Phonological and Lexical Processes in Bilingual Spanish-English Learners

Danielle N. Leonard

Mentor: Ioulia Kovelman

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Author Note

Danielle Leonard, Department of Psychology, University of Michigan.

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Correspondence concerning this article should be addressed to Danielle Leonard, Department of Psychology, University of Michigan, 701 E University, Ann Arbor, MI 48109. Contact: leondani@umich.edu.

Abstract

Bilingual children are projected to comprise the majority of young learners in the United States over the next two decades. As a result, it is becoming increasingly important to improve our understanding of how bilingual children learn to read. In speech and print, words are comprised of sounds (phonemes) and meaning (semantics), and therefore children's phonological and semantic competence is foundational for learning to read. Accordingly, the present study focuses on how young bilinguals master the sounds and meanings of words in both of their languages. As a pilot project for a longitudinal 5-year functional magnetic resonance imaging (fMRI)/behavioral assessment of children grades K-4, the present study focused on preparing and piloting phonological and semantic experimental paradigms with monolingual English and bilingual Spanish-English adults (N = 12). Adult participants completed a phonological sound matching task. We have also designed a semantic word-picture matching task, as well as non-verbal (color/tone-match) control conditions. Adult participants showed above 95% accuracy and the items that the adults found complex or confusing were adjusted to yield 100% accuracy. The future direction of the study is to implement the experimental tasks with young bilingual children using brain imaging technology to expand our understanding of emergent bilingual literacy.

Keywords: bilingualism, literacy, phonology, semantics

Phonological and Lexical Processes in Bilingual Spanish-English Learners

A world-wide increase in multi-language speakers as well as an increase in dual immersion programs where children are exposed to multiple languages has occurred in recent years (Center for Applied Linguistics, 2011). 10.7% of children in American public schools are English language learners, meaning that English is their second language (Batalova & McHugh, 2010). In 2008, 75% (2.0 million) of children in U.S. schools who spoke a language other than English spoke Spanish (Batalova & McHugh, 2010). The volume of Spanish speakers in U.S. schools will only continue to grow, which further underscores the critical need to discover how these children learn to read.

The present study aims to determine how bilingual Spanish-English learners acquire reading in comparison to monolingual English learners. Phonology (sounds) and semantics (word meaning/vocabulary) are the two skills that comprise reading (Melby-Lervåg, Lyster, & Hulme, 2012). Accordingly, the present study investigates how bilingual children build phonological and semantic reading skills. As a pilot study, the current project tests adults (N = 12) on two behavioral tasks, one phonological matching task and one semantic matching task. Due to the focus on experimental design, the data is limited to that of the phonological task. To truly uncover how the monolingual and bilingual brain differ, we will be ultimately implementing both tasks to bilingual and monolingual children. These children will be in the pre- to post-literate transitioning phase during our 5-year longitudinal study with a functional magnetic resonance imaging (fMRI) component. The fMRI technology allows us to view real time brain activity via bloodflow, thus permitting the deteciton of neurological differences between monoligual and bilingual brains. With this method, we hope to discover how early exposure to Spanish and English at home and in school influences children's reading acquisition in both of their languages.

Phonological awareness is an individual's ability to reflect upon and manipulate the sound structure of spoken words. Since words are composed of sounds and spoken language is a crucial prerequisite to literacy, phonological awareness is one of the most influential determining factors in predicting a child's literacy (Melby-Lervåg et al., 2012). Semantic knowledge is the second critical skill for one's success in reading acquisition. If a child simply recognizes and produces sounds without meaning, the language has no purpose. Semantic knowledge, or knowledge of word meaning, is necessary for literacy skills, early and higher order skills, as well as phonological processing (Nation & Snowling, 1998). The present study addresses these two skills using two tasks: (1) a metaphonological task in which participants must determine if the onset (beginning) sound of two words match (e.g. book and bell match, desk and cup do not) and (2) a semantic task in which participants see a picture, hear two words, and are asked which word is more closely associated with the picture (e.g. a picture of someone skiing would be semantically realted to winter, not summer).

