained professionals to determine if parents are good or poor at adherence. Future studies should examine both clinicians' and parents' adherence to testing protocol to enable comparisons between these potential testing agents and determine if parents are indeed fit for this role.

Lastly, although this study primarily focuses on analyzing parent behaviors and developing redesign recommendations to support parent adherence, it is unclear whether parent interferences have positively or negatively impacted the performance of their children on the assessment. Parent behavior is dynamic and complex and should be interpreted by considering the joint parent-child interaction as a unit of analysis. Ongoing investigation should also examine specific parent behaviors in relation to their children's test performance. A follow-up comparability study is currently being conducted to compare parent-supervised administration and researcher-supervised administration. Future results will inform whether test performances differ across parents vs. trained researchers.

CONCLUSION

To develop online language assessment tools for bilingual children, we designed MECO-LAB, the first web-based bilingual Mandarin-English language assessment tool of its kind. We examined the feasibility of parent administration

with 16 bilingual parent-child dyads by analyzing parents' interference and support behaviors when these dyads jointly interact with the web interface. Our findings indicated that without any former training, 11 out of 16 parents demonstrated adherence to assessment protocols, suggesting the initial feasibility of using parents as test agents for MECO-LAB to their children. Although MECO-LAB has the potential to become a web-based language screening tool, it is important to note that this tool should not be used for diagnostic purpose but can be used together with parent questionnaires and clinician evaluation to obtain a comprehensive understanding of bilingual children's language ability.

The focus of MECO-LAB is on investigating children's ability to answer these questions rather than being able to accurately answer all items, which a normative standard of age-appropriate test performance is yet to be established. Ultimately, clinical language assessments need to achieve sensitivity and specificity to classify children with and without language impairments accurately. Ongoing research in this area should continue creating web-based tool for bilingual children who speak other minority languages, increase parent-child participation and awareness in early language assessments, and inform designers and researchers with better design guidelines for creating collaborative parent-child interaction for language assessment on the web. The MECO-LAB platform will remain an outreach venue in the scientific community and open for use by clinicians and researchers who are interested in implementing language measures for Mandarin-English speaking bilinguals.

ACKNOWLEDGEMENT

This project is supported by a Spencer Foundation grant (#201900085) awarded to the second author. We thank all the participants for their support, and students and staff from the Language Learning and Bilingualism lab at the University of Delaware for their insightful comments on previous versions of this document.

SELECTION AND PARTICIPATION OF CHILDREN

Participating child-parent dyads were recruited via local cultural heritage events and social media posts. Written consents for experiment participation and video recording were obtained from parents. In order to protect their personal information, all parents were instructed to complete the administration of MECO-LAB by entering a numeric identifier assigned by researchers. Video recordings and participant background information were labeled with the same numeric codes and maintained on a password-protected lab computer. Upon the completion of MECO-LAB redesign and evaluation, parents will receive a detailed report that includes both their child's performance and information about the performance of other children who belong to the same age group with similar parental education.

REFERENCES

- [1] Cristina-Adriana Alexandru. 2010. Usability testing and improvement of telemedicine websites. Master of

