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Prosody: An Important Cue to Word Learning

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Psychology

PROSODY: AN IMPORTANT CUE TO WORD LEARNING

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by

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Abstract

Infants rely on cues from their environment during language acquisition. Prosodic features of words are one such cue and involve changes in stress and rhythmic patterns within speech. Studies have examined prosody's influence on word segmentation and have found it to be a useful cue for detecting word boundaries (Johnson & Seidl, 2009). What is less understood is how prosody helps infants form associations between novel labels and their referents during word learning. The present thesis investigated the influence of prosodic cues on word learning. The looking times were recorded of 13 infants (19-25 months) exposed to object-label pairings that either did or did not contain a prosodic manipulation. Results revealed shorter vs. longer looking times to prosodic cues congruent or incongruent, respectively, with previous pairings. Looking times to novel or consistent pairings involving no prosodic cues did not differ. These findings suggest that prosody may help facilitate word learning.

Keywords

Prosody, language acquisition, word learning, infancy, statistical learning

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Introduction

Infants enter this world with the complex task of acquiring a language based on the multifaceted input they receive from those around them. Before infants can begin to form word utterances they are prelinguistically parsing input from the environment into meaningful units that eventually result in the acquisition of language. Infants must learn how to segment these speech sounds into distinguishable patterns, discover the differential frequencies of these patterns and make sense of them all without any explicit instruction. How infants are able to conquer this developmental milestone has become a large focus for language researchers in recent years and has been an unsolved mystery for decades. Advances in infant methodology have helped developmental researchers begin to unravel pieces of this mystery through the use of new innovative techniques that offer insight into the mind of a prelinguistic infant. One line of research looks at an infant's ability to statistically segment speech sounds by mapping transitional probabilities between syllables within and across word forms (Saffran, Aslin & Newport, 1996). An infant's sensitivity to this statistical structure has proven to be a strong mechanism underlying their ability to segment and learn new words and has been observed in infants as young as 8 months of age (Saffran, Aslin & Newport, 1996). Another strategy that infants rely on for word segmentation involves perceiving the stress and rhythmic patterns in speech, also known as prosodic cues (Lew-Williams & Saffran, 2012).

Prosody is one of the first components of speech to which infants are highly sensitive. In just a mere matter of months, infants are already able to detect subtle differences in stress patterns between their native language and foreign languages (Estes

& Bowen, 2013). Although both statistical structure and prosodic cues have been shown to aid in early word segmentation, there is still much debate as to the cue on which infants rely most readily (Estes & Bowen, 2013). As well, these advancements, although promising, have focused primarily on how infants perceive and discriminate speech sounds in their environment with less focus on how they are able to bridge the gap between these sounds and their meaning during and after their first year of life. The purpose of the present study was to assess the role of prosodic cues in early word learning using an artificial language made up of nonsense words with and without a prosodic manipulation. By implementing an artificial language, bias related to prior word knowledge is reduced. Similar to Estes & Hurley (2013)'s work, the present study predicted that prosodic cues would help facilitate early infant word learning.

Early perception of prosody

Prosody refers to intonation and stress patterns of words and phrases that occur in speech (Koester, 2014). Infants perceive prosodic patterns in speech and may rely on these cues to aid in their acquisition of language. Unlike other cues, prosody is one of the earliest environmental cues to which infants are sensitive with evidence indicating the emergence of prosodic development in utero (Gonzalez-Gomez & Nazzi, 2012). Auditory learning emerges around the third trimester of pregnancy, as infants are able to perceive prosodic features across the abdominal barrier (Mampe, Friederici, Christophe & Wermke, 2009). Prenatal infants are able to perceive the prosodic contour of their mothers' voice while in utero and use this prosodic information to aid in later postnatal prosodic processing (Partanen et al., 2013). Phonetic aspects of speech, however, are less discriminable, meaning that they are not as well perceived across the abdomen, making prosodic cues much more salient for the fetus. Researchers have provided evidence for early sensitivity to prosody through studies that observe neural changes in infant brain activity to trained targets before and after birth (Partanen et al., 2013). Infants in one study were exposed to variants of a trisyllabic pseudoword during pregnancy and showed enhanced brain activity to pitch changes for the trained variants after birth compared to controls. An increase in brain activity after birth was also positively correlated with more prenatal speech exposure to the target while in utero (Partanen et al., 2013). This illustrates the important role of auditory exposure during pregnancy and the early sensitivity to prosody in prenatal development.

Similar studies have also demonstrated that inadequate prosodic exposure in utero is detrimental to later prosodic processing after birth. Infants who are born preterm are at greater risk of displaying later prosodic processing deficits than infants who are full term. Preterm infants (gestational age that is < 33 weeks) have been shown to suffer significant deficits in production and prosodic processing due to their shorter prenatal prosodic exposure (Gonzalez-Gomez & Nazzi, 2012). Such infants are delayed in their ability to make distinctions between their native language and rhythmically similar languages compared to full term infants. One study found that German 4- and 6-month-old preterm infants compared to full term controls, were unable to distinguish between words with a troachaic stress pattern that is characteristic of German (stress on the first syllable) and words with an iambic stress pattern (stress on the second syllable) (Peña, Pittaluga & Mehler, 2010). Even when both preterm and full term infants were matched on neurological age and had comparable postnatal exposure to speech, preterm infants were still delayed in their ability to discriminate between different stress patterns but full term infants were able to make the distinction. These findings suggest that prenatal exposure is an important parameter for enhancing the ability to distinguish between stress patterns of rhythmically similar languages.

Along with enhancing the ability to perceive differences in speech patterns, early prosodic exposure also influences the production of speech sounds in early postnatal neonates. In their first days, newborns' cries already resemble the same prosodic contour as their mother's native language. Mampe and colleagues (2009) looked at the different crying patterns of French and German newborns in their first few days of life and found differences in their melody and intensity contours. The French newborns produced cries with a rising contour (low to high), which is characteristic of French speakers, and the German newborns produced cries with a falling contour (high to low), which is consistent with intonation patterns in German. Even though these infants were all born full term and share the same physiology, their cry patterns were distinctly different. These results yet again emphasize the early impact that prosody has on later language learning and how it also shapes language production.

