Behavioral and Psychophysiological Responses of 4-month-old Infants to Differing Rates
of Infant Directed Speech

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(Abstract)

Infants of various ages across the first postnatal year have shown behavioral preferences (i.e., more attention) to visual displays when looking resulted in the presentation of Infant-Directed Speech (IDS) compared to Adult-Directed Speech (ADS). Although IDS differs from ADS on a variety of measures, most research has focused on various pitch characteristics (i.e., IDS is higher in absolute pitch and more variable in pitch across utterance length). Work from our lab has found that when the pitch characteristics of IDS were held constant, but the temporal features were manipulated, younger (but not older) infants attended more to slower rates of IDS, even though it was unlikely that they had heard such speech (when speech is spoken at this slow rate, the fundamental frequency cannot be maintained). The purpose of this study was to expand our investigation of how speaking rate affects infant attention by adding the physiological measure of heart rate to our protocol. Of specific interest was whether infants would show differential amounts of heart-rate (HR) decelerations as a function of rate (i.e. greater decelerations to slowed speech). 4-month-old infants were tested with normal IDS (unaltered rate) and slow IDS (rate was twice as slow as normal). Behaviorally, infants did not differentially attend to a display as a function of speech type. Psychophysiologically, infants showed more pronounced HR decelerations to slow than to normal IDS. The discrepancy between measures of attention is discussed, especially with regard to the organization of attention in infants of this age.

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Chapter 1

Introduction

One of the definitive goals in the area of infant speech perception is the discovery of those features of speech that most effectively capture and maintain attention. This task is challenging considering the rapid developmental changes that occur within sensory system functioning throughout the first postnatal year of life (Ruff & Rothbart, 1996). In order for infants to learn language, their attention must become selectively focused on those aspects of speech that enhance linguistic meaning and communicative intent.

It has been well established that across the first postnatal year of life, infants exhibit behavioral preferences for Infant Directed (ID) over Adult Directed (AD) speech (see Cooper, 1997, for a review). ID speech is characterized by higher or exaggerated vowel pitch, greater pitch variability, shorter utterances, longer pauses between utterances, slower rate/tempo, increased phrase repetition, and increased amplitude as compared with AD speech (Fernald & Mazzie, 1991; Fernald & Simon, 1984; Jacobson, Boersma, Fields, & Olson, 1983; Masataka, 1992, 1996; Papousek, Papousek, & Symmes, 1991). One of the purposes of this study was to examine the relationship between two different measures of attention (behavioral and psychophysiological) while infants at 4-months of age were presented with contrasting patterns of ID speech. By incorporating two different measures of attention, the change in response patterning between and within each attentional phase can be observed, allowing for a more complete understanding of how infant attention is modulated as a function of speech.

Across many cultures of the world, adult caretakers modify the prosodic features of their speech when interacting with young infants. These prosodic adjustments in ID speech (e.g., higher pitch, greater pitch variability, slower tempo, and increased rhythm) have been assumed to modulate and regulate infant attention in important ways. ID speech has been shown to more effectively capture and maintain infant attention as compared to AD speech (Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker & McLeod, 1992; Werker & McLeod, 1989) as well as been shown to help infants regulate

their emotional arousal and gain information about the communicative affect of the speaker (Fernald, 1984; Stern, Spieker, & MacKain, 1982). Thus far, the two prosodic features that have undergone the most research are pitch and rate.

In a series of experiments, Cooper, Cooper, Ostroff, and Aslin (2003) established that speaking rate is influential when considering infants' preferences for ID speech. Testing 1-month-olds, it was found that infants preferred to listen to female ID speech spoken at a normal rate over an accelerated version (ID-Fast), even when the pitch characteristics of these two speech samples were held constant. However, when given the opportunity to listen to ID speech at its normal rate verses a decelerated version (ID-Slow), 1-month olds preferred the slow speech, again pitch characteristics were held constant. Of particular interest was the finding that the average looking times for ID-slow speech were inordinately long, compared to the average looking times expected from previous studies with 1-month-olds. Could this be attributable to a decrease in the activity of the parasympathetic branch of the autonomic nervous system (e.g. heart rate slowing and decreased body movements), possibly, dramatically helping to maintain a longer period of *sustained* attention? Because the preference for slow speech was unexpected, a follow up study was conducted with 4-month-olds which found similar results, although the magnitude of the effect was lower. This same experiment was again conducted with infants at 8-months of age, finding no effect for slow speech on infants' attentional preferences.

In attempt to further investigate the perceptual role of slow speech, Cooper (2001) found somewhat contradictory findings regarding infants' attention to the feature of speaking rate. The purpose of these experiments was to explore whether the visual display characteristics (either complexity or structure) could influence 3- to 4-month-olds' auditory preferences for ID speech. The design of these studies was such to further investigate whether an attentional relationship exists among multimodal factors and how the infants' overall state of arousal may influence that relationship. More specifically, would the infants' preference for ID-Slow speech still emerge, independent of the changes in the visual display characteristics?