- Science. Dissertation. University of Edinburgh. Edinburgh, UK.
- [2] American Speech-Language-Hearing Association. 2019. Demographic profile of ASHA members providing bilingual services, year-end 2018. Available from www.asha.org.
 - [3] Michael Berger. 2006. Computer assisted clinical assessment. *Child and Adolescent Mental Health*, 11(2), 64-75.
 - [4] Rajoshi Biswas, Peter Chang, Hasitha Dharmasiri, Gaurav Patel, and Ashutosh Sabharwal. 2013. AsthmaGuru: a framework to improve adherence to asthma medication. In *Proceedings of the 4th Conference on Wireless Health*, 11. ACM.
 - [5] John Booke. 1996. SUS: a "quick and dirty" usability scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & A. L. McClelland (Eds.), *Usability Evaluation in Industry*, 189-194. London: Taylor and Francis.
 - [6] Jennifer A. Brown and Juliann J. Woods. 2015. Effects of a triadic parent-implemented home-based communication intervention for toddlers. *Journal of Early Intervention*, 37(1), 44-68.
 - [7] Sandra L. Calvert, Victoria J. Rideout, Jennifer L. Woolard, Rachel F. Barr, and Gabrielle A. Strouse. 2005. Age, ethnicity, and socioeconomic patterns in early computer use: A national survey. *American Behavioral Scientist*, 48(5), 590-607.
 - [8] Themba Carr, Wendy Shih, Kathy Lawton, Catherine Lord, Bryan King, and Connie Kasari. 2016. The relationship between treatment attendance, adherence, and outcome in a caregiver-mediated intervention for low-resourced families of young children with autism spectrum disorder. *Autism*, 20(6), 643-652.
 - [9] Julia M. Carroll, Claudine Bowyer-Crane, Fiona J. Duff, Charles Hulme, and Margaret J. Snowling. 2011. *Developing language and literacy: Effective intervention in the early years*. John Wiley & Sons.
 - [10] Meng-Ying Chan, Yi-Hsuan Lin, Long-Fei Lin, Ting-Wei Lin, Wei-Che Hsu, Chia-yu Chang, Rui Liu, Ko-Yu Chang, Min-hua Lin, and Jane Yung-jen Hsu. 2017. WAKKEY: Assisting Parent-child Communication for Better Morning Routines. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing*, 2287-2299. ACM.
 - [11] Philip S. Dale, Catherine Crain-Thoreson, Angela Notari-Syverson, and Kevin Cole. 1996. Parent-child book reading as an intervention technique for young children with language delays. *Topics in Early Childhood Special Education*, 16(2), 213-235.
 - [12] Jack S. Damico. 1985. Clinical Discourse Analysis: A functional approach to language assessment. In C.S. Simon (ed.) *Communication Skills and Classroom Success: Assessment of language-learning disabled students*, 165-204. San Diego: College-Hill Press.
 - [13] Marketa Dolejsova, Denisa Kera, Cristiano Storni, Rohit Ashok Khot, Ivan John Clement, Inka Pavelka, and Puneet Kishor. 2017. Digital health & self-experimentation: design challenges & provocations. In *Proceedings of the 2017 CHI conference extended abstracts on human factors in computing systems*, 510-517. ACM.
 - [14] Cathal Doyle, Rodreck David, Jane Li, Markus Luczak-Roesch, Dayle Anderson, and Cameron M. Pierson. 2019. Using the web for science in the classroom: Online citizen science participation in teaching and learning. *OSF Preprints*. doi: 10.31219/osf.io/n953p.
 - [15] Lloyd M. Dunn and Douglas M. Dunn. 2007. *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.
 - [16] Tina J. Eichstadt, Nancy Castilleja, Melissa Jakubowitz, Adrienne Johnson. 2013. Standardized assessment via telepractice: qualitative review and survey data. Paper presented at the annual meeting of the American-Speech-Language-Hearing Association, Chicago, IL.
 - [17] Mary S. Erbaugh. 2006. Chinese Classifiers: Their use and acquisition. In P. Li, H. Tan, E. Bates, & O. J. L. Tzeng (Eds.), *Handbook of East Asian Psycholinguistics: Chinese*, 39-51. Cambridge: Cambridge University Press.
 - [18] Larry Fenson. 2007. *MacArthur-Bates communicative development inventories*. Baltimore, MD: Paul H. Brookes Publishing Company, 2007.
 - [19] Shalom M. Fisch, Jennifer S. Shulman, Anna Akerman, and Gael A. Levin. 2002. Reading between the pixels: Parent-child interaction while reading online storybooks. *Early Education and Development*, 13(4), 435-451.
 - [20] Glenn Flores and Sandra C. Tomany-Korman. 2008. The language spoken at home and disparities in medical and dental health, access to care, and use of services in US children. *Pediatrics*, 121(6), e1703-e1714.
 - [21] Margaret Friend, and Melanie Keplinger. 2008. Reliability and validity of the Computerized Comprehension Task (CCT): data from American English and Mexican Spanish infants. *Journal of child language*, 35(1), 77-98.
 - [22] Daniel M Gloyd. 2003. Positive user experience and medical adherence. In *Proceedings of the 2003 international conference on Designing pleasurable products and interfaces*, 17-21. ACM.
 - [23] Roberta M. Golinkoff, Jill G. De Villiers, Kathy Hirsh-Pasek, Aquiles Iglesias, Mary Sweig Wilson, Giovanna Morini, and Natalie Brezack. 2017. *User's Manual for*

the Quick Interactive Language Screener (QUILS): A Measure of Vocabulary, Syntax, and Language Acquisition Skills in Young Children. Paul H. Brookes Publishing Company.