Prosody outranks other early environmental cues

Although infants perceive many environmental cues to learning throughout development, prosodic characteristics in speech appear to have a stronger impact on language acquisition than other early developing cues. Other early cues involve aspects of social interaction such as eye gaze, gesturing and facial movements and have all been found to aid in language acquisition but vary in their effectiveness at different developmental time points (Brooks & Meltzoff, 2005; Rowe et al., 2008; Weikum et al., 2007). Infants must use the cues that align well with their stage of learning and perception. As learning language is a complex task, a variety of strategies across development may support word segmentation. Learning to identify the prosodic stress patterns of one's native language is one such strategy. For English learning infants, this strategy involves developing a bias for words that contain a strong first syllable stress, as this most commonly signifies word onset in English. Another strategy involves statistically tracking the transitional probabilities of syllables between and across word forms (Johnson & Seidl, 2009). This strategy, also known as statistical language learning, involves determining the likelihood of how often certain syllables appear in combination either within or across word forms. Different syllable combinations have a greater likelihood, or a higher probability, of occurring in combination than low probabilistic combinations. For example, if we take the English sound sequence "*pretty baby*", the within-word transitional probability of *pre* to *ty* is greater than the between-word probability of *ty* to *ba* (Saffran, Aslin & Newport, 1996). When syllable combinations have a higher transitional probability, chances are they belong to the same word and in turn become more salient to the infant thus aiding in word segmentation.

Although both strategies have been shown to aid in word segmentation, there is still much debate over which cue is initially more influential to the infant. One possibility is that infants begin learning by statistically tracking the regularities in speech and once they have had enough exposure to various word combinations they begin to recognize that most English words contain specific first syllable stress to indicate word onset and can use this regularity to assist with word segmentation (Johnson & Seidl, 2009). Another possibility is that statistical mechanisms play a more secondary role and that infants attend to the regularity of stress cues initially by attending to isolated words and shorter utterances (Johnson & Seidl, 2009). There has been evidence to suggest that young infants are only able to segment words using statistical mechanisms if prosodic cues are also present within the input. Thiessen, Hill and Saffran (2005) presented 7-month-old infants with nonsense sentences where the only cue to word boundaries was the statistical structure of the sentences. One group of infants, however, heard these sentences with exaggerated pitch peaks and an overall higher average fundamental frequency (F_0) than another group of infants who heard the same sentences without these stress cues. The researchers found that infants were able to distinguish words from the syllable sequences when the sentences were presented with these additional prosodic characteristics. These results suggest that prosodic characteristics in speech are facilitating word segmentation, and that statistical mechanisms alone are not sufficient at this early age of infancy. However, it is important to investigate how these cues differ with regards to their effectiveness later in development when word learning emerges.

Another study by Johnson and Seidl (2009) found that, at 11 months of age, infants still depend on prosodic cues to facilitate word mapping even when statistical cues are also present. In this study, infants were familiarized with an artificial language that contained no cues to word boundaries other than the statistical structure of the language. In one experiment, word-final stress was added to the statistical words in the speech stream, which contradicts the more familiar first syllable stress common in English words. The researchers hypothesized that if the infants were able to rely only on statistical cues to segment words from the speech stream, they would be able to segment these words regardless of the conflicting stress cue. Contrary to their initial predictions, Johnson and Seidl found that infants extracted words from the stream of speech that were defined by stress cues but not statistical cues. This result further suggests that stress pattern may be more influential to word segmentation in infancy.

More recently, Estes and Bowen (2013) were interested in directly comparing differing levels of prosody (strong/weak stress patterns) with differing levels of transitional probabilities (words that contained high or low transitional probabilities between syllables) in 19 month olds to determine which cue is a more viable contributor to natural language learning and the ways in which these different cues interact for optimal learning. Infants were presented with two objects and a corresponding label containing either a high or low phonotactic probability and occurring in a strong stress (troachiac) or low stress (iambic) condition. The researchers hypothesized that infants would rely on the phonotactic and prosodic regularities of their native language such that infants might rely on a combination of both cues to assist in word learning. Estes and Bowen predicted that words with higher phonotactic probability would be easier to learn than those with a lower probability and that infants would have a trochaic (strong first syllable stress) bias for learning words as it is consistent with English lexical stress patterns. The results revealed that infants were only able to learn labels that contained both a high transitional probability as well as a trochaic stress. If labels were presented with a high phonotactic probability but contained an iambic stress, the infants were unable to learn them. The same was true if a label contained a low phonotactic probability but contained a trochaic stress cue. Thus, infants required support from both common stress patterns and learned statistical regularities. This finding may indicate a possible developmental shift that emerges when infants become less reliant on prosodic cues at a later age and require both familiar stress patterns and phonotactic regularities in combination for optimal learning.

Prosody as it appears in infant directed speech

It is evident that prosody plays a large role in language segmentation, and there is considerable evidence to suggest that prosody is one of the most influential cues in detecting word boundaries for infants at a young age. Less is known about prosody's influence in forming associations between words and their referents (Estes & Bowen, 2013). Although it is important to explore the magnitude of prosody's role in language acquisition, it is also important to understand why prosodic cues are so influential in early language learning. Research investigating the mechanisms that underlie word learning have often examined how prosody appears in infant directed speech and the benefits that this form of speech may have on infant language development. Infant directed (ID) speech is an exaggerated, distinctive speaking style that adults often use when they are addressing infants. It is characterized by a higher overall pitch with a wide pitch range, exaggerated vowels, longer pauses and a slowed tempo (Estes & Hurley, 2013). ID speech is multifaceted and encompasses many different linguistic and social cues including repetitive phrases, shorter utterances, exaggerated facial expressions and gesturing. All of these elements aid in language learning, however, the biggest change from typical adult-directed speech to infant directed speech is in the prosodic characteristics of vocal pitch, loudness and rate of speech (Broesch & Bryant, 2015).

It is believed that ID speech is a species-specific evolutionary adaptation that exists cross-culturally (Broesch & Bryant, 2015). Studies comparing these specific vocal changes across different languages have identified characteristics of ID speech in French, German, Italian, Japanese, British, Turkish, Hungarian, English and Mandarin Chinese (Fernald et al., 1989; Grieser & Kuhl, 1988; Endress & Hauser, 2010). As well, indigineous, nonindustrialized and nonliterate individuals of Shuar (South American hunter-horticulturalists) were able to reliably distinguish between English ID and AD speech as well as recognize the specific intentions that were present in both forms of speech (approval, prohibition, comfort) although the raters were significantly better on this latter task when the speech was presented using infant directed speech (Bryant & Barrett, 2007). If such a distinctive form of speech exists cross-culturally, including cultures with fundamentally different languages and lifestyles and is exhibited by not only mothers, but also fathers and older children (Fernald et al., 1989), it would seem plausible that this form of speech is serving a unique developmental purpose.

