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The presence of sound symbolism effects for 3-D objects

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THE PRESENCE OF SOUND SYMBOLISM EFFECTS FOR 3-D OBJECTS

by

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We, the undersigned members of the Graduate Faculty of the University of Alabama in Huntsville, certify that we have advised and/or supervised the candidate on the work described in this thesis. We further certify that we have reviewed the thesis manuscript and approve it in partial fulfillment of the requirements for the degree of Master of Arts in Psychology.

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ABSTRACT
The School of Graduate Studies
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To disentangle the source of the bouba/kiki effect, vowels were presented either as phonemes, with a view of the mouth, and via the written word to assess the presence of the effect with 3-D objects. Using 3-D objects enabled the determination of whether the effect is influenced by the sensory mode (touch, visual) used to identify the object. Results indicated that the effect is present when labeling 3-D objects; however, when the rounded vowel was presented first, the effect was facilitated for those who saw the mouth produce the word and touched the objects. When the nonrounded vowel was presented first, ratings of confidence in the choice were highest in the grapheme condition. Implications and future research are discussed considering the neural mechanisms of cross-modality matching.

Abstract Approval: Committee Chair ___[signature]___

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LIST OF ABBREVIATIONS

Abbreviation	Definition
RV	Rounded Vowel
NRV	Nonrounded Vowel
2-D	Two-Dimensional
3-D	Three-Dimensional

LIST OF SYMBOLS

Symbol	Definition
d	Estimation of power for t-test
F	ANOVA statistic
M	Mean (Arithmetic average)
N	Total sample size
n	Sample size
p	Probability statistic
partial η^2	Estimation of power for ANOVA
SE	Standard Error
t	t-test statistic
Tukey's HSD	Post Hoc for ANOVA

CHAPTER 1

INTRODUCTION

1.1 Language

The factors affecting language acquisition have been studied extensively, yet the nature of the sounds and their significance is still under debate. Hockett (1960) argued that a meaning and the sound used to represent it is an arbitrary association. Since that time, a substantial amount of studies have accumulated which provide an opposing view that sounds can be symbolic. Nuckolls (1999) argued that numerous anthropological studies also support sound symbolism and concluded that sound symbolism could improve the knowledge of linguistic structures and language processes. Sound Symbolism offers insights into the learning of language, and a biologically based theory of language can account for sound symbolism.

The universality of human language has biological underpinnings. The two primary tasks of language consist of speech comprehension, a perceptual process, and speech production or speaking, a motor operation. The Wernicke-Geschwind Model incorporates both of these processes. According to this model, Wernicke’s Area in the temporal lobe is in charge of speech comprehension, whereas Broca’s Area in the frontal lobe is responsible for speech production. These areas are connected by fibers of the arcuate fasciculus. During a conversation, spoken words are sent through auditory pathways to Wernicke’s Area where the meaning is extracted. This information is then

sent to Broca's Area, which relays commands to the motor strip to produce speech. Information about written language is sent from visual areas to the Angular Gyrus in the parietal lobe where the meaning is processed. There are other areas of the brain involved in speech comprehension and speech production as well, including the supplementary speech area, dorsal frontal cortex, and the sensory and motor strips (Kolb &Whishaw, 2006). It is clear that the human brain is wired for language, and theories of language development, such as arbitrariness and sound symbolism, should explain how these neural processing areas work to create language. The neuroanatomy of language demonstrates that polymodal association areas could be involved in its processing.

1.2 Arbitrariness

The prevailing theory against sound symbolism is that of arbitrariness, posited by structural linguists, which holds that the relationship between sounds and their meaning is arbitrary. While Hockett (1960) acknowledged communication in other species shares some of the same 13 design features as human language, the presence of all 13 design features differentiates human communication from all other species. The eminent design feature includes that of arbitrariness which states that there are no precise or essential associations between sounds used and their meaning. This results in an unlimited number of communication possibilities and provides its significant advantage. Hockett states that communication in other ways, such as in pictures or a bee's dance, is not arbitrary. A picture shows clearly the point of reference and a bee systematically alters the speed of the dance based on the location of nectar. Structural linguists hold that sounds convey their meaning through contrasts with other sounds such that the sounds themselves cannot convey a meaning.

Some studies have taken a computational approach in support of an arbitrary theory of language. Gasser (2004) admits that there are cases of symbolism in human language, but states that these are exceptions to the rule of arbitrariness. Gasser argues that arbitrariness is necessary because of the large volume of words in a language. He suggests this arbitrariness aids in keeping word meanings separate during the learning process. Gasser also states that word learning and word retrieval in humans is a competitive process which is facilitated by arbitrariness. Symbolic associations place constraints on the amount of words and sounds that can be encoded, whereas arbitrary relationships allow a large number of these associations because they place fewer constraints on available cortical regions.

Developmental research provides evidence that the associations between sounds and meaning are arbitrary, but leaves room for a role of Sound Symbolism. Monaghan and Christiansen (2006) suggest that a child learning a language must learn both a specific meaning for a word and to categorize the word. Monaghan and Christiansen used computer simulations and found that arbitrariness between sounds and their meanings facilitated language learning under noisy conditions when contextual information was available to the learner, as is the usual situation when children are learning language. Arbitrary associations between a sound and its meaning allow the sound string to be quickly distinguished from other words. Conversely, they also found that the associations between words and their categories may be systematic. This suggests that there is both arbitrariness and systematicity in languages, and this facilitates learning.

Evolution could potentially produce a language with arbitrary associations between sounds and signals, but one that could still be facilitated by Sound Symbolism. Nowak and Komarova (2001) suggest that the assumption that the association between sound and meaning is arbitrary creates the problem of coherence. If individuals can assign different sounds to the same object, a coherent communication system may never evolve. For this evolution to occur, successful communication between individuals must have an advantage. Nowak and Komarova suggest that this advantage is increased reproductive success, which is the essence of natural selection. Individuals who successfully communicate produce more offspring who inherit a mechanism that enables them to learn the same communication system, thereby propagating a particular system. However, Nowak and Komarova (2001) recognize that language ultimately resulted from the use of existing structures in novel ways. If that is the case, the assumption that sound and meaning associations are arbitrary is not the only plausible conclusion. These existing structures could include innate mappings between sound and meanings which could then be inherited by offspring and utilized to more efficiently learn language.

1.3 Sound Symbolism

Since Saussure taught his course on general linguistics in the early 1900's, arbitrariness has been staunchly defended by structural linguists who hold that sounds convey their meaning through contrasts with other sounds, such that the sounds themselves cannot convey a meaning (Nuckolls, 1999). Beginning in the late 1920's, research began which supported an alternative theory, that of Sound Symbolism. This theory holds that the vocal sounds in words have meanings in and of themselves. Most notably, Kohler found in 1929 that adults tend to associate nonsense words containing

rounded vowels (such as bouba) with curvy shapes and words with nonrounded vowels (kiki) with angular shapes (Imai, Kita, Nagumo, & Okada, 2008). This effect has been replicated consistently since that time and has also been found to occur even in toddlers as discussed in detail below (Maurer, Pathman, & Mondloch, 2006). Also in 1929, Sapir demonstrated an example of magnitude symbolism in which English speakers associated new words containing the vowel /i/ with smallness more often than words containing /a/ (Imai et al., 2008). These early studies indicate that perceptual cues influence features of language.

Additionally, numerous anthropological studies of small scale societies support Sound Symbolism. Nuckolls (1999) provided a number of examples of these. The Navajo language treats sound as equivalent to the very forces of life as air gives life and is the method by which sounds are transmitted. The Kalapalo of Brazil consider sound to be a means to connect with each other and the universe as a whole. Additionally, the language of the Kaluli people of Papua, New Guinea, includes an abundance of sound-imitative words, particularly those involving sounds of nature. Because of the universality of language and the widespread occurrence of examples of sound symbolism, more recent research has investigated a biological explanation for sound symbolism in language development. One aspect of Sound Symbolism is that it requires the convergence of different perceptual systems. Polymodal processing areas in the cortex could be responsible for its occurrence.