Semantic and phonological processing combine to form the dual-processing model for reading acquisition. This model has almost exclusively been researched in English, although some other models do exist (Ziegler, Perry, & Coltheart, 2000). The model proposes that written language can be processed by one of two routes: phonological and orthographic (Maris, 2009). These routes develop simutaneously and can be used in combination or individually to recognize a word (Sprenger-Charolles, Siegel, Jiménez, & Ziegler, 2011). The phonological route describes a process in which the reader sounds out the words and thus depends more on the phonology. The orthographic route is more useful for words that are not spelled how they sound, as the reader recognizes the word as a learned unit rather than a series of sounds (See Figure 1 for an example of reading in both routes).

This model demonstrates why bilinguals aquire reading in a way that differs from monolinguals through the focus on orthographic depth. English and Spanish differ in regards to orthgraphic depth, which is how the orthographic spelling of a word maps onto the phonetic pronunciation, or in simpler terms, sound-to-spelling consistency. This difference places them in two distinct routes of the model: English is more concentrated in the orthographic route while Spanish relies more heavily on the phonological route. Spanish is relatively orthographically shallow with few irregularities. Readers of Spanish can thus rely more strongly on their phonological route and the tactic of sounding out words. English is much deeper than Spanish; it has many irregular spellings that do not directly map onto the phonetic pronunciation. This requires readers to develop a strong orthographic route to compensate (Sprenger-Charolles et al., 2011).

Researchers including Goswami, Ziegler, & Richardson (2005) hypothesize that only English and other orthographically deep language learners fully develop their orthographic route. Other language learners may be able to rely so much on the phonological route that their orthographic route never needs to fully develop. In this way, each language possesses its own dual route in which the pathways are strengthened (or weakened) to fit the learner's language.

Here we propose to extend this theoretical perspective to include bilingual learners. What exactly does the brain of someone learning both an orthographically deep and an orthographically shallow language look like? Their dual route model must be a very unique combination. Perhaps their reading is "better" due to the strength of both routes or maybe it is more phonological such that they depend on sounding out words while learners of only an orthographically deep language recognize words as wholes.

The present study, especially with the use of the fMRI brain imaging method, will be able to map and show how these brains are learning, including determining which routes are activated. Previous research demonstrates that different areas of the brain are more active depending on the route. Specifically, orthographically deeper languages, which rely on the orthographic route, reveal more Broca's area and frontal lobe activation. These areas are associated with higher level processing. On the other hand, readers of more shallow languages often display Wernike's activation, which is an area associated with phonology and thus the phonological route (Perani et al., 1998). The results of the current project will critically inform attempts to adjust teaching to help these children obtain literacy.

Previous research has already shown that bilingualism affects phonetic knowledge. The L1 (first language, mother-tongue) of bilinguals can be influenced by the phonetics (i.e. sounds) of the L2 (additional or new language, language of school or community) and vice versa, regardless of the proficiency level of the L2 (Yusa et al., 2010). Infants are born with the capability to recognize every possible phoneme, but they quickly lose the ability to identify those to which they are not exposed. Bilinguals thus have an advantage because they maintain the ability to discriminate between more phonemes. Infants as young as 10 months have been able to demonstrate neural discrimination between Spanish and English phonemes that monolingual brains were unable to detect (Garcia-Sierra et al., 2011).

Unsurprisingly, bilingual children in grades two and three have significantly outperformed monolingual children in phonological awareness segmentation tasks in a preliminary study (Kovelman, Baker, & Petitto, 2008). These findings reinforce the relevance of phonological awareness in research surrounding reading acquisition in bilingual children. Additionally, bilingual children often have an advantage in semantic tasks because they are so accustomed to managing a higher magnitude of verbal input and because they possess two lexicons (Marian & Spivey, 2003).

We aim to shed light on these differences in bilingual reading acquisition via our two behavioral tasks with children in an fMRI machine to map sound sensitivity and vocabulary/semantic circuits. We have two distinct, competing hypotheses: (1) Bilinguals will outperform monolinguals in the metaphonological matching tasks and semantic tasks. When we introduce the neuroimaging techniques we also predict more Wernicke's area activation in bilinguals due to the increase in phonological activation and thus a stronger phonological route. (2) Since the bilingual children will be recruited from an immersive program starting at age five and they are living in the United States, they will not vary from the monolingual English speaking children because they are beginning to acquire literacy at the same age. For the current pilot study, we predict that adult bilinguals and monolinguals will achieve 100% accuracy in their respective language(s).