Several aspects of ID speech contribute to an infant's ability to learn language. Firstly, the increased pitch and variation in pitch contours that exist in ID speech help to elicit and hold an infant's attention while heightening arousal level. These increases in attention and arousal have been proposed to prime the infant's system for learning (Estes & Hurley, 2013) and orient the infant towards the speaker. Prosodic features in ID speech also provide cues to acoustic, lexical and grammatical information within the input. For example, adults tend to exaggerate vowel sounds when using ID speech compared to AD speech and mothers who have more distinct vowel sounds have been shown to have infants with better language perception skills, specifically phoneme distinction (Estes & Hurley, 2013). Prosodic features also aid in an infant's ability to detect word boundaries. Curtin, Mintz and Christiansen (2005) proposed that several months of exposure to an infant’s target language would shape how they represent stressed and unstressed syllables, such that they should show a bias towards stress-initial syllable strategies. Consistent with the researchers’ predictions, 7- and 9-month old infants were able to rely on their increased sensitivity to strong initial syllable strategy when stress was the only cue available to word segmentation. These results suggest that infants’ bias towards attending to stressed syllables is exceedingly helpful in extracting word forms and perceiving word boundaries. What remains less well understood is how these prosodic cues facilitate language learning at the word learning level, when infants begin to form associations between words and their referents.

The influence of prosody on word learning

As reviewed above, there is an extensive body of research that focuses on how infants use prosodic cues to guide their early speech perception and word segmentation, but fewer studies have focused on how infants utilize prosody to assist them in the word learning process of forming lexical representations, that is, linking objects and their associated labels. As infants move beyond their ability to successfully segment words in their native language, they begin forming associations between newly learned words and their referents. Early word learning is a process that grants an infant entry into a complex symbolic system and supports the growth of later abstract conceptual representations formed from basic object-label associations. By 9-10 months, infants are already showing preferences for words that correspond with the phonological and prosodic characteristics of their native language. They are beginning to encode specific phonetic detail (e.g. ‘tup’ is not ‘cup’) and indexical detail (e.g. speaker identity) (Werker & Yeung, 2005). After

10 months though, infants are beginning to recognize more word forms irrespective of their indexical detail and especially if the words are stressed in English word-initial positions (for English environments). By 14 months, infants are able to learn two contrastive object-label pairs by demonstrating they can discriminate between the two, however, at this age infants are unable to differentiate between minimally contrastive pairs (e.g. ‘bin’ and ‘pin’) (Werker & Yeung, 2005). Interestingly, infants are able to dissociate those same pairs when the pairs are presented without associated referents. It is possible that, at 14 months, infants have not acquired a level of cognitive maturity that enables them to keep up with the increased computational demand of detecting subtleties in speech when a visual referent is included (Werker & Yeung, 2005). While this developmental constraint may hinder an infant’s ability to strengthen the associations between words and their referents, prosodic cues can help facilitate these associations and make them more salient in memory.

One study by Zangl and Mills (2007) proposed that prosodic characteristics in ID speech might actually allow infants to form stronger associations between words and their referents because of increases in brain activation for prosodic words. Six and 13-month old infants were presented with lists of familiar and unfamiliar words that were presented with and without prosodic manipulation. Both age groups demonstrated significantly larger ERP amplitudes in conditions with additional prosodic cues compared to conditions without such cues. The larger ERP amplitudes for prosodic conditions suggest that infants are highly sensitive to the rich acoustic characteristics of prosodic cues in speech. As well, even while asleep, infants show increased blood flow to the frontal lobe regions of the brain while listening to words with additional stress (Saito et al., 2006).

Similarly, Ma, Golinkoff, Houston and Hirsh-Pasek (2011) were interested in discovering if words embedded in a passage would be learned if those words were presented with speech containing prosodic cues compared to speech without such cues. Target words were inserted into passages that were read to the infant before the test phase. Infants who were 21 and 27 months of age were then shown objects with labels taken from the passages with and without prosodic target words. Twenty-one month old infants learned the object-label associations for the labels using prosodic speech, but labels were not learned if the target words were originally presented without prosodic cues. Interestingly though, infants at 27 months of age were able to learn the labels regardless of whether or not they contained a prosodic manipulation. The researchers suggested that perhaps prosody is an early perceptual cue on which infants rely for initial word learning, but that their reliance on these cues diminishes with age as the infant develops more sophisticated word learning strategies.

Another more recent study by Estes and Hurley (2013) was aimed at discovering what aspects of prosody facilitate word learning. These researchers were also interested in word learning differences for ID and AD speech. In one condition, 17-month-old infants were presented with object label pairs in ID speech, and another condition had object label pairs presented in AD speech. Not surprisingly, infants in the ID speech condition were able to learn the associations successfully, whereas those in the AD speech condition were not. The present study replicated many aspects of the Estes and Hurly study with an aim to investigate a similar question in 19-25 month olds.

Another naturalistic approach would be to examine the effects of prosody on word learning over successive sessions, giving the infant time to encode the newly learned words. Looking at an infant's ability to recall trained words at a later time closely resembles how infants learn words in actuality. If infants are learning words successfully they should be able to recognize and remember them at a later time. Singh, Nestor, Parikh and Yull (2009) wanted to assess infant's long-term memory for words 24 hours after the original testing session. During a learning phase, they presented infants with a series of target words that were produced in either ID or AD speech and then they recited passages to the infants a day later. Word learning was successful 24 hours after the initial testing for words presented in ID but not AD speech.

Measuring word learning in infants

It is quite evident that prosodic cues are highly influential across language development, specifically with regards to perception and detection of sounds, word segmentation and word learning. However, there is still an unsettled debate over how influential prosodic cues are later in infancy relative to other available cues. As well, much of the existing research has focused primarily on how infants perceive speech sounds and how they use prosodic characteristics to find word boundaries and segment word forms. Fewer studies have focused on how infants use these early developing skills to bootstrap later word learning towards the second year of life.