To address cross-modality matching phenomenon, synesthesia, a perceptual phenomenon, can inform a biological theory of language evolution. In synesthesia, stimulation in one sensory pathway evokes an automatic secondary perceptual response.

There are many different types of synesthesia; the most common is the association of colors with letters or numbers. Ramachandran and Hubbard (2001) suggest that these associations arise from increased connections between color and grapheme processing areas of the brain which are adjacently located in the fusiform gyrus. Additionally, they propose that everyone is born with increased connections between areas of the brain, but these connections are subsequently pruned throughout normal development. The pruning mechanism is defective in synesthetes, resulting in lasting connections. This is supported by fMRI research in which colored-hearing synesthetes were studied (Nunn et al., 2002). When spoken words were presented, the area specialized for color perception, called V4 or V8, was activated in synesthetes but not controls. This cross-activation indicates a neural basis for synesthetic color perceptions.

Ramachandran and Hubbard (2001) also propose that the representations in motor brain maps of certain lip and tongue movements may be symbolically associated with certain sounds and phonemic representations. Supporting this idea is the discovery of mirror neurons which fire when viewing another person perform an action. These mirror neurons could be the link between sound and motor lip and tongue movements. Ramachandran and Hubbard hold that these key factors, symbolic associations between sound and shapes and between sounds and oral movements, combined to produce a language which then further evolved.

Presuming that all people are born with increased connections between areas of the brain that are later pruned, perhaps these connections could be present in muted form in all adults. In support of this, Rich, Bradshaw, and Mattingley (2005) found that both synesthetes and nonsynesthetes provided many of the same color-to-grapheme matches.

It is possible that an underlying mechanism that determines these associations in synesthetes and nonsynesthetes exists. The authors report evidence that people generally match brighter lights to higher pitched sounds. Similarly, synesthetes report a brighter color perception as the pitch of a spoken vowel was increased.

Similar cross-modality matching can be found in the investigation of language. Maurer et al. (2006) report that there are consistencies across languages in using words with the vowel “i” in association with objects that are smaller, brighter, closer, and with a higher pitch, and words with the vowels “a” and “o” for objects that are larger, darker, farther away, and with a lower pitch. Many adjectives in the English language referring to larger objects include rounded vowels (large, huge) which require widening the vocal tract and lips to produce the sound. Adjectives referring to smaller objects often include nonrounded vowels (tiny) which involve a narrowing of the vocal tract and lips to produce the sound. Research has suggested that these patterns are not universal; however, they are seen in a variety of languages including English, Japanese, Maori, Mandarin, and even African click languages.

There is evidence to suggest that the cross-modality associations found in synesthetes are easily appreciated by nonsynesthetes. Ward, Moore, Thompson-Lake, Salih, and Beck (2008) investigated judgments made by nonsynesthetes on the aesthetic appeal of audiovisual (AV) clips created by synesthetes compared to control AV clips. The control clips included altered versions of those created by synesthetes, random clips, and clips created by nonsynesthetes. Overall, the clips created by synesthetes were favored over the control clips. Even though not everyone is aware of these associations between senses, this study supports the idea that they are present in everyone. Ward et al.

Suggest that while synesthetes experience these associations, nonsynesthetes must construct these associations through a bottom-up process.

These associations serve an important function according to Sound Symbolism for it is these associations that potentially facilitate language learning. Imai and colleagues (2008) investigated the facilitation of verb learning by Sound Symbolism. Imai et al. Report previous literature which indicated that novel verb generalization is especially difficult for children aged 3 or younger regardless of primary language. Additionally, a class of words called mimetics in the Japanese language exist which clearly show sound symbolic properties. Mimetics are similar to onomatopoeias in the English language and include not only words for animal sounds (nyaa for cats), but also words referring to events and states where sound is not essential (goro for a heavy object rolling, and koro for a light object rolling). Mimetic words can also denote perceptual and emotional experiences (nurunuru: being slimy, pika: a flash of light, and sowasowa: being restless). Child directed speech by Japanese mothers has been shown to contain mimetic words, especially action words, in abundance.

In this study, Imai et al. (2008) created sound symbolic verbs which were rated by adult English and Japanese speakers as representing a particular action. These verbs and videos showing two different actions were then presented to children aged 2 and 3 years old. The children were asked to point to the video that was showing the action word spoken by the technician. Before the experimental trials, children completed four practice trials in which they were asked to select which person was jumping as they were shown two videos of the same person either jumping or waving a hand in order to familiarize them with the procedure. Children who were not cooperative or who showed

a position bias by consistently selecting the video on one side were excluded from data analysis. Children in both age groups chose the predicted video significantly more often than chance.

Furthermore, Imai et al. (2008) investigated whether 3 year old children would be better able to generalize novel sound symbolic action verbs across a change in the object being acted upon or actor performing the action. The experimenters taught Japanese children novel sound symbolic verbs and novel verbs that were not sound symbolic that were associated with a particular action. The children were tested for their ability to generalize the verb to another actor or object being acted on. The results confirmed that the children could generalize the sound symbolic verbs at levels significantly above chance but failed to do so for the verbs that were not sound symbolic. This supports the assertion that sound symbolism could function to facilitate verb learning.

Many studies on the facilitation of word learning by sound symbolism invent the words used as stimuli. To expand this research, Parault and Schwanenflugel (2006) required participants to actually generate a definition for obsolete English words. Two types of words were used: sound symbolic and non-symbolic words. Participants produced more accurate definitions for sound symbolic words, indicating that sound symbolism bestows added information about the meaning of the word. This extra information serves to facilitate learning of new words. This study adds strength to this idea, as previous research had primarily used nonsense words and associated meanings were presented to the participants.

These sound symbolic associations could potentially arise from learned language conventions rather than a natural bias. Nygaard, Cook, and Namy (2009) suggest that

tasks across languages can provide some insight into the nature of these associations. Nygaard et al. Presented evidence that sound symbolism aids cross-lingual word learning in adults. English speakers learned spoken Japanese words paired with English meanings that either matched the true meaning of the word, were antonyms for the true meaning, or were randomly selected from a the list of words used. Participants learned the words more accurately and responded faster in the matched pairs and antonym condition than in the random pair condition. These results suggest that there are associations between sound and meaning in languages, even in languages that are unfamiliar. These associations also affect encoding and retrieval of the meaning of unfamiliar words, as reaction time was affected. The authors suggest that these symbolic properties may be important for word learning and processing in adults, as well as for the acquisition of spoken language in young children.

1.4 Bouba/Kiki Effect

A remarkable example of Sound Symbolism is the bouba/kiki effect in which adults overwhelmingly associate nonsense words containing rounded vowels (RV; such as “bouba”) with rounded shapes, and words with nonrounded vowels (NRV; such as “kiki”) with pointed shapes typically presented in two dimensional drawings. Numerous studies have shown this effect in adults and children as young as 8. Maurer et al. (2006) proposed that this effect would be seen in toddlers at an age where it would be beneficial for the purpose of learning language. In their study, children with an average age of 2.8 years were shown four different pairs of shapes and asked which picture matched one of two words spoken by the investigator in view of the children. Validity trials were included as exclusionary criteria; a group of adults were also tested in the same way as a

comparison. The results showed that both adults and children associated the rounded shapes with the words containing RV, and vice versa, significantly more than chance. Additionally, the results of the adults and children were not significantly different. These results support the idea that language learning can be facilitated by naturally occurring biases such as these sound shape associations. In this study, the investigator called attention to the face and mouth as the word was pronounced to the child. The distinct contributions of seeing the mouth pronounce the word, the feeling of pronouncing the word, or hearing the sound of the word could not be established in this study. Ramachandran and Hubbard (2001) also discussed the bouba/kiki effect, and concluded that it suggests innate biases underlying the associations of certain sounds with certain objects.

Studies on the bouba/kiki effect do have a few flaws. The stimuli used are specifically chosen to demonstrate the effect of interest, leading participants to potentially become aware of the manipulations. There is also a lack of similar results with more general stimuli. Westbury (2005) used an implicit interference task to compensate for these issues. Stimuli (words or nonwords, and single letters or numbers) were presented inside spiky or curvy frames. Reaction times indicated interference as could be predicted from previous studies on this effect. Rounded shapes facilitated the identification of rounded consonant strings while interfering with the identification of nonrounded consonant strings, and vice versa. These results indicate that the associations occur pre-semantically and support a neurological basis of Sound Symbolism. While the study was important, again the data were collected by the presentation of 2-dimensional (2-D) figures.