- [24] Naomi Singerman Goodz. 1989. Parental language mixing in bilingual families. *Infant Mental Health Journal*, 10(1), 25-44.
- [25] Lee A. Green, Donald Nease, and Michael S. Klinkman. 2015. Clinical reminders designed and implemented using cognitive and organizational science principles decrease reminder fatigue. *The Journal of the American Board of Family Medicine*, 28(3), 351-359.
- [26] Mark Guiberson and Barbara L. Rodríguez. 2010. Measurement properties and classification accuracy of two Spanish parent surveys of language development for preschool-age children. *American Journal of Speech-Language Pathology*, 19, 225-238.
- [27] Julia Hofweber, Theodoros Marinis, and Jeanine Treffers-Daller. 2016. Effects of dense code-switching on executive control. *Linguistic approaches to bilingualism*, 6(5), 648-668.
- [28] Shenai Hu, Anna Gavarró, Mirta Vernice, and Maria Teresa Guasti. 2016. The acquisition of Chinese relative clauses: contrasting two theoretical approaches. *Journal of Child Language*, 43(1), 1-21.
- [29] Ruiting Jia and Johanne Paradis. 2018. The acquisition of relative clauses by Mandarin heritage language children. *Linguistic Approaches to Bilingualism*.
- [30] Saskia M. Kelders, Robin N. Kok, Hans C. Ossebaard, and Julia EWC Van Gemert-Pijnen. 2012. Persuasive system design does matter: a systematic review of adherence to web-based interventions. *Journal of medical Internet research*, 14(6), e152.
- [31] Saskia M. Kelders, Robin N. Kok, and Julia EWC Van Gemert-Pijnen. 2011. Technology and adherence in web-based interventions for weight control: a systematic review. In *Proceedings of the 6th International Conference on Persuasive Technology: Persuasive Technology and Design: Enhancing Sustainability and Health*, 3. ACM.
- [32] Kathryn Kohnert. 2010. Bilingual children with primary language impairment: issues, evidence and implications for clinical actions. *Journal of communication disorders*, 43(6), 456-473. doi:10.1016/j.jcomdis.2010.02.002
- [33] Alison E. Lane, and Jenny M. Ziviani. 2010. Factors influencing skilled use of the computer mouse by school-aged children." *Computers & Education*, 55(3), 1112-1122.
- [34] Rebecca G. Lieberman-Betz. 2015. A systematic review of fidelity of implementation in parent-mediated early communication intervention. *Topics in Early Childhood Special Education*, 35(1), 15-27.
- [35] Sam McLellan, Andrew Muddimer, and S. Camille Peres. 2012. The effect of experience on System Usability Scale ratings. *Journal of usability studies*, 7(2), 56-67.
- [36] Michael A. Norman and Peter J. Thomas. 1991. Informing HCI design through conversation analysis. *International Journal of Man-Machine Studies*, 35(2), 235-250.
- [37] Elizabeth D. Peña, Ronald B. Gillam, and Lisa M. Bedore. 2014. Dynamic Assessment of Narrative Ability in English Accurately Identifies Language Impairment in English Language Learners. *Journal of Speech, Language, and Hearing Research*, 57(6), 2208-2220. https://doi.org/10.1044/2014_JSLHR-L-13-0151
- [38] Andy Pilny, Brian Keegan, Brooke Wells, Chris Riedl, David Lazer, Jason Radford, Katya Ognyanova, Leslie DeChurch, Michael Macy, Noshir Contractor, Waleed Meleis. 2016. Designing online experiments: Citizen science approaches to research. In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion*, 498-502. ACM.
- [39] Kamila Polišíenská and Svetlana Kapalková. 2014. Improving Child Compliance on a Computer-Administered Nonword Repetition Task. *Journal of Speech, Language & Hearing Research*, 57(3).
- [40] Nan Bernstein Ratner, Betsy Parker, and Paige Gardner. 1993. Joint book reading as a language scaffolding activity for communicatively impaired children. In *Seminars in Speech and Language*, 14(4), 296-313. 1993. Thieme Medical Publishers, Inc.
- [41] Jason Reed, Whitney Rodriguez, and Angelique Rickhoff. 2012. A framework for defining and describing key design features of virtual citizen science projects. In *Proceedings of the 2012 iConference*, 623-625. ACM.
- [42] Ulf-Dietrich Reips. 2000. The Web experiment method: Advantages, disadvantages, and solutions. In *Psychological experiments on the Internet*, 89-117. Academic Press.
- [43] Roozbeh Sadeghian and Stephen A. Zahorian. 2015. Towards an automated screening tool for pediatric speech delay. In *INTERSPEECH*, 1650-16
- [44] Gabrielle M. Salib, Juan Fernando Maestre, Kenneth B. Nimley, Nadia Dowshen, and Gabriela Marcu. 2018. The Role of Reflection and Context in Medication Adherence Tracking for People Living with HIV. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM.