The first experiment confirmed a preference for ID-Slow over ID-Normal speech regardless of the complexity of the visual, geometric display (looking times were longer when ID-Slow speech was heard, independent of the visual pairing of different complexities as compared to those displays paired with ID-Normal speech). The second experiment found that when the visual display was reorganized in the form of a schematic face (compared with the geometric display consisting of the same components), that regardless of speech type (again ID-Slow verses ID-Normal) there was longer visual attention (looking) to the schematic face. This study failed to produce a significant speech preference for ID-Slow speech, suggesting that infants' attention to speech can be overridden by the structural organization of the visual information. This finding has implications for other studies, as it exemplifies the importance of considering other factors in the testing situation (specifically those characteristics of the visual display) and those specific to the infant (e.g. endogenous arousal) as they relate to the observed findings.

Not only is slowed speech a characteristic found in normal infant environments, but it has also been shown that deaf mothers are communicating with their deaf infants at a significantly slower tempo as compared to communication amongst their friends (Mataska, 1992). Because slow speech could allow infants to maintain longer sustained attention as well as aid in the process that encodes linguistic information, there is a need for investigation of this perceptual feature. This study also provides an opportunity to explore how slow speech can impact the autonomic nervous system functioning (specifically the parasympathetic system), through changes in heart rate. Despite the largest effect observed in 1-month-olds, infants at 4-months of age were selected based upon the applicability of Richards' model to infants older than 3 months.

There have been numerous studies that have investigated infants' attention to speech (for a review, see Cooper, 1997). In most testing protocols, some measure of the infant's visual behavior is taken as an index of attention. For example, the duration of time that an infant will attend (visually fixate) to a visual display when it is paired with

speech has been found to depend on the type of speech presentation, with longer looking times being expected for the speech type that is most attractive to them (Cooper, Abraham, Berman, & Staska, 1997; Cooper & Aslin, 1990, 1994; Pegg, Werker, & McLeod, 1992).

However, it is not always sufficient to use discrete 'looking' measures for assessing the broader construct of attention, as attention is not just influenced by external stimulus properties but is also influenced by internal states reflective of the functioning of a general arousal system. This nonspecific arousal system helps to sustain attention and maintain a vigilant state (Richards, 2001). If the mechanism of attention is partially defined as the integration of focused autonomic and cortical activity toward a specific source of information (Porges, 1976), it is necessary to measure and correlate the existing behavioral measures with the addition of those measures which reflect the activity of central and autonomic nervous systems, such as heart rate. The addition of a psychophysiological measure provides a way to examine the functioning of the internal, arousal system, offering insight into defined phases of attention (which can not be determined by 'looking' alone). Heart rate has been found to be the most commonly used psychophysiological measure of studying infant attention (Richards, 2001) and is one that is reflective of the influence of the arousal system of the brain (through parasympathetic nervous system control).

When studying infant attention, changes in heart rate (HR) have been used as a measure of autonomic modulation in response to psychological manipulations (Richards, 1987). Using Richard's model of attention, heart rate changes have distinguished four attentional phases during stimulus presentations: *pre-attention*, *stimulus orienting*, *sustained attention*, and *pre-attention/attention termination* (see Figure 1).
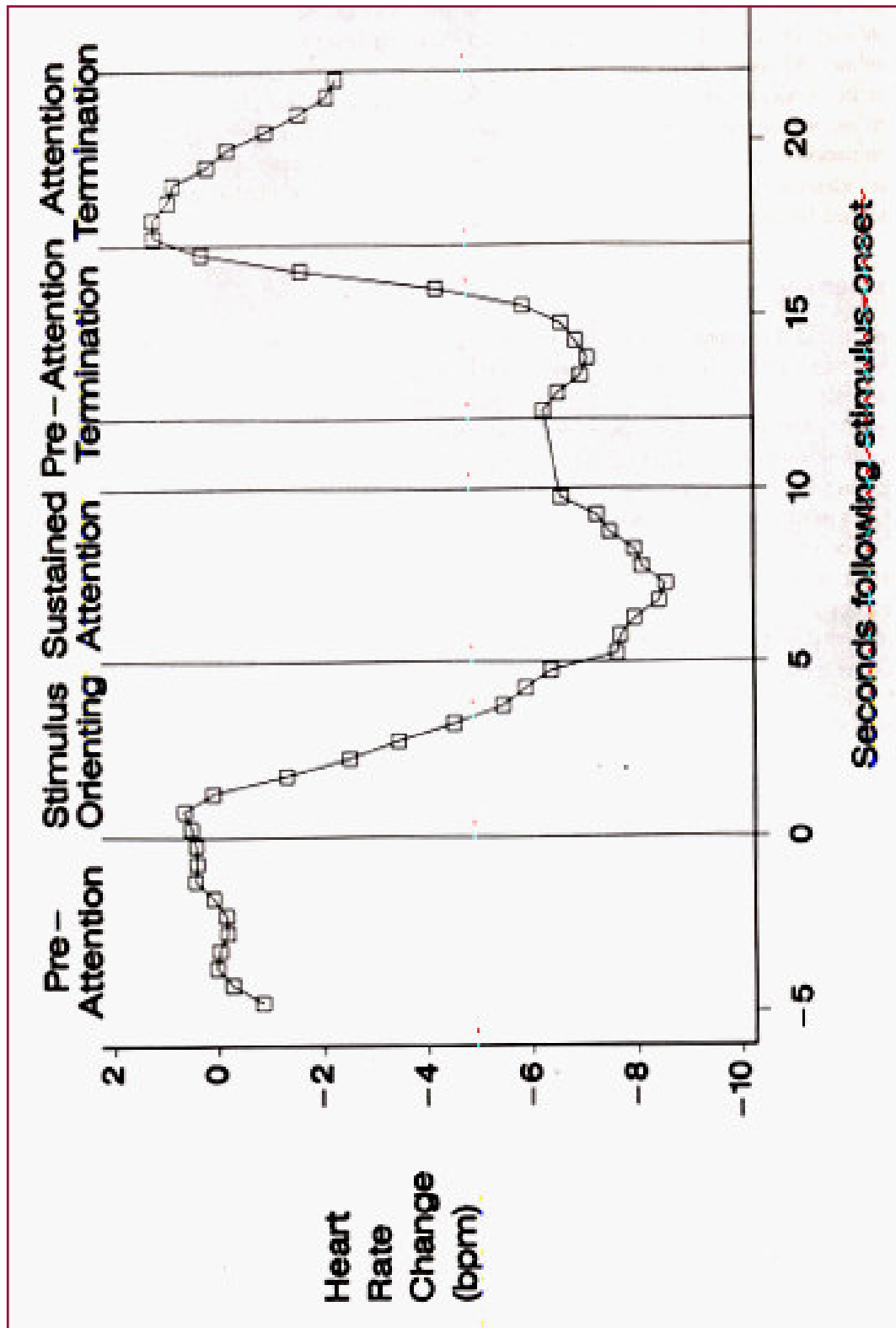
Figure 1: Richards' Model of Attention