1.5 Object Recognition

Previous studies on the bouba/kiki effect primarily used 2-D line drawings of the figures used as stimuli. There is consequently a lack of information about whether the effect generalizes when perceiving three dimensional (3-D) objects. With 3-D stimuli, the process of object recognition is important. There are two competing theories about how objects from different viewpoints are recognized. Recognition by Component theory states that objects are formed from geons which have specific view-invariant properties. The contrasting theory suggests that people can identify objects because of a stored set of 2-D images. Attention is also important for object perception. Feature Integration Theory proposes a preattentive stage followed by a focused attention stage which leads to perception. In the preattentive stage, objects are broken into their components and then combined in the focused attention stage. Attention functions to connect the features (Palmeri & Gauthier, 2004).

Object recognition does not only occur through the visual system, but can occur through touch or hapsis (haptic processes). The sensation of touch results from activation of mechanoreceptors whose axons travel in bundles to the spinal cord through the dorsal column-medial lemniscus. These pathways decussate before arriving at the thalamus which then sends the information to the somatosensory cortex in the parietal lobe. Like vision, haptic touch is highly lateralized. The body maps on the cortex show that more cortical space is allotted to certain parts of the body, such as the fingers and lips. This is important for identifying objects through active, or haptic, touch. Fine details can be discriminated easily through the fingertips, facilitating the identification of an object

without visual information (Palmeri & Gauthier, 2004). There are no studies to date that have explored whether the bouba/kiki effect influences object labeling via haptic touch.

In 1962, Gibson discussed the importance of distinguishing between passive touch and active touch. He describes active touch as exploratory, not just simply receptive, though up until that point touch had been studied primarily as a passive sense. Gibson equates the movement of the fingers during active touch with the movement of the eyes while scanning an environment. He also denotes that the normal state for both senses is active, in that the eyes scan the environment and in a tactile situation the fingers are used to explore the environment. More recent research has explored the neural basis of haptic touch and found that haptic object perception activates extrastriate areas involved in vision (James et al., 2002).

Humans and other primates rely on vision as the primary sense for object recognition. Its major advantage over touch is the ability to attain information about objects out of arm's reach; however, touch can provide a wealth of information about an object in hand. Previous research has indicated that vision and touch systems may share similar mechanisms of higher-order processing. James and colleagues (2002) proposed that the touch system actually utilizes the visual object recognition pathways. In their study, participants studied novel 3-D objects either visually or haptically. They then entered a functional magnetic resonance imaging (fMRI) scanner and viewed the primed objects and non-primed objects, as well as haptically investigated non-primed objects. Viewing non-primed objects activated the middle and lateral occipital areas (MO and LO) and the fusiform gyrus (FG) of the lateral occipitotemporal complex (LOC) which is consistent with other studies. Activation in the MO and LO increased to the same degree

when viewing objects that had been either visually or haptically primed. This pattern of activation suggests that cross-modal priming utilizes a common haptic and visual representation system. Activation overlapped in the MO for visual and haptic investigation of non-primed objects, making this the likely site of shared neural substrate between haptic and visual systems. This suggests that touch and vision should be equally valid means of identifying objects.

1.6 Hypotheses

Studies on the bouba/kiki effect and word learning indicate that Sound Symbolism facilitates language acquisition and demonstrates the potential for cross-modality matching. Ramachandran and Hubbard (2001) suggest a biological theory of language evolution in which mirror neurons systematically unite representations in motor brain maps of certain oral movements and certain sounds and phonemic representations. A follow up study on the bouba/kiki effect manipulating the presentation of words with RV or NRV could provide interesting information, especially with procedures that systematically counterbalanced the initial presentation of vowels. Furthermore, testing the effect with 3-D objects and by two different modes of inspection supplements the information from previous studies.

Presentation of vowel sounds was manipulated because previous studies on the bouba/kiki effect did not determine whether the source of the effect is produced from seeing the mouth pronounce the word, the feeling of pronouncing the word, or hearing the sound of the word (Maurer et al., 2006). To address this deficit, I developed a study to disentangle the source of the effect by presenting the vowels either as phonemes alone (aural condition), a view of the mouth while the phoneme was being pronounced (oral

condition), and via the written word (grapheme condition). Also, the literature was missing information about how the vowel sounds could influence choosing a 3-D object that would match the sound. My first hypothesis was to predict that words with RV would result in choice of rounded 3-D object and words with NRV would result in choice of spiked 3-D object, demonstrating the presence of the bouba/kiki effect (Maurer et al., 2006).

In addition to demonstrating the bouba/kiki effect for 3-D objects, the manipulations addressed how the sounds were presented and how the objects were inspected. My second hypothesis was that there would be a main effect for presentation of the sounds (aural, oral, grapheme). I expected that the sound in addition to association with kinesthetic feedback provided by viewing mouth movements as the phonemes were spoken (i.e., the oral condition) would have the greatest impact on the measurements (Maurer et al., 2006). Finally, I manipulated the mode of inspection by presenting the 3-D objects to be inspected through touch or vision. My third hypothesis was that this mode of presentation could affect the measurements (Palmeri & Gauthier, 2004).

This study allowed the effect to be generalized to stimuli with greater ecological validity. Previous studies on the bouba/kiki effect required participants to choose between 2-D forms. Choosing a 3-D object adds visuospatial haptic information and could lend support to Ramachandran and Hubbard’s (2001) biologically based theory of language. Expected associations would indicate that Sound Symbolism can be generalized to relationships between sounds and the selection of a 3-D object through both depth cues of visual processing and somesthesis provided by haptic touch.

CHAPTER 2

METHOD AND PROCEDURE

2.1 Participants

College students (*N* = 155) enrolled in psychology classes at the University of Alabama in Huntsville were recruited to participate in this study. Those with self-identified movement disorders, uncorrected visual impairment, or hearing impairment were restricted from participating. As presented in Table 2.1, there were 112 female participants and 41 male participants with an average age of 20.53 (*SE* = .28). The majors represented were Nursing with 29, Science 34, Engineering 29, Liberal Arts other than language 52, Business 7, and Language 3. Some demographic information was missing; however, the majority of participants were Caucasian (63.87%), with 22.58% African American, and 11.61% identified as Hispanic/Asian/Other. Table 2.1 also shows the demographics separated by those who saw the RV first and those who saw the NRV first. No data is presented from 17 participants who were excluded due to the participant not following instructions or malfunction of the computer, speaker, or presentation. All APA ethical guidelines were followed. Participants under the age of 19 were required to obtain parental consent. The IRB approved this project on September 14, 2010 (see Appendix A) and the consent form is shown in Appendix B.

Table 2.1 Demographics for RV, NRV, and Total

Demographic	RV	NRV	Total
Female (%)	72.72	73.68	73.2*
Male (%)	27.27	26.32	26.8*
Race (%Caucasian)	67.53	60.26	63.87**
Average Age (*M)*	20.00	21.04	20.53***
SE	.30	.47	.28

*Two participants provided no response for this question
**Five participants provided no response for this question
***One participant provided no response for this question
Note: The mean age is presented, *SE* refers to the standard error of the mean

2.2 Design

This was a 2 x 2 x 3 (Vowels: rounded, nonrounded by Inspection: haptic, visual) by Presentation: oral, aural, grapheme) mixed design with Vowel as a within-subjects factor, as shown in Appendix C. The stimulus containing one of the two words with either RV (mabuma) or NRV (takete) were projected on screen to provide either just the sound (aural), a mouth moving to produce the sound (oral), or the written word (grapheme). Appendix D shows examples of the presentation. The 3-D objects were a round ball and a star cemented on the bottom of an open box or hidden within a draped box where the participant could touch the object, as shown in Appendix E. The participant chose which of the two objects the word represented. The object selected was

recorded and tallies were generated for a vowel-object match score that corresponded with the bouba/kiki effect. Ratings (1-10) of confidence that the object matched the word and likelihood that someone else would choose the same object were also measured.