It must be acknowledged that studying word learning in infants requires specialized experimental techniques because infants cannot engage in traditional, forced-choice pointing responses to reveal their choices. One of the most widely employed paradigms is the habituation task in which a novel stimulus is presented until the infant habituates, that is, until the infant looks away from the stimuli. Repeated exposures to the stimuli result in shorter looking times reflecting the reduced novelty of the stimuli to the infant (Fernald, Zangl, Luz Portillo & Marchman, 2008). As such, reduced or comparatively short looking times are considered to reflect recognition that the stimulus is not novel but has been seen/heard before. It has been argued that this pattern reflects infant learning.

One way that infant learning can be tested in a habituation task paradigm is by employing a Switch task (Werker et al., 1998), as was the case in the present study. The Switch Task involves presenting stimuli that are either congruent or incongruent with stimuli to which the infant has previously shown habituation in the learning phase. In the case of the present study, this involved a learning phase with repeated exposures to target object-label pairs either with or without prosodic manipulation followed by a test phase in which object-label pairs were presented either as the same pairs (congruent with previous exposure) or switched (incongruent, and in violation of previous exposure). The rationale behind the Switch Task is that if infants have learned the original pairings during the habituation phase they would look longer during the test phase to trials containing a novel violation. Switching the labels in the test phase means that the frequency of prior exposure to the stimuli remains constant: The only novel aspect of the test phase is the object-label pairing. The present study examined whether prosodic cues facilitated word learning by comparing test phase looking times to object-label pairs with or without prosodic cues that were either congruent or incongruent with previous exposure in the learning phase.

The Present Study

The current study explored how prosodic cues may facilitate associations between words and their corresponding referents in infants approaching their second year. In order to reduce bias based on previously learned phonetic knowledge, novel words were employed. Infants were presented with novel nonsense words that either contained a prosodic manipulation or were spoken in monotone. These words were presented as single word utterances and presentation was paired with simultaneously presented objects. In order to compare habituation to the object-label pairs with or without prosodic cues, a version of the Switch task, similar to Estes and Hurley (2013) was employed. The present study aimed to replicate the results of Estes and Hurley (2013) and identify whether associations are strengthened for words containing a prosodic element compared to words with no prosodic manipulation. Based on past research favoring the role of prosody in word learning, the current study predicted that words containing exaggerated prosody would facilitate the learning of novel word associations. Although infants of about 2 years of age were expected to learn all object-label pairings as has been found by Ma et al. (2011), greater learning was expected for the pairings that contained prosodic labels. As such, looking times to violations of previously learned object-label pairs would be expected to be longer for labels with than without a prosodic cue. Longer looking times to all violations regardless of prosodic cue would reflect learning of all pairings to which the infant had been exposed.

Method

Participants

The participants were 22 infants (7 females) between 19 and 25 months of age (*M* = 22.3, *SD* = 1.84). Participants were recruited from the Developmental Psychology Participant Pool at Western University via telephone or email. Parents completed a health history data collection form for the infant prior to the study (see Appendix A). To be included in this study, infants had to come from homes where English was the primary language spoken (two participants had exposure to a secondary language (Chinese; Filipino) in the home). Infants also had to be born full-term and without any neurological impairments, and have no history of chronic ear infections or hearing problems. One infant had nystagmus, a condition of involuntary eye movement, however his looks to targets were unaffected and his eyesight was deemed normal by parental report. Nine infants were excluded due to fussiness (7), inattention (1) or equipment failure (1). One child who completed half of the test trials (4/8) was retained in the analyses. Written parental consent was provided and parents were compensated for their visit and for their travel costs. Children were also given storybooks and a junior scientist certificate (see Appendix B) for participating in the study. The study was approved by the Non-Medical Research Ethics Board (NMREB).

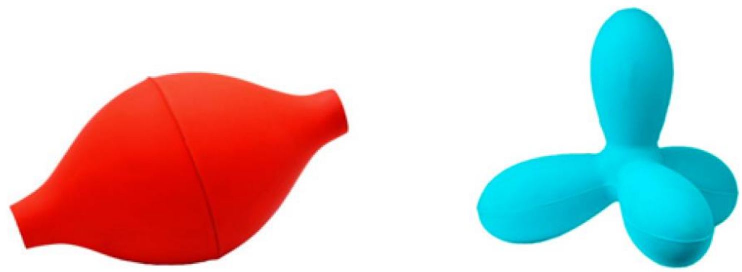
Stimuli

Auditory Stimuli. Test items consisted of four bisyllabic nonsense words, *gabu*, *kudo*, *motay*, and *naypo*. Each syllable had a single consonant – vowel structure (CV) and included early developing consonants and tense vowels. Tense vowels were employed because they are not as likely to be reduced when spoken. The nonsense words were produced by a native English female speaker using equal stress across syllables to create two prosodically neutral (henceforth, monotone) nonwords (*gabu* and *naypo*) and using emphatic stress on the first syllable to create two nonwords with prosodic marking (henceforth, prosodic) involving first syllable stress (*ku'do* and *mo'tay*). From these, two languages of two nonwords containing one prosodic and one monotone nonword were identified (language 1: gabu, ku'do; language 2: naypo, mo'tay). Infants were randomly assigned to either language. To create the nonwords, several tokens of each nonword were recorded in a double walled IAC sound booth with a pedestal microphone (AKG C 4000B) located approximately 30cm from the speaker's mouth and routed to a USBPre 2 pre-amplifier (Sound Devices). The token considered the best example of an unstressed (monotone) or stressed (prosodic) word was chosen and uploaded into *Sound Forge Audio Studio* (Sony Creative Software Inc., 2013) editing software. Table 1 presents syllable fundamental frequency and duration for each nonword measured using *Praat* (Boersma & Weenink, 2001). The between-syllable differences within words for fundamental frequency were markedly higher for the prosodic than monotone words. In order to ensure that the nonwords differed according to the prosodic patterns planned, 10 adults were asked to judge which of two nonwords sounded like they contained an added stress. Each adult heard each nonword pair 5 times and chose the word that they believed contained differential syllable stress. These listeners correctly identified the word that contained a prosodic cue with 100% accuracy.