According to Richard's model, *pre-attention* or the automatic interrupt component (Graham, 1979), reflects the detection of transient changes in environmental stimulation, which begins the first phase in the attentional process. Without further stimulus processing, a brief bi-phasic HR response occurs (deceleration- acceleration), with a long duration rise time resulting in little or no heart rate change and a short rise time manifesting a "startle reflex" (Richards & Casey, 1992). This component requires little or no processing resources, does not habituate, and is independent of stimulus intensity or duration (Richards & Casey, 1992).

The automatic interrupt activates the next phase, *stimulus orienting*, during which the infant evaluates stimulus novelty, processes preliminary stimulus information and decides whether to allocate further mental resources (Kahneman, 1973; Richards & Casey, 1992). This phase of orienting reflects activity early in the information-processing system and may involve stimulus processing and resource demands (Richards & Casey, 1992; Siddle & Spinks, 1992). Heart rate change during this phase consists of a large deceleration, lasting approximately 5 seconds (Richards & Casey, 1992).

Next is the period of *sustained attention*, during which the slowed heart rate remains below prestimulus levels, which cognitively involves subject-controlled processing of stimulus information (Richards, 2001). The arousal system of the brain controls the heart rate changes that originate from cardioinhibitory centers in the orbitofrontal cortex. These centers act through the parasympathetic nervous system to slow heart rate when the arousal system is engaged. The degree of deceleration of heart rate during sustained attention is thought to reflect the depth of the arousal (Richards, 2001). In this phase, heart rate is not only slower, but also less variable, and respiration amplitude and body movements also decrease (Jennings, 1986). The duration of sustained attention is highly dependent on the state of the infant, novelty of the stimulus, stimulus complexity, and characteristics of the infant (Richards & Casey, 1992). Sustained attention not only enables the infant to extract more detailed information about the event, but also undergoes the most developmental change with age. That is, infants become more efficient in their attentional control over time.

Finally, during the *pre-attention/attention termination* phase, heart rate returns to prestimulus levels and sensitivity to new stimuli may become attenuated (Richards & Casey, 1992). Pre-attention/attention termination is accompanied by heightened levels of distractibility, lack of acquisition of stimulus information, and lack of selective modality effects (Richards, 2001). Pre-attention termination occurs when the infant continues to fixate on the stimulus but does not have the same kind of autonomic activity invested that is reflected during sustained, focused attention (Richards & Casey, 1992).

Because heart rate changes are reflective of parasympathetic nervous system regulation, changes in heart rate activity should shed light on how infants' attention is being modulated and regulated in the context of the speech experience. Additionally, Richard's attentional model has never been specifically tested with events occurring within the auditory modality. Thus, one of the purposes of this study was to explore how existing behavioral measures (used to measure attention to visual and auditory events) correlates with a psychophysiological model. This study was designed to explore the relationship between two different measures of attention: (1) behaviorally, as in the traditional looking measure, and (2) psychophysiologically, utilizing heart rate as a measure of attention; with attention being defined as the selective focus of cognitive resources toward some specified event (e.g. heart rate slows and body movements decrease; Porges, 1992). The results of this study are among the first to associate changes in the autonomic nervous system functioning (specifically in the parasympathetic branch) with alterations in the prosodic features of speech, specifically speaking rate.