- [45] Kimberly Scott and Laura Schulz. 2017. Lookit (part 1): A new online platform for developmental research. *Open Mind*, 1(1), 4-14.
- [46] Kimberly Scott, Junyi Chu, and Laura Schulz. 2017. Lookit (Part 2): Assessing the viability of online developmental research, results from three case studies. *Open Mind*, 1(1), 15-29.
- [47] Stacey D. Scott, Regan L. Mandryk, and Kori M. Inkpen. 2003. Understanding children's collaborative interactions in shared environments. *Journal of Computer Assisted Learning*, 19(2), 220-228.
- [48] Li. Sheng, Ying Lu, and Pui Fong Kan. 2011. Lexical development in Mandarin-English bilingual children. *Bilingualism-Language and Cognition*, 14(4), 579-587.
- [49] Seokwoo Song, Seungho Kim, John Kim, Wonjeong Park, and Dongsun Yim. 2016. TalkLIME: mobile system intervention to improve parent-child interaction for children with language delay. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 304-315. ACM.
- [50] Donna Thal, Donna Jackson-Maldonado, and Dora Acosta. 2000. Validity of a parent-report measure of vocabulary and grammar for Spanish-speaking toddlers. *Journal of Speech, Language, and Hearing Research*, 43(5), 1087-1100.
- [51] US Department of Health and Human Services. 2017. *Policy statement on supporting the development of children who are dual language learners in early childhood programs*. Retrieved from https://www.acf.hhs.gov/sites/default/files/ecd/dll_policy_statement_final.pdf.
- [52] L. M. van der Lubbe and Michel CA Klein. 2019. Designing a system with persuasive communication to improve diet compliance for elderly users. In *Proceedings of the 13th EAI International Conference on Pervasive Computing Technologies for Healthcare*, 234-241. ACM.
- [53] Eva van Leer and Nadine P. Connor. 2015. Predicting and influencing voice therapy adherence using social-cognitive factors and mobile video. *American journal of speech-language pathology*, 24(2), 164-176.
- [54] Sheri Vasinda and Jodi Pilgrim. 2019. Are We Preparing Students for the Web in the Wild? An Analysis of Features of Websites for Children. *Journal of Literacy & Technology*, 20(2).
- [55] Anita M-Y. Wong, Laurence B. Leonard, Paul Fletcher, and Stephanie F. Stokes. 2004. Questions Without Movement: A study of Cantonese-speaking children with and without specific language impairment. *Journal of Speech, Language, and Hearing Research*, 47(6), 1440-1453.
- [56] Peng Zhou and Stephen Crain. 2011. Children's knowledge of the quantifier Dou in Mandarin Chinese. *Journal of Psycholinguistic Research*, 40(3), 155-176.