Table 1. Acoustic characteristics for prosodic and monotone labels. Differences in fundamental frequency (F_0) were observed across the first and second syllable in each label. In each condition prosodic labels contained a much larger difference score than the monotone labels.

Labels		**Duration of 1st syllable**	**Duration of 2nd syllable**	**Mean F_0 (Hz) of 1st syllable**	**Mean F_0 (Hz) of 2nd syllable**	**Difference in Mean F_0 (Hz)**
Prosodic	*ku'do*	0.30	0.39	295.6	152.3	143.3
	mo'tay	0.29	0.34	229.5	167.7	61.8
Monotone	*gabu*	0.39	0.44	176.7	156.2	20.5
	naypo	0.39	0.46	182.1	182.8	0.70

Visual stimuli. The two novel objects (retrieved with permission from Estes & Bowen, 2013) employed in the experimental task are shown in Figure 1. Object 1 was displayed at 20 x 17 cm and Object 2 was displayed at 19 x 20 cm using jpeg images. Objects were presented at either the bottom left or bottom right of the monitor, and were animated to move back and forth (i.e., to 'jiggle' in place) while the auditory stimuli were being presented. To prevent a possible bias for object preference, one of the objects was paired with a prosodic word in one language, and with a monotone word in the other language.



Object 1 Object 2

Figure 1. Novel objects that were paired with spoken labels. Object 1 was paired with words *gabu* (monotone) and *mo'tay* (prosodic) and Object 2 was paired with words *ku'do* (prosodic) and *naypo* (monotone).

Apparatus

Each infant was tested in a sound attenuated booth on their caregiver's lap while the caregiver was seated on a comfortable chair with adjustable height so the infant could remain at eyelevel with a large 70-inch monitor one metre across from the infant. To prevent bias, the caregiver wore noise-cancelling headphones while listening to music in order to be unaware of the audio recordings being played and to avoid providing any cues to the infant. A video camera below the monitor was connected to a digital recording device that displayed the infant's face to an experimenter in an adjacent control room. On either side of the video camera, two speakers were mounted to play labels corresponding to the side of each visually presented object. Blackout floor length curtains were hung from the ceiling to ensure the infant had no other visual distractions; the lights were also turned off to ensure focus remained on the monitor. The experimenter controlled the experiment and monitored responses by the infant via the video camera. Trials were either timed or were stopped by a button press from the experimenter based on the infant's response.

Procedure

Infants completed a learning phase and a test phase. Prior to starting any trials, a children's cartoon was presented on the monitor for 12 seconds to attract the infant's attention to the monitor. Immediately after the cartoon finished, the learning phase began (See Figure 2). Stimuli presentation was controlled using *Eprime* (Schneider, Eschman & Zuccolotto, 2012). For each trial, the visual object appeared at the bottom left (or right) of the screen and the paired auditory stimuli played repeatedly. The trial continued for 10 seconds, after which a cartoon figure appeared in the middle of the screen to draw the infant's attention back to the centre. A total of 20 learning trials were presented including 10 trials of each of the two nonword-object pairings. Each label trial lasted 10 seconds as each label was repeated 5 times with 1000 ms of silence between each label. In total, there were 20 learning trials and each infant heard each label 50 times. Each label (from either language 1 or language 2) was paired simultaneously with a visual object. The presentation of the auditory label corresponded to the side in which the visual stimuli appeared. The trials were presented in pseudorandom order such that no trials were presented in succession more than twice and such that objects appeared on both the left and right side. The total time for the learning phase was approximately 3.5 minutes.

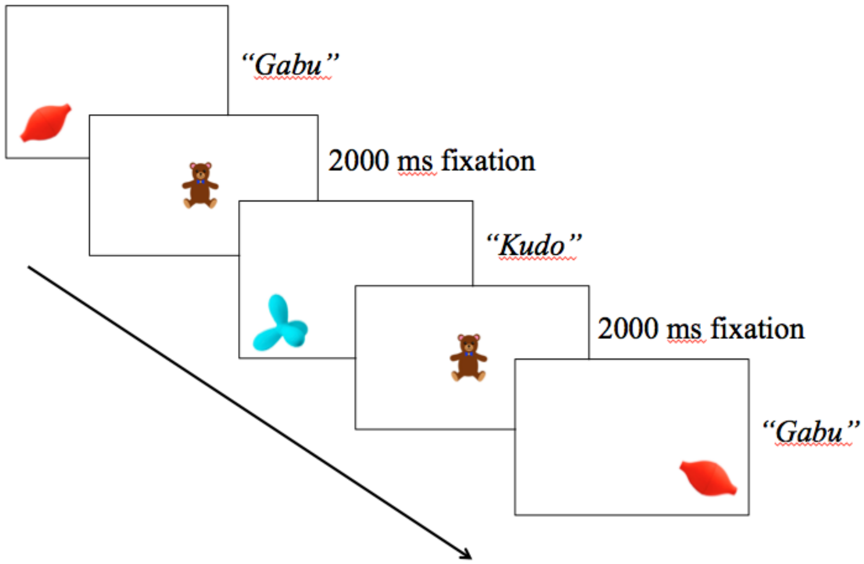


Figure 2. Habituation paradigm. The object's associated label played simultaneously from an adjacent speaker for 10 seconds, followed by 2000 ms fixation between trials. Objects appeared in pseudorandom order such that no trials were presented in succession more than twice.

The test trials began immediately after the learning phase. The trial format was the same as that for the learning trials except that the test trial durations were infant-controlled, meaning that the object-label pairing was continued until the infant looked away for at least 1 second (or 20 seconds had elapsed). Infant responses were monitored by the experimenter such that once the infant looked away for at least 1 second, the experimenter pressed a button to advance to the next test trial. A total of 8 test trials (as described below) were completed.

In the test phase, there were *congruent* and *incongruent* test trials (4 of each). In the congruent test trials, the object-label pair presented was the same as those presented in the learning phase. In the incongruent test trials, the previously learned object-label associations were violated such that each object was presented with its incorrect label (i.e., the other nonword from the language). For example, object 1 in the pairing of language 1 was associated with the label *gabu* in the learning trials, but in incongruent test trials, it was presented with the other nonword from language 1, *ku'do*. In this way, all stimuli presented during the test trial had been viewed by the infant in the learning phase the same number of time with the only difference being which objects and labels were paired in some cases. Video recordings of each infant's looking times were recorded for offline analyses. It should be noted that the one infant who completed 4 of the 8 test trials completed one trial for each condition (1/2).