The following were hypothesized: (1) 4-month-old infants would show longer average looking times to ID slow speech as compared to ID normal speech, as was found in the study by Cooper, Cooper, Ostroff, and Aslin, 2003 , (2) ID slow speech would elicit greater heart rate decelerations at onset (*stimulus orienting)* and longer sustained decelerated heart rate periods (*sustained attention)* to ID slow compared to ID normal speech, and (3) there would be a positive relationship (e.g., correlation) between the

distinct dependent measures, look duration and heart period activity (e.g., as looking time increases, heart period would increase).

Chapter 2

Method

Participants

This study consisted of one group of 4-month-old infants ($\underline{n}$ = 24). Infants were recruited from the surrounding area through the local birth announcements, first by receiving an invitation letter (see Appendix A) to all available families and then a follow up phone call. None of the infants included in the final sample had any history of prenatal or postnatal complications and were in good health at the time of the testing (as assessed by parental report). The final sample was composed of 11 males and 13 females; $\underline{M}$ age = 125.85 days $\underline{SD}$ = 6.43. An additional 5 infants were tested but were not included in the final analysis due to excessive crying (2), equipment failure (2), and excessive movement, preventing reliable coding (1). Data from parental report established the final sample was composed of infants primarily from Caucasian-American, middle class, college educated families.

Speech Samples

This study utilized the same speech recordings as those used in Cooper, Cooper, Ostroff and Aslin (2003): ID-normal (unaltered ID speech) and ID slow (ID speech that was 50% slower than that of the ID-normal). These ID speech samples were created using *Digital Performer*, a waveform-editor program for the Power MacIntosh. Because vowel spaces tend to be relatively long and stable in regard to pitch and amplitude, this algorithm essentially slowed the speaking rate by duplicating portions of the vowel space. This created a longer speech utterance without significantly altering their pitch characteristics (see Table 1). The two speech types consisted of the same four sentences and all infants heard both speech types.

Table 1 Mean Pitch, Pitch Variability, and Duration of Utterances

Utterance	Mean Pitch	SD	Duration
Good Morning			
ID-Normal	374.27	153.59	1.28
ID-Slow	367.44	155.75	2.54
How are you today?			
ID-Normal	317.6	105.3	1.23
ID-Slow	323.87	120.16	2.49
What are you doing?			
ID-Normal	373.41	105.3	1.23
ID-Slow	362.02	145.53	2.51
Let's go for a walk!			
ID-Normal	373.41	151.31	1.25
ID-Slow	362.02	145.53	2.51

Apparatus

The parents and infants were seated in front of a black panel (5'8" tall x 3'9" wide), which contained the 15-inch screen of a computer monitor (Dell model, D1028L) placed 3' off of the floor, two speakers (Sony model, SRS-88PC) which were centrally located above and below the monitor, and a camcorder lens (Panasonic VHS model, AG 170) which set 6 inches off to the left of the monitor (for viewing the infant during testing).

The video camcorder projected the infants onto the observer monitor located in an adjacent room and was also used to videotape each session. A G4 MacIntosh computer administered the infant-controlled preference procedure developed by Cooper and Aslin (1990) that was written for the MacroMedia Director software program. The computer controlled the presentation of the visual and auditory stimuli, recorded the length of each trial and also concurrently sent a pulsed tone to event-mark both the heart rate and video records (for trial onset and offset).

The visual display consisted of colored concentric circles, which progressed in contrast toward the center of the screen for each presentation. The sound level of the speech recordings was held constant across infants (presented between 65-70db SPL; A scale).

For the recording of heart rate, Ag-AgCl disposable electrodes (Unitrace, UMP3-B) were attached to the infant's chest in a triangular array. One active lead was placed high upon each side of the sternum with the ground electrode being attached on the lower left area of the rib cage (Berg, 1972). The leads were connected to an isolated bioelectric amplifier (James Long Company model, RPC-01/04 BN) which fed into the A/D Interface and then into a 12-bit data acquisition system (IO Tech, Daqbook/112) connected to a Pentium 3 computer. Beat-to-beat heart periods, defined as the interval between successive R-waves in the ECG, were sampled at a rate of 1 kHz (Richards, 2001).

Procedure

Upon arrival to the Infant Perception Laboratory at Virginia Tech, parents were asked to sign an informed consent form (see Appendix B) as well as to complete a short questionnaire to find out more about family demographics (see Appendix C) and infant characteristics (see Appendix D).

Prior to entering the testing room, the electrodes were placed on the infant's chest. After the infants were assessed (by the experimenter) as being in a calm and alert state, they were placed on their parent's lap in the testing room. At the onset of the session, and between all subsequent trials, a flashing, red dot (7 ½ inches in diameter, 60 flashes per minute) against a white background was presented in order to attract the infant's attention toward the screen. In order to control for bias during the observation of each infant, the observer was located in an adjacent room with the speakers turned off, as to be unaware of the auditory speech presentations.