2.3 Materials

A computer with speakers was used to present stimuli. The words used (mabuma, takete) were taken from the study by Maurer and colleagues (2006). A video showing a person speaking the word was used for the oral presentation, the sound from the video with no picture was the aural presentation, and a written word presented on screen was used for the grapheme presentation (44 point Arial font, black text on white). Vowels were presented for 3 s and participants had a 15 s time limit to choose the object. Partitions of approximately 14.5 in. were placed in front of each station to block the view of other participants while still providing a clear view of the stimuli on the screen. A 3 min video on study skills, obtained from youtube.com, was used for a distracter task. The second trial presented the vowel counterbalanced to the initial trial.

The objects were presented in boxes with lids. Cardboard boxes were approximately 8.5 in. long by 8.5 in. wide by 5 in. tall. The objects used as the 3-D targets were four sets of ornaments (spiked star shape, rounded ball) and were approximately 1 in. in diameter. The ball and star were secured to the bottom of the box with hot glue in counterbalanced order (star/ball; ball/star). Flaps were cut into the front of the box and covered so that participants could place their hand into the box without seeing the objects for the haptic condition. The top lifted off the box so that participants in the visual condition could view the objects but not touch them. The objects were labeled as 1 and 2 inside the box for the visual condition and on the lid of the box for the

haptic condition. For sanitary purposes, disinfectant wipes were used to clean the boxes and participants were provided hand sanitizer.

2.4 Procedure

Participants were randomly assigned to presentation groups with counterbalanced presentation of vowels and 3-D objects (see Appendix F for the counterbalancing scheme). Participants were scheduled in groups of four; however, partitions to block view of others' materials were placed at each station. Consent forms were then collected. Investigators requested that cell phones be placed on silent and stated that talking during the session was not allowed. The hand sanitizer was provided to each participant prior to the session to reduce contamination with germs.

Participants were seated at a table with the box containing the objects, response sheets, and a partition blocking the view of the other participants. Participants were instructed to choose the object which matched the word they were presented on screen and/or through the speakers. Technicians answered questions about the task before beginning the experimental trial. The first word was presented and the participants were instructed to remove the lid to view the object (visual condition) or to place their dominant hand inside the box and touch the object (haptic condition). Participants had up to 15 s to inspect the objects and responded by circling 1 or 2 on the response sheet. After choosing an object, participants gave ratings (1-10) of confidence that the object matched the word and likelihood that someone else would choose the same object. The data sheets are presented in Appendix G. Participants then viewed a distracter video on study skills for approximately 3 min. Participants were instructed to turn the paper over to respond to two questions about the video. The next word was then presented

(counterbalanced across sessions) and the participant again had a 15 s time limit to choose an object by the same inspection mode as in the first trial, with the same dependent variables recorded.

After this, demographic information and manipulation check questions (extent of art background; association of color with words, music, or sounds, disabilities or issues using hands or arms, or neurological impairments involving touch sensation in the hands) were distributed (see Appendix H). The response sheets were collected and after any questions from participants were addressed, they were thanked for participating and asked not to discuss details of the experiment with other students. Investigators then signed activity logs and the participants were released. The length of session was approximately 30 minutes. Technicians then wiped the boxes with disinfectant wipes after sessions.

CHAPTER 3

RESULTS

3.1 Bouba/Kiki Effect

As can be seen in Table 3.1, participants chose in the expected direction (i.e., ball for the RV sound, star for the NRV sound) significantly more often than not. This produced a significant interaction for the Chi Square Test of Independence, $X^2(2, N = 310) = 67.94$, $p < .001$. For the RV, 62.6% of participants chose in the expected direction and 83.2% of participants chose in the expected direction for the NRV. This result showed that the bouba/kiki effect was present for the selection of 3-D objects.

Table 3.1 Selection of Objects by Vowel

	Ball	Star
RV	97	58
NRV	26	129

Note: These are the actual number of selections of each object made by the participants.

3.2 Order Effects

The presence of the bouba/kiki effect was extracted on a ratio scale by adding whether the response matched the expected object (maximum score of 2 for both correctly matched) that would correspond with the vowel. Order effects based on whether the RV or NRV was initially presented were detected when the matching scores were analyzed, $t(154) = -6.09$, $p < .001$, $d = 1.02$, meaning the match score of those seeing the NRV was higher than those seeing the RV first. The rest of the statistical analyses will be presented separately for those who were presented RV first and those who received the NRV first.

3.3 Initial Rounded Vowel

3.3.1 Total Match Score Figure 3.1 presents the total match score as a function of Inspection (i.e., whether participants viewed or touched the objects) and Presentation. A 2 × 3 ANOVA revealed a significant main effect for Presentation on total match score, $F(2, 75) = 4.63$, $p = .01$, $\eta^2 = .12$, indicating the matches were more likely to occur with the Oral presentation. Tukey's HSD post hoc comparisons showed that the oral presentation with touch condition ($M = 1.67$, $SE = .14$) differed significantly from the grapheme presentation with vision condition ($M = 0.67$, $SE = .23$). Inspection by touch facilitated the effect compared to visual inspection, resulting in a significant main effect for Inspection, $F(1, 75) = 4.33$, $p = .04$, $\eta^2 = .06$. Although the lines converge in Figure 3.1, there was no significant interaction $F(2, 75) = .52$, $p = .60$.

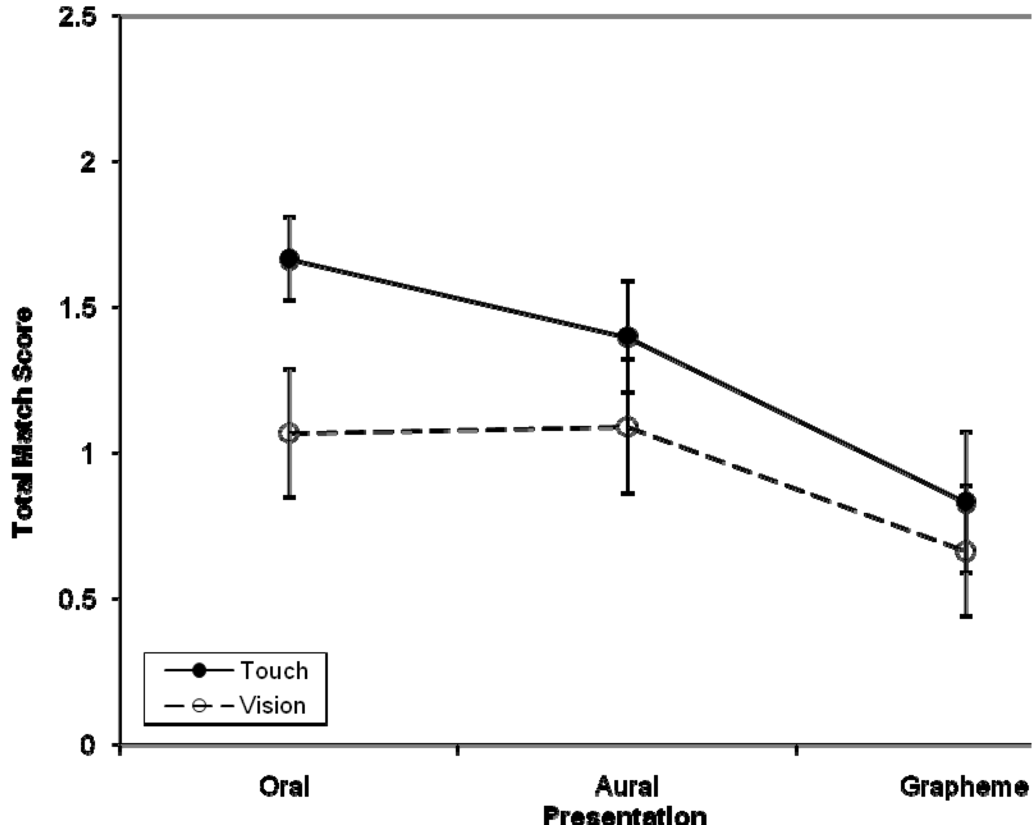


Figure 3.1 Total Match Score for RV as a Function of Presentation and Inspection

3.3.2 Confidence Ratings A 2 × 2 × 3 (Trial by Inspection by Presentation) mixed ANOVA demonstrated that confidence ratings were not significantly different between Presentations, $F(2, 75) = .58$, $p = .56$, or Inspection $F(1, 75) = 1.02$, $p = .32$, or by Trial, $F(1, 75) = 1.16$, $p = .29$, nor was there an interaction $F(2, 75) = 1.08$, $p = .35$ Figure 3.2 shows the confidence ratings as a function of Presentation and Inspection for each Trial.