Method

Participants

The participants, N = 12, for this pilot study were adult residents of Ann Arbor, MI. N = 8 native English speakers completed the English metaphonological task and N = 4 native Spanish speakers completed the Spanish metaphonological task.

Behavioral Tasks

The present study is preparatory for an fMRI neuroimaging study with children, but all of the tasks in this pilot were strictly behavioral. These behavioral tasks will later be administered with fMRI technology on children throughout multiple testing sessions. While both tasks are described in detail and designed as a part of this project, the focus on experimental design limits the data of the present thesis to that of the metaphonological task.

Task 1: Match Task. The Match Task is a phonological awareness task used for mapping sensitivity to the sounds of one's language. This task has two different forms: auditory (listening) and visual (reading). Children around age six will complete the auditory version and children around age nine will complete the visual version.

Task 1a: Auditory Match Task. During the auditory experimental run, the participants heard two noun words and saw an image representing the first word on a PowerPoint slide. For the present project, a native English speaker read the words to the participant. To ensure proper phonemic pronunciation, the participant heard a recording of a native Spanish speaker for the Spanish condition. The participants were asked to judge whether the first sounds (i.e. the onset sounds) of the words matched (see Figure 2 for example trials). They verbally indicated their response to the researcher (yes/no for English and sí/no for Spanish) and the researcher recorded their response. During the control condition, participants heard two tones and were asked if they matched. For consistency, half of the trials were matching and half were non-matching.

Task 1b: Visual Match Task. During the visual experimental run, the participants read two noun words and were presented with an image representing the first word on a PowerPoint slide. They were then asked to judge whether the first sounds of the words matched (see Figure 3 for example trials). They verbally indicated their response to the researcher who recorded the data. During the control condition, participants saw two geometrical figures and were asked if they matched in color. Brightness will act as a cue for children who are colorblind (see Figure 4 for a demonstration of brightness control). For consistency, half of the trials were matching and half of the trials were non-matching.

Task 2: Semantic Task. The semantic task is used for mapping the vocabulary/semantic knowledge circuits, which demonstrate one's vocabulary. During the experimental run, participants saw a picture and heard two words and were asked to determine which word best fits the picture (see Figure 5 for example trials). There were three conditions to this task: English, Spanish, and Control. The English and Spanish tasks consisted of auditory stimuli in their respective language. The control condition was the same visual control used in the metaphonological task. Due to the focus of this project on experimental and stimuli design, this task is not included in the present pilot study but will be implemented in the later study.

Stimuli

The pictures used are drawn mainly from the International Picture Naming Project (Szekely et al., 2005) and the Snodgrass and Vanderwart set (Snodgrass, Gay, & Yudisky, 1996), both of which are standardized based on several decades of research. The words do not vary significantly within sets in terms of phonemes, syllables, frequency, and imaginability rating.

English words were measured based on the aforementioned factors using the MRC Psycholinguistic Database (Coltheart, 1981; Wilson, 1988) and the syllables and phoneme counts were confirmed manually. The Spanish words were measured using the EsPal Spanish Lexical Database (Duchon, Perea, Sebastián-Gallés, Martí, & Carrerias, 2013) and syllable and phoneme counts were confirmed manually for each task.

No cognates (words that sound similar and mean the same thing between two languages) were present between Spanish and English stimuli to prohibit word selection disruption, which can occur due to the properties of cognate words in the bilingual lexicon and the inability to deactivate access to the other language. In this way, it becomes nearly impossible to accurately measure the properties of one language with the other language consistently interfering in the lexicon (Kroll, Bobb, Misra, & Guo, 2008).

Procedure

Participants completed the two tasks on a computer via PowerPoint slides. All stimuli were randomized using Excel. Participants saw the picture and heard/read the respective words and were asked to inform the researcher of their decision. Researchers (native English speakers) presented English stimuli verbally and played a recording of a native Spanish speaker during the Spanish auditory tasks. Again, for the Sound Matching task the decision was whether or not the onset sound of the words match while during the semantic task participants determined which word best represented the picture shown. Participants completed 10 practice trials and confirmed their understanding of the instructions with the researcher before beginning the experimental trials.