Once the observer determined that the infant was visually attending to the screen, the first trial began. The auditory and visual events (e.g., ID Normal speech and the bullseye) were played continuously until the observer judged the infant to be no longer looking at the screen (for at least 1 second). The flashing dot reappeared and the next trial began when the infant looked at the display (e.g., ID Slow Speech and the bullseye). Each session continued in this manner for a total of 10 alternating speech trials (5 ID-normal and 5 ID-slow), with the order of speech type counterbalanced across participants. Although the procedure usually only lasted for approximately 15 minutes, in order to be counted in the final sample the infants must have remained awake and alert throughout the entire session. The acquisition of heart rate (HR) was continuous throughout the session, and later aligned with the looking data (via the event marker).

Chapter 3

Results

In order to assess interrater reliability of looking times, three trained coders reviewed the taped sessions for all 24 infants. Each trial within a session was coded four times (the original (online) coder and three offline coders). Pairwise Pearson's bivariate correlations were calculated on the coders' rating agreements (i.e., each offline coder with the online coder), and ranged from .87 to .99, with an average correlation of .92. All correlations were significant at the .01 level (two-tailed). For this reason, there were no trials excluded from the following analyses.

Looking Times as a Function of Speech Type

To determine whether infants looked longer at the visual target during either ID-Normal or ID-Slow speech trials, mean looking times to both speech types were calculated by dividing the total time spent looking during each presentation by five, the number of trials presented (see Table 2 for individual subject averages). A mixed 2 x 2 analysis of variance (ANOVA) was performed on the infants' mean looking times, with order (ID-Normal first, ID-Slow first) as the between-subjects factor and speech type (ID-Normal, ID-Slow) as the within-subjects factor. Contrary to what was predicted, there was no significant main effect of speech type, $\underline{F}(1, 22) = .024$, $\underline{p} > .05$, with the average looking time to ID-Normal ($\underline{M} = 24.23$, $\underline{SD} = 14.59$) not differing from the average looking time to ID-Slow ($\underline{M} = 23.72$, $\underline{SD} = 14.17$). Neither order of speech presentation, $\underline{F}(1, 22) = .07$, $\underline{p} > .05$, nor an order by speech type interaction, $\underline{F}(1,22) = .11$, $\underline{p} > .05$, proved to be significant.

Table 2: Participants Individual Data　　(n =24)

	Average Looking Time (s)		Average Heart Period (0-5s., ms)	
Subject	ID-Slow	ID-Normal	ID-Slow	ID-Normal
1	8.39	11.67	488.26	469.61
2	10.17	10.20	449.85	440.69
3	10.46	14.01	435.09	443.00
4	10.93	27.30	394.08	392.09
5	11.37	12.21	393.85	397.91
6	12.03	16.46	405.61	400.98
7	12.37	12.29	443.10	422.53
8	13.54	21.28	421.53	444.84
9	16.58	12.59	432.99	423.85
10	17.85	9.03	395.14	372.81
11	18.25	58.88	415.69	410.56
12	19.02	18.85	445.27	428.57
13	19.70	29.67	394.92	388.03
14	20.73	53.90	353.69	348.79
15	22.35	16.59	388.60	384.15
16	22.65	13.18	375.08	383.52
17	26.00	17.11	384.62	386.43
18	28.22	32.71	377.43	368.74
19	32.34	30.27	381.06	379.07
20	37.76	15.62	397.49	392.74
21	41.70	55.53	441.41	410.68
22	44.62	25.28	440.74	451.91
23	54.43	33.43	409.52	400.03
24	57.93	33.38	381.05	382.78
	M = 23.72	M = 24.23	M = 410.25	M = 405.18
	SD = 14.17	SD = 14.59	SD = 31.40	SD = 29.91

Because research has demonstrated that novel objects and events tend to engage attention (e.g. Columbo & Bundy, 1983), with infants often looking longer at the display on the first trial compared to subsequent trials, the length of the first trial (as a function of speech type) was examined independently. However, there was no significant difference in the looking times on the first trials to ID-Normal speech ($\underline{M}$ = 36.09, $\underline{SD}$ = 64.90) compared to ID-Slow speech ($\underline{M}$ = 26.68, $\underline{SD}$ = 34.07; $\underline{t}$ (22) = .45, $\underline{p}$ > .05). Due to the large standard deviation associated with the mean looking time in the ID-Normal first condition, the individual subject data were scrutinized, and two infants were removed due to excessively long looks on the first trial (both were more than 3 standard deviations away from the respective mean; 240.27 sec. and 129.15 sec.), and a t-test was re-computed without them. However, this secondary analysis revealed no significant difference in the looking times on the first trial to ID-Normal speech ($\underline{M}$ = 17.52, $\underline{SD}$ = 9.21) compared to ID-Slow speech ($\underline{M}$ = 17.36, $\underline{SD}$ = 11.45; $\underline{t}$(20) = .04, $\underline{p}$ >.05). Further, a third ANOVA was conducted including all infants, with the length of the first trial being omitted from the calculations of mean looking times, which confirmed no significant difference between ID-Normal ($\underline{M}$ = 22.89, $\underline{SD}$ = 13.87) and ID-Slow speech ($\underline{M}$ = 23.34, $\underline{SD}$ = 13.07; $\underline{F}$(1,22) = .027, $\underline{p}$ > .05). Neither order of speech presentation, $\underline{F}$(1,22)=.01, $\underline{p}$ >.05, nor an order by speech type interaction, $\underline{F}$(1,22) =.05, $\underline{p}$ >.05, were significant.