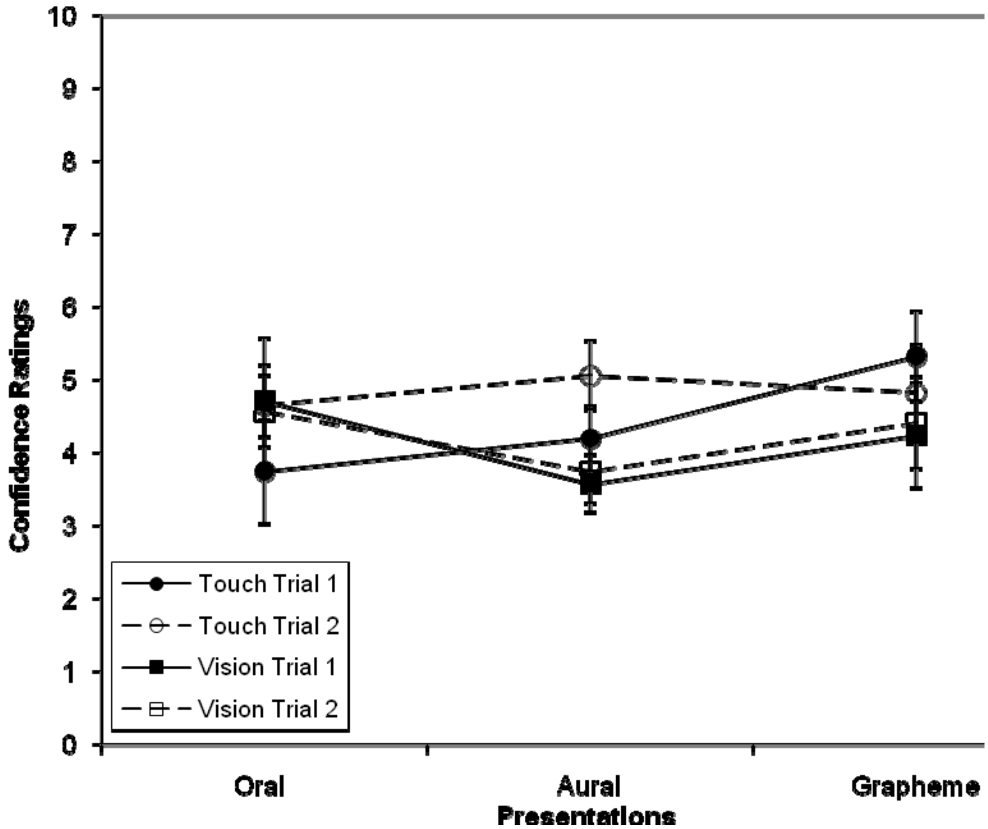


Figure 3.2 Confidence Ratings for RV as a Function of Presentation and Inspection for Each Trial

3.3.3 Likelihood Ratings Ratings of the likelihood that someone else would make the same choice were analyzed by a 2 × 2 × 3 repeated measures ANOVA and did not significantly differ among Presentations, $F(2, 75) = .09$, $p = .91$, or Inspection, $F(1, 75) = .46$, $p = .50$, or Trial, $F(1, 75) = 1.95$, $p = .17$, with no interaction $F(2, 75) = 1.88$, $p = .16$. Table 3.2 presents these results.

Table 3.2 Likelihood Ratings for RV by Presentation and Inspection

Trial 1

	Touch		Vision	
Presentation	*M*	*SE*	*M*	*SE*
Oral	5.3	.46	6.4	.56
Aural	5.6	.48	5.8	.41
Grapheme	6.5	.61	6.3	.54

Trial 2

	Touch		Vision	
Presentation	*M*	*SE*	*M*	*SE*
Oral	5.3	.68	6.1	.52
Aural	6.5	.35	5.7	.56
Grapheme	5.1	.23	5.4	.54

Note: The scale for this rating was 1-10, with higher numbers reflecting a higher likelihood that someone else would choose the same object.

3.4 Initial Nonrounded Vowel

3.4.1 Total Match Score The results for this group were stable and consistent across Presentation and Inspection. This means that the presence of the bouba/kiki effect was not affected by Presentation cues or Mode of inspection. A 2 × 3 ANOVA revealed no main effect for Presentation, $F(2, 76) = .05$, $p = .95$, no main effect for Inspection, $F(2, 76) = .04$, $p = .85$, and no interaction, $F(2, 76) = .1.45$, $p = .24$. Figure 3.3 presents these results.

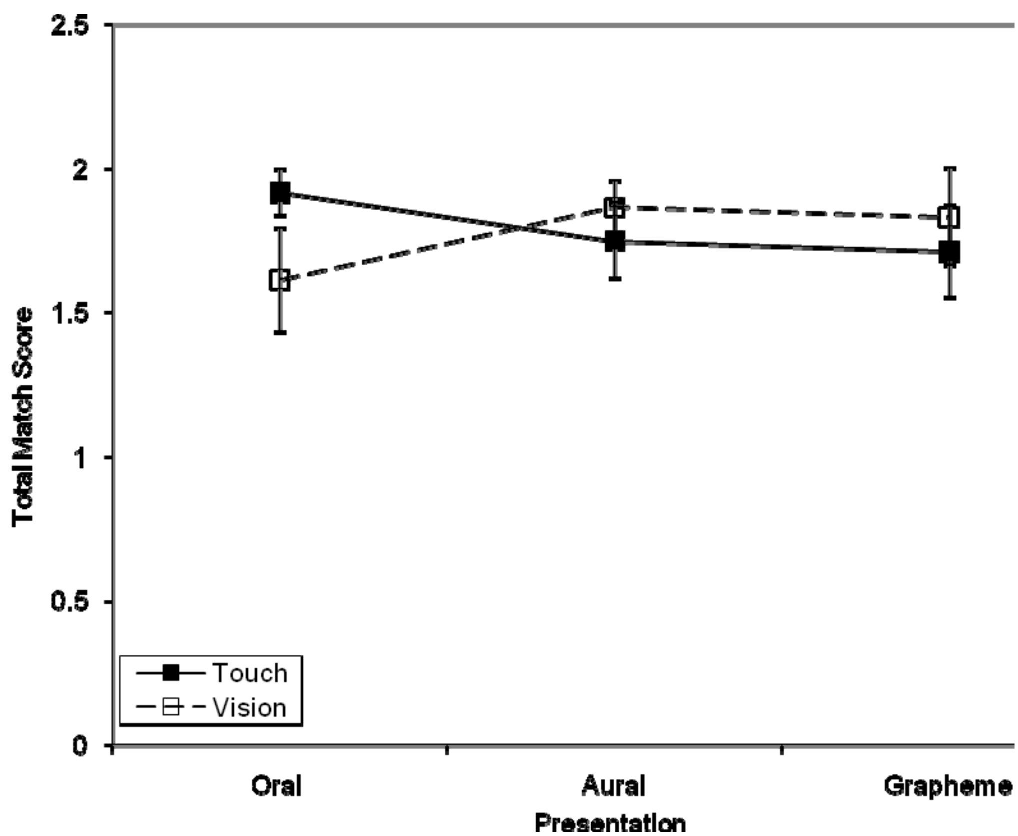


Figure 3.3 Total Match Score for NRV as a Function of Presentation and Inspection

3.4.2 Confidence Ratings A 2 × 2 × 3 mixed ANOVA revealed a significant main effect for Presentation on confidence ratings, $F(2, 76) = 3.83$, $p = .03$, $\eta^2 = .10$, indicating that participants reported the greatest confidence in their choices with the grapheme condition. Inspection mode made no difference on confidence ratings, $F(1, 76) = 2.25$, $p = .14$, nor did Trial, $F(1, 76) = 2.04$, $p = .16$. There was also no interaction, $F(2, 76) = 0.004$, $p = 1.0$. This result is shown in Figure 3.4, which presents the confidence ratings as a function of Presentation and Inspection for each Trial.