Results

Quantitative Data

English. After piloting on N = 8 native English speaking adults we were able to adjust our stimuli and correct all detected errors. The participant accuracy ratings ranged from 95-98.3% for the auditory condition ($M = 0.97$, $SD = 0.004$) and 95-100% for the visual condition ($M = 0.99$, $SD = 0.006$) (see Table 1 for a complete list of participant responses and accuracy). T-test results indicate a significant difference between the mean scores of the visual and auditory conditions, $t(6) = 4.55$, $p = 0.004$, such that adults completed more trials accurately in the visual condition than in the auditory condition.

Spanish. After piloting on N = 4 native Spanish speakers, we were able to adjust the stimuli and correct all detected errors. The participant accuracy ratings ranged from 98.3-100% for the auditory condition (M = 0.99, SD = 0.005) and 96.7-100% for the visual condition (M = 0.99, SD = 0.008) (see Table 2 for a complete list of participant responses and accuracy). T-test results indicate no significant difference between the mean scores of the visual and auditory conditions, $t(2) = 0.02$, $p = 0.99$.

Comparison across languages. T-test results indicate no significant differences between the Spanish and English auditory tasks, $t(5) = -1.69$, $p = 0.15$, or between the Spanish and English visual conditions, $t(2) = 0.26$, $p = 0.53$. Taking into account the small sample size, we also conducted an ANOVA analysis which showed no significant difference among any of the tasks (English visual, English auditory, Spanish visual, Spanish auditory), $F(3,20) = 2.26$, $p = 0.11$.

Qualitative Data and Stimuli Adjustment

English. We found consistent patterns among the incorrect answers which we were able to alter in order to improve the task. Originally, stick-shape and shed-stage were two matching pairs. However, upon piloting it became obvious that since /*sh*/ and /*s*/ are two distinct phonemes, it is more logical to pair shed-shape and stick-stage. Furthermore, several participants chose egg-arm as a matching pair so we elected to eliminate any pairs containing two vowel onset sounds. Cross-kite was another pair that participants frequently answered incorrectly, saying it was non-matching. We presumed that this, as well as kitten-cover, was due to the orthographic difference. While this error most likely will not occur in pre-literate children, we opted to make these trials into practice trials to reinforce the idea that the first sound, not the first letter, has to match. We had a similar finding with matches like farm-floor, wheelchair-window, celery-ceiling, and printer-paddle because participants were relying too much on the initial syllable sound instead of the initial phonemic sound. To combat this, we made these practice trials to emphasize the importance of the first phonemic sound.

Spanish. We found consistent patterns among the incorrect answers, similar to English, which we altered to improve the task. As previously mentioned, Spanish is a very orthographically shallow language. Therefore, the issue of phonemic versus orthographic matching, as in English, was eliminated. However, multiple participants did not distinguish between the first phonemic sound and first syllable sound, such that they said matching pairs mundo-mano and niño-nieve did not match because the initial syllable sound differed. We plan to combat this by clarifying the instructions and designating these two pairs as practice trials.

Discussion

The overarching goal of the study is to gain a better understanding of the neurobiological and learning mechanisms that support bilingual reading acquisition. The specific goal of this thesis project was to design and pilot experimental tasks of phonological and semantic competence in English, Spanish, and Chinese languages. The study focus on phonology (language sound) and semantics (word meanings) is motivated by the findings that as children transition from language in speech to language in print, they must learn how to recognize units of language sounds and language meanings in print. We hypothesized that learning to read in Spanish and in English simultaneously will benefit children's phonological processing and ability to recognize sound and meaning in print, yielding better performance on phonological reading tasks in bilinguals relative to monolinguals. The present study also aimed to achieve 100% accuracy during the experimental protocol from adult pilot participants, as the task is ultimately aimed at young beginning readers in grades K-4. The goal of the project is to improve our understanding of language and reading acquisition across learners, languages, and educational contexts.