Although there was no significant difference in mean looking times when collapsed across all trials of each speech type (with or without the first look), it was possible that longer visual fixations to one speech type may have been more apparent early in the session rather than later (i.e., some degree of habituation may have occurred from the early to later trials). In order to determine if there was a difference in infants looking behavior within parts of the session (look durations being longer in the first half of the session as compared to the last half), a 2 x 2 x 2 ANOVA was conducted on looking times with order (ID-Normal first, ID-Slow first) as the between-subjects factor and speech type (ID-Normal, ID-Slow) and time (first half, second half) as the within-subjects factor. Due to an uneven number of trials (5 of each speech type), the first half of the session was defined by the average of the first two trials of the same speech and the

second half was defined by the average of the last two trials of the same speech. The middle two trials were not included in these analyses (trial 5 and trial 6). The result of this analysis failed to find significant main effects for speech type, $F(1,22) = .09$, $p > .05$, for order, $F(1,22) = .01$, $p > .05$, or for time, $F(1,22) = 3.17$, $p > .05$. However, there was a significant time x order interaction, $F(1,22) = 4.18$, $p < .05$. There were no other significant interactions; speech x order $F(1,22) = .34$, $p > .05$, speech x time $F(1,22) = .36$, $p > .05$, or speech x time x order $F(1,22) = .63$, $p > .05$.
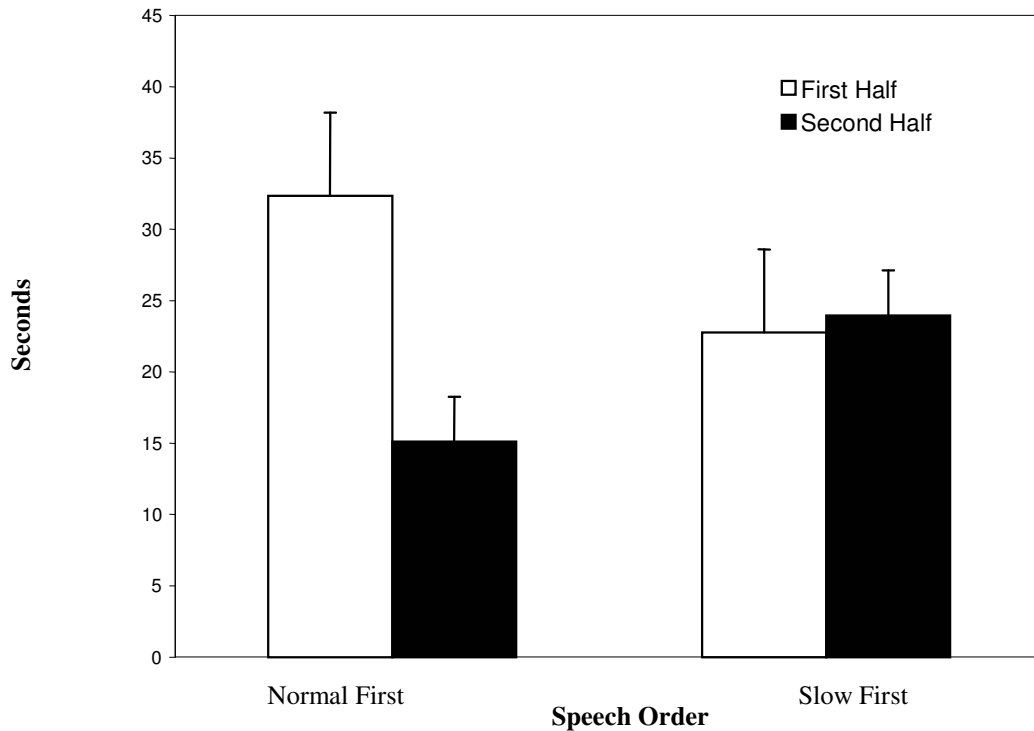

Figure 2: Significant Time x Order Interaction

Further analysis of the time x order interaction revealed a significant effect for infants who heard normal speech first, with the average looking time during the first half of their sessions ($M = 32.35$, $SD = 23.44$) being significantly higher than the second half of their sessions ($M = 15.11$, $SD = 6.76$; $t(11) = 2.36$, $p < .05$; see Figure 2). In contrast, there was no difference between the first half and the second half of the sessions for those

infants who heard slow speech first ($\underline{M}$ =23.17, $\underline{SD}$ =16.32 vs. $\underline{M}$ =23.96, $\underline{SD}$ =13.86, $\underline{t}$(11)= -.15, $\underline{p}$ >.05).

Heart Rate Changes as a Function of Speech Type

After data collection, the beat to beat heart rate record was visually scanned in order to remove any segment of the record during which the signal was lost or became undetectable. Overall, little data were removed from each record. The mean interbeat intervals (i.e. average times between successive R waves) were then calculated within each trial by custom software from the James Long Company.