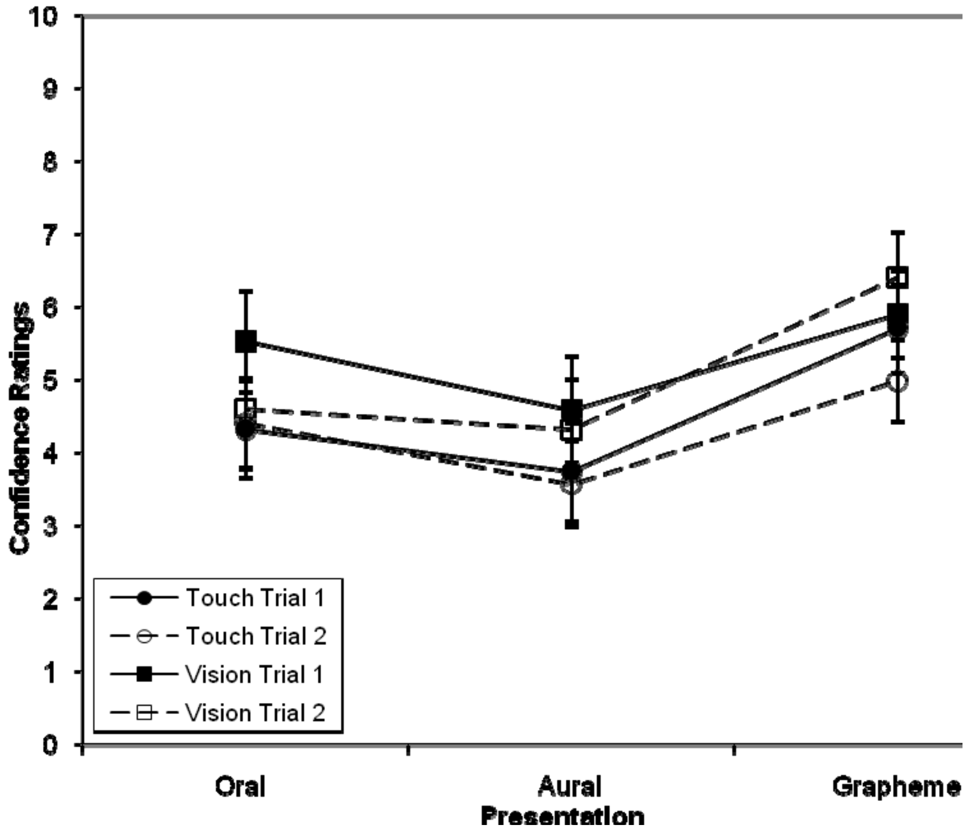


Figure 3.4 Confidence Ratings for NRV as a Function of Presentation and Inspection for Each Trial

3.4.3 Likelihood Ratings Likelihood ratings were again not significant for Presentation, $F(2, 76) = 2.72$, $p = .07$, or for Inspection, $F(1, 76) = 1.09$, $p = .30$, or for Trial, $F(1, 76) = .02$, $p = .90$ and there was no interaction, $F(2, 76) = 1.28$, $p = .29$. These results are presented in Table 3.3.

Table 3.3 Likelihood Ratings for NRV by Presentation and Inspection

Trial 1

	Touch		Vision	
Presentation	*M*	*SE*	*M*	*SE*
Oral	5.8	.46	6.2	.45
Aural	5.0	.56	5.0	.46
Grapheme	5.3	.51	6.8	.58

Trial 2

	Touch		Vision	
Presentation	*M*	*SE*	*M*	*SE*
Oral	5.9	.53	5.8	.53
Aural	5.3	.35	5.0	.46
Grapheme	5.6	.52	6.5	.59

Note: The scale for this rating was 1-10, with higher numbers reflecting a higher likelihood that someone else would choose the same object.

CHAPTER 4

DISCUSSION

4.1 Findings

The hypothesis that the bouba/kiki effect would be present for 3-D objects was confirmed, as predicted from previous studies (Maurer et al., 2006). This further supports Sound Symbolism, as 3-D objects have greater ecological validity than 2-D line drawings that have served as stimuli in previous studies. These data not only replicated a classic sound symbolism paradigm, but expanded the effect to include sensorimotor engagement and not just sound and vision.

The presence of order effects produced by which vowel was presented first has not previously been reported with this paradigm, but illustrates the importance of counterbalancing. When the RV was presented first, those in the oral condition who saw the mouth moving to produce the sound were more susceptible to the bouba/kiki effect than those in the aural and grapheme conditions. Additionally, the effect was facilitated by touch rather than vision. However, initial presentation of the NRV resulted in stable and consistent demonstration of the bouba/kiki effect regardless of how the word was presented or the object inspected. This pattern was not reflected in the confidence ratings, as they were highest in the grapheme presentation for those who were presented the NRV first. The presentation of the word made no impact on the confidence of those

who were presented the RV first. These results are intriguing and demonstrate the importance of counterbalancing the presentation of stimuli, investigating the different sources of words in the environment, and manipulating how one inspects objects in the real world.

The source of the order effects is unclear. Previous studies have either randomized presentation (Imai et al., 2008) or presented the target stimuli in the same order to all participants (Maurer et al., 2006). It is possible that the NRV (takete) used in this study primed participants to choose the expected object. The spiked object provided rich ecological information, with multiple spikes and hard edges. These factors combined to result in a strong correspondence between the vowel sound and the object across presentations and inspection mode. The RV had lower expected responses overall which could also be explained by the features of the objects used. The rounded object was a ball ornament with a glass surface. It is possible that the hard texture of the ball provided incongruent information, possibly resulting in lower rates of expected matches for the RV, in contrast to what might occur with a soft surface. Typically the images that correspond to RVs are cloud-shaped line drawings that one would associate with soft textures (Maurer et al., 2006; Westbury, 2005)

The hypotheses that the source of the presentation and the inspection mode would affect responses were supported when the RV were analyzed separately from the NRV. When RVs were presented first, expected matches were more likely to occur with the Oral presentation and inspection by touch favored the bouba/kiki effect compared to visual inspection. Presumably mirror neurons would fire when viewing the stimuli of the mouth moving to produce the sound of the word. This activation could facilitate

choosing the expected object in the touch condition because of the additional kinesthetic information and somesthetic associations. Ramachandran and Hubbard (2001) refer to cross-activation of two motor maps, similar to synesthetic perception, but which they term synkinaesia. They suggest that primitive language may have arisen from gestures and hand movements to include associated tongue and lip movements and their resulting sounds. The underlying basis of these associations is the location of the hand area and mouth area in the motor cortex in the frontal lobe, as they are adjacent (Buccino et al., 2001). Cross-activation between these areas could account for the facilitation of object choice in the touch condition when viewing the person's mouth moving to produce the sound.

Ratings of confidence that the object matched the word and the likelihood that someone else would make a similar decision were not very informative. The only significant effect was that the Grapheme provided the greatest confidence when the NRV was presented first. The use of nonsense words to test Sound Symbolism is necessary to decrease conscious associations; however, the nonsense word potentially led to some confusion among the participants. A small number of participants in the Oral and Aural conditions, where the sound of the word was presented, reported that they did not hear the word or had difficulty hearing the word. The technician positioned in the back of the room stated that the sound was adequate in all sessions. It is possible that those reporting they did not hear the word did not understand the word because they were expecting a word they recognized, classifying this misunderstanding as not being able to hear the word. The task then became more similar to a typical lexical decision task wherein a string of letters is determined to be a word or nonword (Kolb & Whishaw, 2006). Seeing

the word in print would eliminate the confusion based on only hearing the word, potentially raising confidence ratings. The greater confidence for the grapheme would be ecologically valid for a college student who was familiar with the English language. Assessing the responses of non-English speakers would be an interesting test of the robust nature of this result.