During the pilot of the experimental design, we found that adult participants had better accuracy during the visual word recognition as opposed to the auditory word recognition and all participants achieved above 95% accuracy. This outcome is to be expected of adult proficient readers who become automatic in print recognition. The opposite outcome (better performance during the auditory than visual task) is expected for young beginning readers as they have not yet acquired this skill. The ANOVA test demonstrated that the tasks between languages are not overall significantly different in terms of difficulty, which is important to eliminate any experimental bias. Finally, the high accuracy in adult participants boosts our confidence in the efficiency of the experimental design for future testing with children.

While the present thesis study only used behavioral measures, we predict that the introduction of the fMRI imaging with children will show greater Wernike's activation and thus a stronger phonological route in bilinguals. This reliance on the phonological route may also result in reduced activation in Broca's area in comparison to monolinguals.

Preliminary studies surrounding English-Spanish dual-immersion programs have shown that students in these programs, Spanish-speakers learning English or vise-versa, tend to match monolinguals in traditional programs on language acquisition. Not only do they learn to read English, they also develop the second target language (Alanís, 2000; Christian, 1996; Genesee, Lindholm-Leary, Saunders, & Christian, 2005). Furthermore, Spanish-English bilingual learners tend to have a higher phonological awareness than English monolinguals due to the orthographic shallowness of Spanish (Kovelman, Baker, & Petitto, 2008). We thus predict that bilinguals will match, if not out-perform, monolinguals on both tasks.

Another step this project is taking to explore bilingual reading acquisition is the inclusion of Cantonese. The length of this thesis is limited as to not discuss it in detail, but the implementation of a non-alphabetic language is crucial. This group of learners is particularly different because they are acquiring two completely unrelated languages, unlike Spanish and English which are both alphabetic and share many cognates. While we expect Cantonese-English bilinguals to match the accuracy of English monolinguals, it will be interesting to see their neurological activation. Cantonese and English are at opposite ends of the dual-route model, such that Cantonese is extremely orthographically deep and thus dependent on the orthographic route. For this reason, these learners may have more activation in Broca's area than English monolinguals and Spanish-English bilinguals.

Above all, we hope that our results in this pilot study are generalizable to children. The study will be piloted once more on children in Ann Arbor, MI before it reaches the participants in the dual-immersion school in San Francisco, CA. Nevertheless, we have already taken several steps to ensure the generalizability based on the qualitative data of the study.

Firstly, the addition of several practice trials should help participants understand various vague areas that we encountered upon piloting, mainly that orthographical non-matching pairs can be phonological matching pairs (e.g. cross and kite start with different letters, but are phonologically matching). However, this should be less of a problem in pre-literate children who do not think of the words in that manner. The practice trials should also highlight that the metaphonological task only requires a match in the first phoneme and not the entire syllable.

Additionally, we cross-referenced Spanish words with the storybooks used in the San Francisco United School District, where the children will be attending school, and confirmed that the age of acquisition (AoA) of each word was an appropriate match. For the auditory condition we eliminated any words higher than a 600 (i.e. AoA = 6.0 years), and for the visual condition words higher than 900 (i.e. AoA = 9.0 years) were eliminated. We used the MRC Psycholinguistic database (Coltheart, 1981; Wilson, 1988) to obtain the AoA for the stimuli. In these ways, the words should be appropriate and accessible to the children.

The success of dual-immersion programs has been shown time and time again (Alanís, 2000; Christian, 1996; Genesee et al., 2005). We hope that our investigation will contribute to this knowledge and thus an increased implementation of dual-immersion programs. With the growing amount of bilinguals, it is critical that these programs are supported and bilinguals have access to this unique and effective form of education.

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Tables

Table 1

Results for the English Metaphonological Condition; N = 8.

		Wrong Answers		Accuracy	
Participant	Years Exposed	Visual	Auditory	Visual	Auditory
1	Native Speaker	stick-shape shed-stage farm-floor	egg-arm wheelchair-window	95%	96.7%
2	Native Speaker		cross-kite	100%	98.3%
3	Native Speaker		cross-kite	100%	98.3%
4	Native Speaker		egg-arm	100%	98.3%
5	Native Speaker		cross-kite	100%	98.3%
6	Native Speaker	shape-stick	celery-ceiling printer-paddle	98.3%	96.7%
7	Native Speaker		cross-kite kitten-cover egg-arm	100%	95%
8	Native Speaker		cross-kite	100.0%	98.3%

Note. Years exposed refers to language exposure. All participants of the English condition were native English speakers.