Based upon Richard's model of attention, it was expected that the greatest amount of change in heart rate would occur within the first five seconds following stimulus onset, corresponding to the *stimulus orienting* phase, which shows marked heart rate deceleration. In order to assess if there were changes in heart rate as a function of speech type, a 2 x 2 ANOVA was conducted on the average heart period occurring in the first five seconds of each trial, with order (ID-Normal first, ID-Slow first) as the between-subjects factor and speech type (ID-Normal, ID-Slow) as the within-subjects factor. This analysis revealed a significant main effect for speech type, $\underline{F}$(1,22) = 4.31, $\underline{p}$ <.05, with the mean HR to ID-Slow being longer ($\underline{M}$ = 410.25, $\underline{SD}$ = 31.4) than to ID-Normal speech ($\underline{M}$ = 405.18, $\underline{SD}$ = 36.88; see Figure 3). Neither order of speech presentation $\underline{F}$(1,22) = .38, $\underline{p}$ >.05, nor an order x speech type interaction, $\underline{F}$(1,22) =.35, $\underline{p}$ >.05, reached statistical significance.
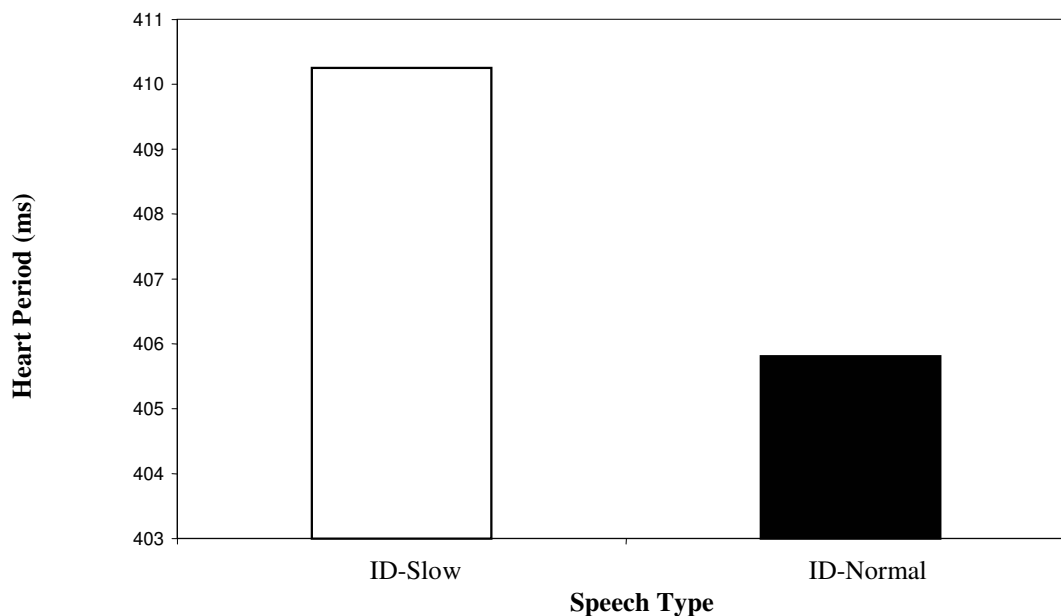
Figure 3: Main Effect for Speech Type in the First Five Seconds

Because it has been shown that with repetition of an event there are gradually smaller heart rate changes elicited, leading to a diminution of the orienting response and to less sustained attention (Ruff & Rothbart, 1996), a 2 x 2 x 2 ANOVA was conducted to determine the potential effect of time on changes in heart period to speech type. This analysis was conducted on the first five seconds of heart period with order (ID-Normal first, ID-Slow first) as the between-subjects factor and speech type (ID-Normal, ID-Slow) and time (first half, second half) as the within-subjects factors (as in the analysis of looking times, first half = trials 1-4 and second half = trials 7-10). As in the analysis above, this ANOVA revealed a significant main effect for speech type, $F(1,22) = 7.49$, $p <.05$), with the average heart period to ID-Slow speech ($M = 410.92$, $SD = 31.94$) being significantly longer than to ID-Normal ($M = 404.4$, $SD = 30.96$). Additionally, there was also a significant main effect for time, $F(1,22) = 8.78$, $p <.05$, with slower heart period in the first half of the session ($M = 413.65$, $SD =32.09$) than in the second half ($M = 401.69$, $SD = 32.82$). There was no significant main effect for order, $F(1,22) = .30$, $p >.05$, and there were no significant interactions; half x order $F(1,22) = .496$, $p >.05$, speech x order

F(1,22) =.24, p >.05, speech x half $\underline{F}$(1,22) = .4, p >.05, speech x half x order $\underline{F}$(1,22) = 2.21, p >.05.