Participants were asked manipulation check questions about the extent of art background, neurological impairments involving touch sensation in the hands or any recent injuries to the hand and fingers, to name the objects they had inspected, and if they consistently associated color with words, sounds, or music. Only 3 participants were Language majors, making it unlikely that the majority of participants were familiar with Sound Symbolism. Fewer than 10% of participants reported an extensive background in art (i.e., major, minor, or several formal classes), minimizing exposure to possible theories in art that may include synesthetic or cross-modal instruction. The signup sheet notified potential participants that they should not participate if their touch perception was impaired, and accordingly no one reported such impairment. Participants were fairly accurate when describing the objects across touch and visual conditions, though no one guessed they were ornaments. Almost everyone correctly identified the ball and many called the spiked star a toy jack or described it as angular or spiky. This adds validity to using haptic touch as a method for object recognition as descriptions were consistent across touch and vision groups. Approximately half of the participants reported that they consistently associated color with words, sounds, or music. This question was intended to assess perceptual phenomenon; however, this high number suggests that participants instead considered common learned associations. Colors are commonly associated with

moods and color is often used in product design (faucets: hot = red, cold = blue; Goldstein, 2007).

The limitations of this study were those that persist throughout the research on the bouba/kiki effect (Westbury 2005). The objects used were specifically chosen to demonstrate the effect, leading participants to potentially become aware of the manipulation. Additionally, by presenting participants with two objects and two words they could simply have chosen the opposite of their first selection for the second trial. This was discouraged by having participants view a short video as a distracter task. Additionally, the first set of questions regarding object choice, confidence ratings, and likelihood ratings were on a separate page from the second set. Simply choosing the opposite on the second trial could account for the strong match scores for those who saw the NRV first; however, the lower match score of those who saw the RV first indicates that it is not necessarily an automatic reversal on the second trial.

4.2 Implications

Possible future research could assess how different textures would alter the results, especially for the rounded object. A soft surface or a surface with multiple rounded edges would further emphasize the roundedness and potentially bring the number of expected matches of the RV to that of the NRV seen in this study. Additionally, future research could investigate different levels of interaction with the objects. For this study, the objects were secured inside the box where the top could be lifted to view them or the hand could be inserted through a flap on the front to touch the objects without seeing them. Allowing participants to interact with and manipulate the objects, such as fully grasping with the whole hand and being able to pick the objects up,

assess weight, and maneuver them, could further add to the visuospatial and kinesthetic information available (Kolb & Whishaw, 2006).

Approximately 75% of participants reported that they repeated the words to themselves after presentation, suggesting that producing the word to oneself is an important process in this effect. Future research measuring the subvocalizations of participants could provide important information. The extent to which participants repeat the word to themselves without making a sound can be measured by surface EMG (sEMG) signals. The facial and neck muscles generate signals during subvocalizations which can be measured with electrodes placed on the skin (Deng et al., 2009). The presence of mirror neurons also indicates that subvocalizations may be important in Sound Symbolism. The shape of the mouth and the muscle movements involved in pronouncing the word, even silently, could modify the effect.

To disentangle the source of the bouba/kiki effect, vowels were presented either as phonemes, with a view of the mouth, and via the written word. Using 3-D objects enabled the determination of whether the effect is influenced by the sensory mode (touch, visual) used to identify the object. This thesis project systematically extended the bouba/kiki effect to 3-D objects. This demonstrates the robust nature of the effect as well as the usefulness of Sound Symbolism for investigating cross-modality matching. Results indicated that the effect is present when labeling 3-D objects; however, order effects were detected based on order of vowel sound presentation. When the RV was presented first, the effect was facilitated for those who saw the mouth produce the word and touched the objects. When the NRV was presented first, ratings of confidence in the choice were highest in the grapheme condition. The fact that the pattern of responses that

corresponded with Sound Symbolism depended on the initial vowel presented to participants was an important design feature of this study and highlights the importance of systematic presentation of stimuli. Had the NRV been presented first in all cases, the contributions of the Oral presentation and the advantage of inspection of object through touch would not have been revealed. The data foster more questions about how to study Sound Symbolism once the stimuli are removed from the 2-D limitations to the richer 3-D perception of objects. Studying neural mechanisms involved in these cross-modality processes using this paradigm should be informative.

APPENDICES

APPENDIX A

IRB Approval Letter

UAHuntsville
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Nicholaos Jones
3328 Morton Hall
Phone: 256.824 2338
Fax: 256.824 2387
Email: irb@uah.edu

Aurora Torres, Ph.D.
Department of Psychology
UAHuntsville
Huntsville, AL 35899

September 14, 2010

Dear Dr. Torres,

As chair of the IRB Human Subjects Committee, I have reviewed your proposal, *Sound Symbolism in 3-D*, and have found it meets the necessary criteria for expedited review according to 45 CFR 46. I have approved this proposal, and you may commence your research. Please note that this approval is good for one year from the date on this letter. If data collection continues past this period, a renewal application must be filed with the IRB.

Please contact me if you have any questions.

Sincerely,

Nicholaos J Jones

Dr. Nicholaos Jones
Chair, UHSC

OFFICE OF THE VICE PRESIDENT FOR RESEARCH
Von Braun Research Hall M-17 Huntsville, AL 35899 T 256.824.6100 F 256.824.6783

APPENDIX B

CONSENT FORM

Consent Form: Boxes Study

You are invited to participate in an investigation of how we think influences decisions about identifying objects. The investigators are students who work under the supervision of Dr. Aurora Torres in the Psychology Department of UAH. We seek 150 participants for this study. ________________ is in charge of your session. Please be advised that if you are under the age of 19, parental consent is required.

PROCEDURE TO BE FOLLOWED IN THE STUDY: Sessions will occur in Morton Hall 129 in groups of 4. When you arrive, you will be asked to give written consent and to use the hand sanitizer provided. Once seated, you are to refrain from touching the box at the testing station. You will be asked to pay attention to the slides on the classroom screen. The slide will be replaced with a blank slide during which you will be asked to make a response that requires you to touch the box in front of you. Follow the specific instructions provided. Once your responses are recorded, a short video clip will be presented, and then the same procedure will be repeated. We will also ask for a general description about you (sex, age, class status) and questions about what you thought of the slides. The session is expected to take up to 30 minutes to complete. The student technicians will answer any questions you have before signing your log sheet and releasing you.

DISCOMFORTS AND RISKS FROM PARTICIPATING IN THE STUDY: There are minimal risks associated with this study. If you are photosensitive, then you should decline and participate in another study. You will be asked to use hand sanitizer to avoid transmission of germs. Students who have uncorrected visual or hearing impairment, the presence of movement disorders, or whose touch perception is compromised should not participate.

EXPECTED BENEFITS: This study will provide no personal benefit to you aside from gaining 1 research credit for participation if you are enrolled in PY 101/102/201. However, your responses will help us understand how we identify objects.

CONFIDENTIALITY OF RESULTS: Data for your session will be recorded as a participant number. Results will be kept strictly confidential. The data from your session will only be released to those individuals directly involved in the study. This consent form will be destroyed 3 years after the study so that the ability to trace the participant number to you will be eliminated.

FREEDOM TO WITHDRAW: You can withdraw your consent and stop participating in the project at any time. This will mean that you will not gain research credits for participating; however, no additional credits will be deducted from your total points.

If you agree to participate in our project, please sign and date below. If you are under 19 years of age, you must have a signature of a parent/guardian.

This study was approved by the Institutional Review Board at UAH and expires in one year from September 14, 2010.