Table 2

Results for the Spanish Metaphonological Condition; N = 4.

		Wrong Answers		Accuracy	
Participant	Years Exposed	Visual	Auditory	Visual	Auditory
9	Native Speaker			100%	100%
10	Native Speaker		niño-nieve	100%	98.3%
11	Native Speaker		mundo-mano	100%	98.3%
12	Native Speaker	tiro-techo colmena-caracol		96.7%	100%

Note. Years exposed refers to language exposure. All participants in the Spanish condition were native Spanish speakers.

Figures

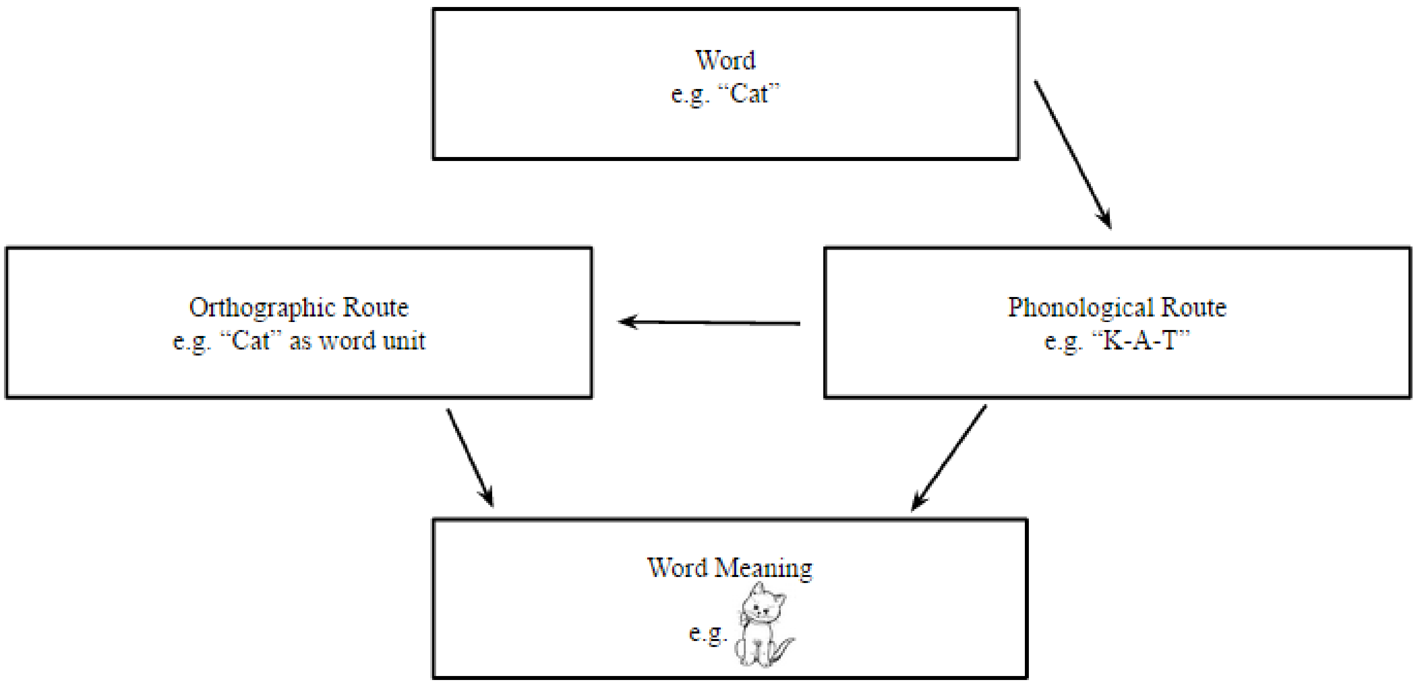

Figure 1. Dual-Route Model. The reader sees the word "cat". The phonological route consists of the reader sounding out the word, e.g. K-A-T, and is useful for orthographically shallow languages or words that have strong sound-to-spelling consistency, such as Spanish. The orthographical route consists of the reader recognizing the word "cat" as a learned unit and is more useful for orthographically deep languages, such as English. Either route, or a combination of the two, can produce the word meaning, or a mental image of what the word means. In this case the representation is a cat.