Data Analysis

All infant looking times were video recorded using a Vaddio PTZ Camera and were exported into *Apple OSX iMovie* software (Apple Inc., 1999) where video files were then analyzed using *SuperCoder* (Hollich, 2008) coding software. In *SuperCoder*, looks to targets were time stamped via a button press using keyboard shortcuts to mark the beginning of each trial, the beginning and end of each look and the end of each trial. A look would be initialized as soon as the infant looked to the target object and a look would end if an infant looked away from the target for at least 1 second or up to a maximum of 20 seconds. Videos were analyzed frame-by-frame by experimenters. In order to ensure intra-rater reliability, the experimenter re-coded responses for all infants. Intra-rater reliability evaluated using a Pearson product moment correlation was found to be *r* = 0.97. A second coder also analyzed the recordings of 4 infants to ensure inter-rater reliability (31% of all trials). The inter-rater reliability was found to be *r* = 0.98.

Results

Table 2 presents the average looking times for the prosodic and monotone trials in the test phase for the congruent and incongruent conditions. Incongruent trials that contained prosodic cues yielded the longest average looking time while the congruent condition with prosody had the shortest looks. It should be noted that looking times were not normally distributed with skewness of 1.244 (*SE* = 0.616) and kurtosis of 1.921 (*SE* = 1.191) for incongruent trials containing prosody.

Table 2. Descriptive statistics for looking times on incongruent and congruent test trials spoken with prosody or in monotone.

Label & trial type	*M*	*SD*	Skewness	Kurtosis
Prosody				
Congruent trials	3.27	1.45	0.13	0.16
Incongruent trials	6.35	3.97	1.24	1.92
Monotone				
Congruent trials	4.36	1.82	0.34	-0.80
Incongruent trials	4.26	2.65	1.00	0.39

In order to assess infant learning, a 2 (Label: prosodic and monotone) X 2 (Test trial type: congruent and incongruent) repeated measures analysis of variance (ANOVA) was completed on the test phase looking time durations. There was a significant main effect of test trial type, $F(1, 12) = 5.72$, $p < 0.034$, $\eta_p^2 = 0.323$, due to shorter looking times on congruent trials. There was also a significant interaction between label and test trial type, $F(1, 12) = 4.89$, $p = 0.047$, $\eta_p^2 = 0.290$. The main effect of label was not significant, $F(1, 12) = 0.463$, $p = 0.509$, $\eta_p^2 = 0.037$. Figure 2 depicts the significant interaction between label and test trial type. To probe the interaction, a series of post hoc pairwise *t*-tests were conducted. There was a significant difference between incongruent and congruent test trials for the prosodic, $t(12) = 2.611$, $p = .023$, $d = 0.797$, but not monotone trials, $t(12) = -.152$, $p = .881$, $d = 0.044$. As well, prosodic and monotone trials were not significantly different when presented as either incongruent $t(12) = 1.565$, $p = .143$, $d = 0.443$, or congruent, $t(12) = -1.907$, $p = .081$, $d = 0.584$. It should be noted that in corresponding nonparametric Wilcoxon signed rank tests completed to confirm these results due to the problem with normality in the data, the same pattern emerged with significantly longer looking times to prosodic labels involving incongruent than congruent pairings, $Z = -2.197$, $p = 0.28$, $r = -.015$. As well, the pattern of results remained the same even when the infant with missing data was removed from the analyses.

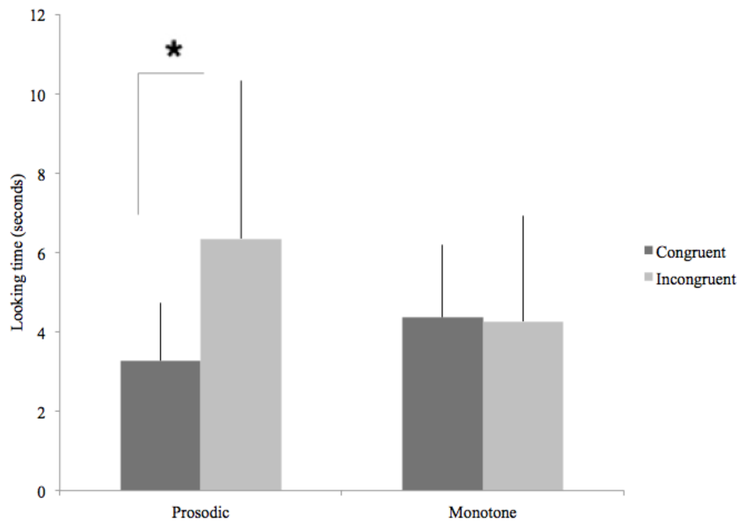


Figure 3. Mean looking times across congruent and incongruent conditions that contained prosodic or monotone labels. Error bars represent standard deviation. Asterisks mark significantly different pairs, $p < .05$.

Further evidence of learning may be reflected by habituation to the presented items during the learning phase. In order to examine this habituation, average looking times across the first three (M = 7.27, SD = 2.43) and the last three trials (M = 3.35, SD = 2.27) of the learning phase were compared. Results revealed significantly longer looking times in the first three than last three trials, $t(12) = 5.04$, $p < 0.001$. This pattern is clearly reflected in Figure 3 showing the average trial times for each of these six trials.