______________________________ ______________________________

Name (please print) Signature

______________________________ ______________________________

Parent/Guardian Signature (if < 19 years old) Date

____

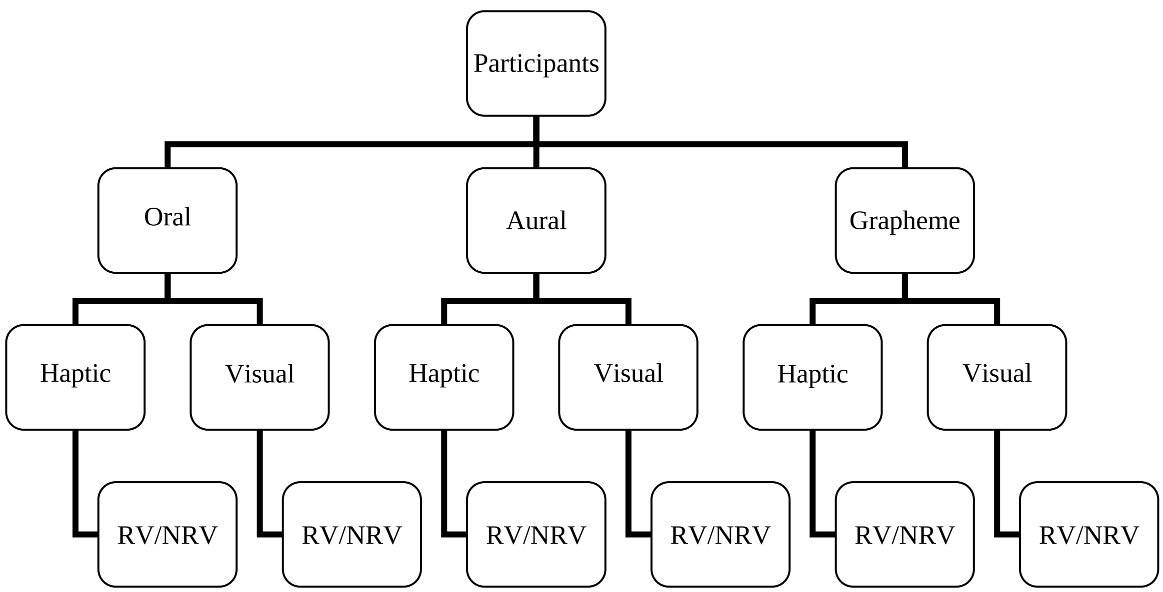
PY Instructor

Contact Person for Additional Information: Dr. Aurora Torres, UAH Psychology Department
824-2320 torresa@uah.edu

You can obtain a copy of this consent form by asking your technician or downloading it from the Angel PY Activity course.

APPENDIX C

DESIGN FLOW CHART



Note: RV = Rounded Vowel; NRV = NonRounded Vowel

APPENDIX D

EXAMPLE STIMULI

Figure D.1 Example Stimuli for the Oral Presentation

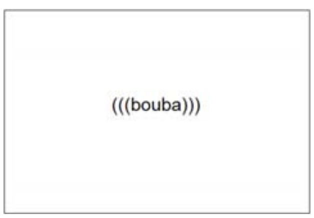


Figure D.2 Example Stimuli for the Aural Presentation.

[Note: Parentheses indicate the word was presented as a prerecorded audio clip played over speakers.]

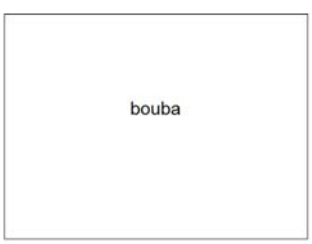


Figure D.3 Example Stimuli for the Grapheme Presentation

APPENDIX E

PRESENTATION BOX

Figure E.1 Stimulus Box with Lid

Figure E.2 Stimulus Box with Lid Removed

APPENDIX F

Counterbalancing Schedule

9-930		
	OVRB	OVRB
	OVRJ	OVRJ
930-10		
	OVNB	OVNB
	OVNJ	OVNJ
2-230		
	OHRB	OHRB
	OHRJ	OHRJ
230-3		
	OHNB	OHNB
	OHNJ	OHNJ
3-330		
	AHRB	AHRB
	AHRJ	AHRJ
330-4		
	AHNB	AHNB
	AHNJ	AHNJ

930-10		
	GVRB	GVRB
	GVRJ	GVRJ
10-1030		
	GVNB	GVNB
	GVNJ	GVNJ
2-230		
	GHRB	GHRB
	GHRJ	GHRJ
230-3		
	GHNB	GHNB
	GHNJ	GHNJ
3-330		
	OHRB	OHRB
	OHRJ	OHRJ
330-4		
	OHNB	OHNB
	OHNJ	OHNJ

9-930		
	AVRB	AVRB
	AVRJ	AVRJ
930-10		
	AVNB	AVNB
	AVNJ	AVNJ
2-230		
	AHRB	AHRB
	AHRJ	AHRJ
230-3		
	AHNB	AHNB
	AHNJ	AHNJ
3-330		
	GVRB	GVRB
	GVRJ	GVRJ
330-4		
	GVNB	GVNB
	GVNJ	GVNJ

10-1030		
	AVRB	AVRB
	AVRJ	AVRJ
1030-11		
	AVNB	AVNB
	AVNJ	AVNJ
11-1130		
	GVRB	GVRB
	GVRJ	GVRJ
1130-12		
	GVNB	GVNB
	GVNJ	GVNJ
12-1230		
	GHRB	GHRB
	GHRJ	GHRJ
1230-1		
	GHNB	GHNB
	GHNJ	GHNJ

10-1030		
	OVRB	OVRB
	OVRJ	OVRJ
1030-11		
	OVNB	OVNB
	OVNJ	OVNJ
11-1130		
	AVRB	AVRB
	AVRJ	AVRJ
1130-12		
	AVNB	AVNB
	AVNJ	AVNJ
12-1230		
	AHRB	AHRB
	AHRJ	AHRJ
1230-1		
	AHNB	AHNB
	AHNJ	AHNJ

10-1030		
	GHRB	GHRB
	GHRJ	GHRJ
1030-11		
	GHNB	GHNB
	GHNJ	GHNJ
11-1130		
	OVRB	OVRB
	OVRJ	OVRJ
1130-12		
	OVNB	OVNB
	OVNJ	OVNJ
12-1230		
	OHRB	OHRB
	OHRJ	OHRJ
1230-1		
	OHNB	OHNB
	OHNJ	OHNJ

APPENDIX G

PARTICIPANT DATA SHEETS

Sheet 1

1. Which object matches the first label?

1 2

How confident are you that this object matches the label?

(low) 1 2 3 4 5 6 7 8 9 10 (high)

What is the likelihood that someone else would choose this object?

(low) 1 2 3 4 5 6 7 8 9 10 (high)

Sheet 2

2. What was the topic of the video?

____

____

3. How useful did you find this video to be?

(neutral)

(low) 1 2 3 4 5 6 7 8 9 10 (high)

4. Which object matches the second label?

1 2

How confident are you that this object matches the label?

(low) 1 2 3 4 5 6 7 8 9 10 (high)

What is the likelihood that someone else would choose this object?

(low) 1 2 3 4 5 6 7 8 9 10 (high)

APPENDIX H

DEMOGRAPHIC QUESTIONNAIRE

Gender (circle): Male Female

Age: ________

Major (circle): Language Science Engineering Nursing

Business Other Liberal Arts

Ethnicity: Not Hispanic or Latino Hispanic/Latino

Race: White Black Asian American Indian or Alaska Native

Native Hawaiian or Other Pacific Islander

What does SQ3R stand for?

____

____

Do you have any associations with the words presented (nicknames, pet names)? If so, what?

____

When hearing the words presented, did you repeat it to yourself?

____

How much of an art background do you have (class or hobby)?

____

Do you consistently associate color with words, music, or sounds?

____

What were the objects used? ____

Is English your primary language? (Circle) Yes No

If not, please list primary language ____________________________________.

What was your first language spoken at home? ______________________________.

Are you bilingual or multilingual? (Circle) Yes No

If yes, please list other languages spoken and note fluency level.

____

____.

Which hand do you normally use to write with? (Circle one) Right Left Both equally

Do you have any impairments of feeling in thumb or forefinger? If yes, please explain briefly.

____

Have you had any recent injuries to the hand, fingers, or thumbs? If yes, please explain briefly.

____

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