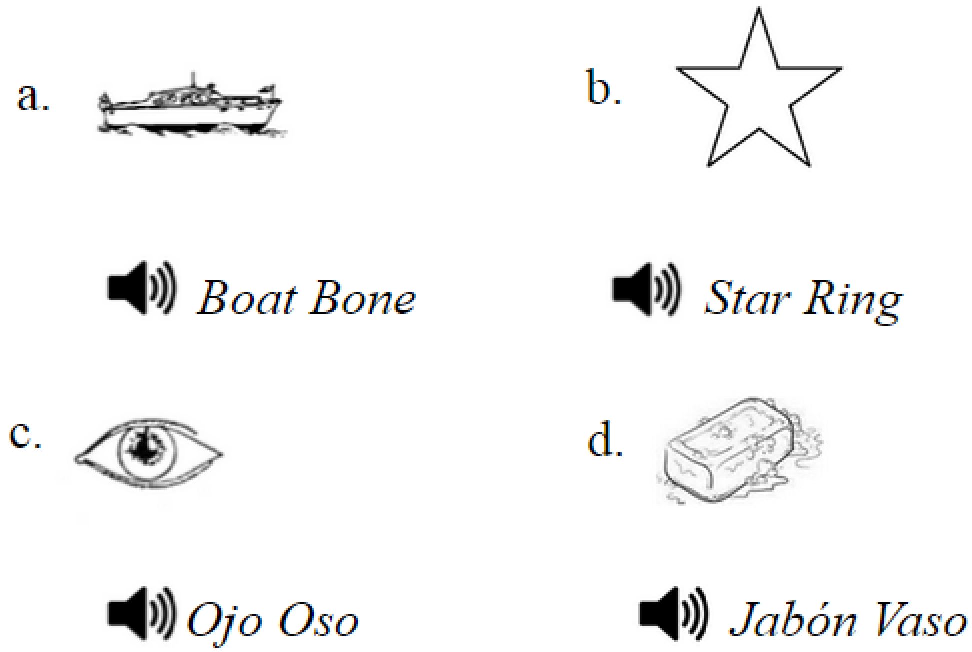

Figure 2. (a) Matching English condition. Participant hears the words "Boat" and "Bone" while the image of a boat is presented. (b) Non-Matching English Condition. Participant hears the words "Star" and "Ring" while the image of a star is presented. (c) Spanish Matching Condition. Participant hears the words "Ojo" (eye) and "Oso" (bear) while the image of an ojo/eye is presented. (d) Spanish Non-Matching Condition. Participant hears the words "Jabón" (soap) and "Vaso" (cup) while the image of jabón/soap is presented.