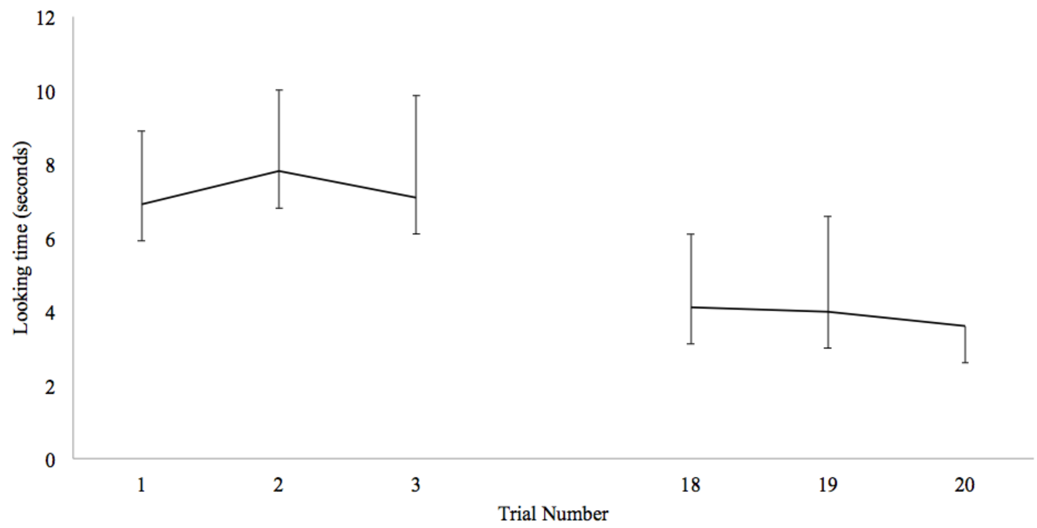


Figure 4. Mean looking times across the first three and last three trials of the learning phase. Error bars represent standard deviation.

Discussion

The present study aimed to investigate how prosody influences word learning during infancy. In this study, infants were presented with object-label pairs containing labels with and without a prosodic manipulation. Infants' looking times to objects were video recorded and analyzed to collect an indirect measure of learning. A version of the Switch task was used in which object-label pairs were presented repeatedly during the learning phase but then were either re-presented in the same pairing (congruent) or with switched pairing (incongruent) during the test phase. Overall, infant looking times were shorter to congruent than incongruent test trials suggesting that learning phase object-label pairings were familiar or learned, a finding consistent with the shorter looking times to the last than first three trials of the learning phase. This overall effect, however, was modified by the prosodic information contained in the spoken label provided. Looking times to the incongruent test trials were significantly longer than congruent test trials only for pairings with labels providing a prosodic cue. No looking time differences were found for monotone test trials that were or were not consistent with previous exposure.

The finding of longer looking times to novel object-label pairings at test suggests that the infants learned the original object-label pairings from the learning phase and perceived the violation of the incongruent forms presented during the test phase. Importantly, though, this perception occurred only if the original pairing had included a label containing a prosodic cue in the form of first syllable stress. For monotone labels, looking times did not differ between object-label pairings previously presented or not. Hence, there is something specific about the prosodic cue that supports the formation of an association between object and label over a small number of exposures.

One reason that the prosodic cues may have been effective at facilitating word learning in the present study is that they employed characteristics consistent with infant directed speech generally. Infant directed speech is often characterized as having a higher overall pitch and a wide pitch range along with other social elements (Estes & Bowen, 2013). The prosodic labels in the current study contained syllables that had a much larger difference in pitch (fundamental frequency F_0) across syllables compared to the monotone labels. This wider range in pitch may have accounted for longer looking time durations during conditions that contained prosodic labels, as it is characteristic of a form of speech most preferred by infants. In infant directed speech, often caregivers and other adults also use shorter utterances or even single words in isolation when addressing infants (Estes & Hurley, 2013), and the words are often presented repeatedly using exaggerated vowels. Similarly, in the current study, all labels were presented repeatedly and in isolation but only prosodic labels contained exaggerated contours. Although other social elements of infant directed speech were not employed, the acoustic characteristics in this form of speech including higher pitch, increased pitch range and exaggerated vowels were all present in the prosodic labels in the current study and may have facilitated stronger associations between those labels and their referents.

Nevertheless, an overall general resemblance to ID speech may not fully account for the large effect size observed when looking times for incongruent and congruent test trials with prosodic labels were compared in the present study. It may be that the use of first syllable stress was particularly facilitative for word learning. The stress pattern employed in the prosodic labels was the dominant word stress pattern for the primary language to which all of the participants in the current study had been exposed during their first year and a half of life. One possible outcome of presenting nonwords with high (prosodic) vs. low (monotone) word likeness to the infants' primary language is that the infants may show a preference for the familiar and look longer to object-label pairings when the label contained a prosodic cue. Indeed, infants have been shown to develop a listening preference for bisyllabic words containing a troachic (strong) rather than iambic (weak) stress (Johnson & Jusczyk, 2001). However, an overall preference for prosodic labels was not evident in the present study. In fact, both the shortest and longest looking times were associated with the presentation of prosodic labels depending on whether the pairing was congruent or incongruent with previous exposure.

Instead of an overall preference for prosodic labels, the pattern of results in the present study suggests that the presence of prosodic cues facilitated the association between presented labels and objects specifically in that the only evidence of word learning was for those object-label pairs involving a prosodic but not monotone cue. It follows from this that prosody was a powerful cue to the learning of object-label associations in the present study. The findings are consistent with suggestions that infants use prosodic regularity to begin treating stressed syllables as word onsets and that this information works as an additional cue to word boundaries (Johnson & Seidl, 2009). As infants become more familiar with their native language, their learning becomes constrained by previous experience and they become biased towards the regularities to which they are most exposed (Thieseen & Saffran, 2007). Previous exposure to the prosodic regularities employed in the present study may have allowed the infants to encode the prosodic label more rapidly, thus requiring less processing resources and allowing the infant to focus on the associated object. This reduced cognitive load would help the infant form stronger associations between these prosodic labels and their referents.

Nevertheless, the idea that the prosodic pattern employed in the present study facilitated learning because it was consistent with previous exposure requires further investigation. Importantly, labels containing a prosodic cue that differed from the primary language to which the infants were exposed were not included in the present study. Such a comparison would be needed in order to identify whether or not added stress alone can improve word learning or if a stress pattern most familiar to the infant is required. Estes and Bowen (2013) presented infants with labels containing strong/weak English stress patterns and high or low phonotactic probabilities and found that infants required support from prior knowledge of both stress patterns and phonological regularities in order to learn the labels. Although these authors compared common and uncommon stress patterns, the additional probabilistic cues provided make it difficult to determine whether or not the uncommon stress on its own could assist word learning.