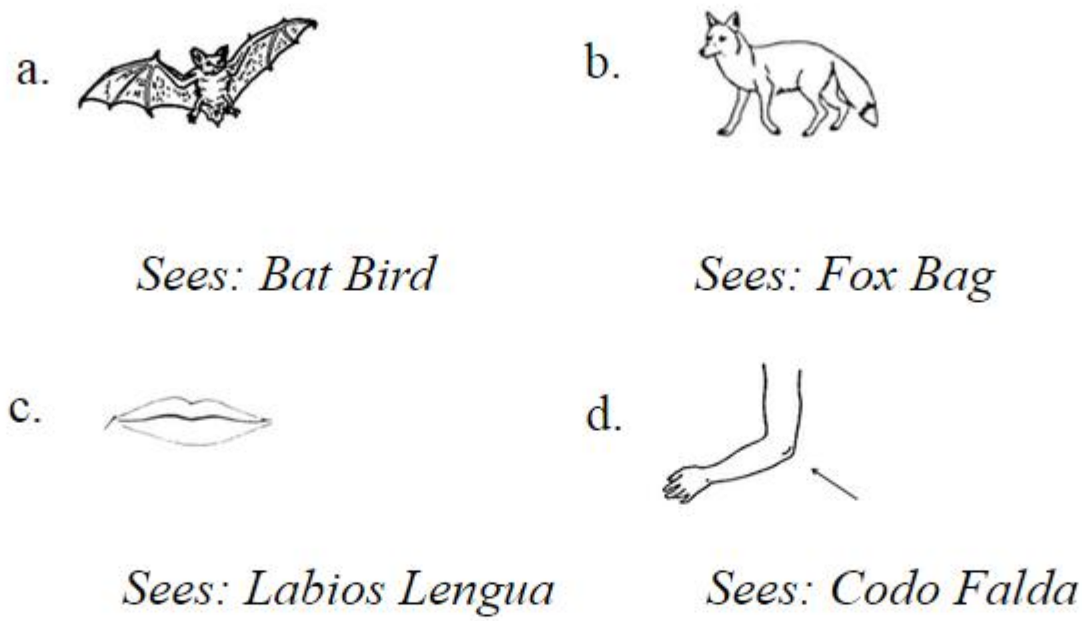

Figure 3. (a) Matching English Condition. Participant sees the words "Bat" and "Bird" while the image of a bat is presented. (b) Non-Matching English Condition. Participant sees the words "Fox" and "Bag" while the image of a fox is presented. (c) Spanish Matching Condition. Participant sees the words "Labios" (lips) and "Lengua" (tongue) while the image of a pair of lips presented. (d) Spanish Non-Matching Condition. Participant sees the words "Codo" (elbow) and "Falda" (skirt) while the image of an elbow is presented.

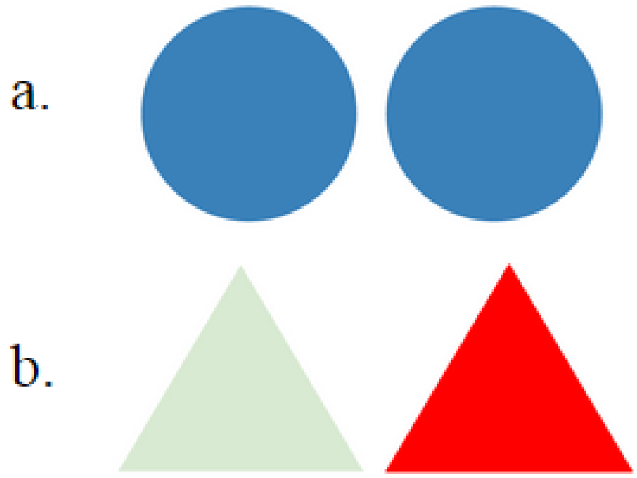

Figure 4. (a) Matching and (b) non-matching visual control task. Colors vary in hue to an extreme such that brightness can act as a cue for children with colorblindness.

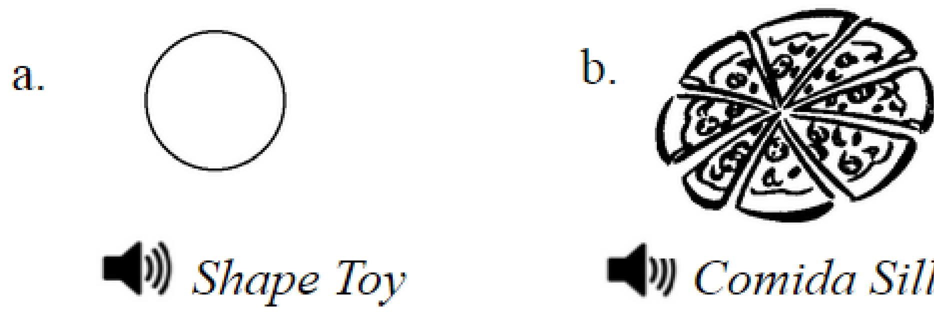

Figure 5. (a) English Condition. Participant hears the words "shape" and "toy" while the image of a circle is presented. (b) Spanish Condition. Participant hears the words "comida" (food) and "silla" (chair) while the image of a pizza is presented.