Another alternative interpretation involves taking a pedagogical perspective on infant word learning. It could be the case that pedagogical knowledge that is transferred from caregivers to infants is triggered by specific communicative cues, such as prosodic cues in speech as in the present study. A pedagogical perspective would suggest that infants are highly sensitive to these cues and that they signal the teacher's communicative intention to manifest new and relevant information about a referent object to the infant (Gergely, Egyed & Király, 2007). This would suggest that the infant directed prosody that was used for certain labels in the present study signaled the infant to prepare for learning, whereas the monotone labels did not signal the same intention. This perspective posits that infants' learning was facilitated by social communicative triggers in infant directed language and may not specifically pertain to the familiarity of the trochaic stress pattern used in our prosodic labels. This perspective could be perceived a possible underlying mechanism that strengthens the associations between words and their object referents.

One surprising finding in the present study was the apparent absence of learning of the object-label pairings for monotone labels. There was no difference in looking times to object-label pairs with monotone labels that either had or had not been presented before. In fact, the effect size for this comparison was negligible. Although it was hypothesized that prosodic cues would facilitate learning, some learning of presented object-label pairs with monotone labels was expected. Nevertheless, after viewing 10 presentations of a pairing involving a novel object and monotone label, infants showed no evidence of perceiving a difference when observing pairs congruent or incongruent with this previous exposure. This finding is consistent with previous work that has suggested that infants at a younger age are unable to learn presented labels unless they contained prosodic cues. Even when statistical regularities were present, Thiessen et al. (2005) found that 7-month-old infants were only able to distinguish words from syllable sequences when the sentences contained exaggerated pitch peaks and an overall higher average fundamental frequency (F_0). These results suggest that prosodic characteristics in speech are facilitating word segmentation at an early age, and that statistical mechanisms alone are not entirely sufficient. The current study extends these findings to word learning and indicates that infants at least up to 25 months of age are sensitive to the prosodic information embedded in speech, and that this sensitivity supports the learning of associations between novel words and their referents. Without such cues, infants were unable to differentiate the monotone labels in the current study as congruent or incongruent with previous exposures.

The findings from this study make a contribution to the literature on infant word learning as the results replicate the findings from Estes and Hurley (2013), such that infant directed prosody was shown to facilitate the associations infants make between sounds and their meaning. Past studies have proposed that an infant's reliance on prosodic cues may be constrained to a specific age range in development (Estes & Bowen, 2013). Ma et al. (2011) found that infants at 21 months of age were only able to learn labels embedded in a passage when they were presented using labels with infant directed prosody but not when the labels were spoken in an adult like fashion. However, at 27 months of age, infants in the study were able to learn labels from the passage regardless of the prosodic features. The authors speculated that as infants develop they reduce their reliance on perceptual cues such as prosody as they become more sophisticated learners. Although this may be true, the present study suggests that infants as old as 25 months are still relying on prosody to aid in their language learning and that this word learning strategy may be useful throughout development.

A potential limitation of the present study design involves the lack of a naturalistic setting. Infants were presented with labels from an artificial language that played through mounted speakers. It may be that greater levels of learning would have occurred using a play paradigm providing social interaction, a context found to facilitate early language development (Kuhl et al., 2003). A further limitation may involve the use of fixed trials during the learning phase. The infants in the present study were all presented with an equal number of 20 total learning trials each of a fixed duration, which does not account for individual differences in habituation to the stimuli. Nevertheless, a fixed trial criterion for habituation in this study ensured that all infants had equivalent exposure to the differing stimuli. As well, infants were able to control the trial onset during the test phase when individual variation was of importance.

The findings from the present study have important implications both theoretically and clinically. This study furthers the notion that prosody facilitates not only language acquisition at the level of word segmentation but is also advantageous during word learning and forming associations between novel labels and their referents. If infants rely on prosodic cues at later ages in infancy, it is important to expose children to prosodic features instilled in infant directed speech even when children continue to be perceptive to other social and statistical cues. Future research should look at how differing cues to word learning work in conjunction as opposed to having them presented in isolation to see what combinations promote optimal learning and to gain a better understanding of the cues that are relevant during different developmental periods.

Conclusion

It has been proposed that prosody is a cue that aids in early language acquisition, specifically with regards to how infants use prosody to guide word segmentation (Johnson & Seidl, 2009). What is poorly understood, however, is how prosody works to facilitate language learning when forming associations between labels and their referents during word learning. This thesis sought to examine if, similarly to Estes and Hurley (2013), prosody enhances learning for novel word labels in 19-25 month old infants. Using a habituation paradigm and a version of the Switch task, it was found that infants looked longer towards words that contained a prosodic manipulation during test phase compared to words that were spoken in monotone. The results suggest that prosodic cues are not only advantageous during early stages of infancy when children are learning to perceive speech sounds and segment words but that prosodic features also aid infants in forming associations between new words and their referents.

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Appendix A: Child Health History Data Collection Form

Child Health History Data Collection Form

Participant ID:____

Child's date of birth (month/year): ______________________ Sex (F) ☐ (M) ☐

The following questions pertain to your child's medical history and will be kept confidential and only used for research purposes

Was your child born preterm?... Yes ☐ No ☐

Does your child suffer from chronic ear infections?............................Yes ☐ No ☐

Have they had more than 5 ear infections?.......................................Yes ☐ No ☐

Does your child suffer from any hearing or vision problems?............ Yes ☐ No ☐

Appendix B: Junior Scientist Certificate

The University Of Western Ontario

The Language and Working Memory Lab Proudly Presents

Participant Name

With the Honorable title of

Junior Scientist

In recognition of Outstanding Participation in Scientific Research

Month/Day, Year

Lisa Archibald, Ph.D.

Appendix C: Ethics Approval

Western Research

Research Ethics

Western University Non-Medical Research Ethics Board
NMREB Amendment Approval Notice

Principal Investigator: Dr. Lisa Archibald
Department & Institution: Health Sciences\Communication Sciences & Disorders,Western University

NMREB File Number: 105866
Study Title: Cues in Infant Language Learning
Sponsor: Natural Sciences and Engineering Research Council

NMREB Revision Approval Date: March 20, 2015
NMREB Expiry Date: December 17, 2015

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol	Protocol - clean copy	
Letter of Information	LOI - clean copy - age range change	2015/02/19

The Western University Non-Medical Science Research Ethics Board (NMREB) has reviewed and approved the amendment to the above named study, as of the NMREB Amendment Approval Date noted above.

NMREB approval for this study remains valid until the NMREB Expiry Date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario.

Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Ethics Officer, on behalf of Riley Hinson, NMREB Chair

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