Again, following Richards' model, in order to assess if ID-Slow speech enabled infants to maintain longer periods of sustained attention, a 2 x 2 ANOVA was conducted on the average heart period occurring in the second 5 seconds into each trial, with order (ID-Normal first, ID-Slow first) as the between-subjects factor and speech type (ID-Normal, ID-Slow) as the within-subjects factor. There was no significant main effect for speech type, $\underline{F}$(1,22) = .68, p >.05., with the average heart period to ID-Normal speech ($\underline{M}$ = 410. 24, $\underline{SD}$ = 27.91) not differing from ID-Slow ($\underline{M}$ = 412. 20, $\underline{SD}$ = 30.36; see Figure 4). There was no significant effect for order of presentation, $\underline{F}$(1,22) = 2.47, p >.05, nor a significant speech x order interaction, $\underline{F}$(1,22) = 2.57, p >.05.
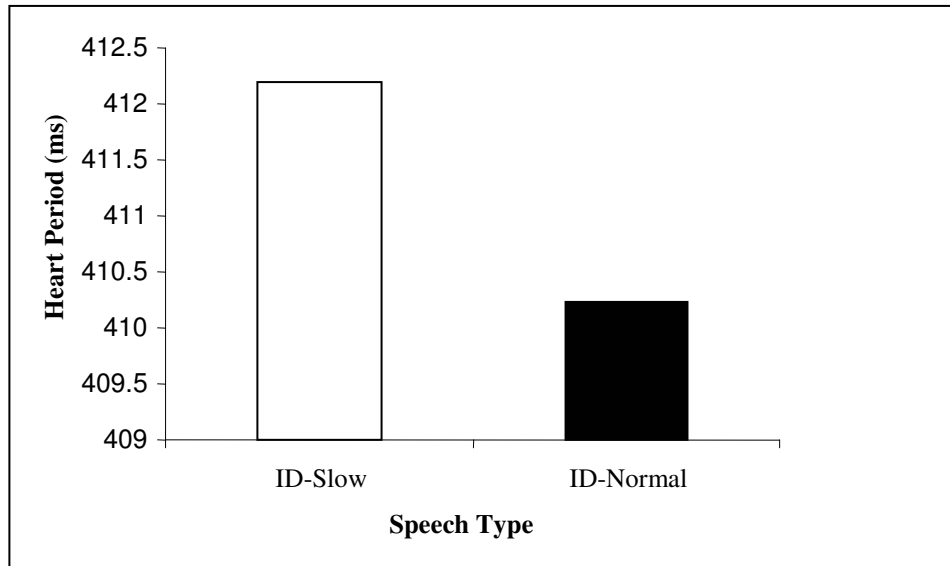

Figure 4: Non-significant Effect for Speech Type

As previously mentioned, this study was among the first to use a physiological measure to assess speech preferences, which traditionally have been measured behaviorally. Therefore, Pearson correlations were conducted in order to assess the relationship between these two dependent measures. Because the largest change in heart rate is typically observed within the first five seconds following stimulus onset, a

correlation was conducted on the average heart period within the first five seconds and the average look duration. It was expected that there would be a positive relationship between the two measures and that as looking time increases, heart period was also increase (heart rate would be slower). This analysis did not reveal a significant correlation between the two attentional measures, $\underline{r}$ = -.21, $\underline{p}$ >.05.

Chapter 4

Discussion & Conclusions

Corresponding to Richard's *stimulus orienting* phase and supporting part of the second hypothesis, it was found that 4-month-olds showed greater heart rate decelerations (longer average heart periods) to ID-Slow speech as compared to ID-Normal speech. This finding suggests that infants have the ability to differentially orient to events depending on stimulus characteristics. In this study, infants oriented more to ID-Slow speech than to the normal speech. Because novelty is salient to heart rate change (Ruff & Rothbart, 1996), the differences observed between the two speech types suggest that slow speech is perhaps perceived as more novel than normal infant-directed speech.

Because studies have shown that with repetition of an event the orienting response becomes attenuated, an additional analysis was conducted that bifurcated the session into halves. According to these results, heart rate decelerated more to ID-Slow speech than ID-Normal speech in the second half of the session. Therefore, infants cardiac oriented to the same degree in the first half of the session but, in the second half, they continued to orient to the slow speech but not as much to the normal speech. This suggests that the rate of speech presentation did elicit differential changes in the functioning of the parasympathetic branch of the autonomic nervous system over time.

The second hypothesis also predicted that the *sustained attention* phase of heart rate would be longer for ID-Slow speech than for ID-Normal. In order to assess this, the average of the second five seconds of each trial was examined, but this did not result in significant differences. This lack of significance could be attributable to the fact that some infants produced looks in which their total looking duration was shorter than ten seconds. This would suggest that in calculations of mean heart period, the *pre-attention/attention termination* phase is being manifested and not that of sustained attention. This would result in higher average heart rate (lower average heart period), due to the increases observed as HR returns to baseline. Theoretically, this could diminish the magnitude of the heart rate deceleration as a function of speech type. It also means that

less data were calculated into the average heart period during the second five seconds because it was based upon however many beats occurred after the first five-second block until the termination of the trial (which could vary from 1 to 4 seconds of data being calculated). Perhaps, if the trials were of a longer, fixed duration, differences in the second five seconds would manifest themselves and be more reflective of sustained attention. An example of this was found in a study conducted by Lewis, Kagan, Campbell and Kalafat (1966) that demonstrated that heart rate was lower during longer episodes of looking than shorter ones.

Another more effective way to follow Richards' phasic model, is to more closely examine the beat to beat changes and define the phases of attentional processing by changes in heart period, independent of a fixed timescale. Due to limitations in the software utilized in this study, a more fine analysis could not have been performed at this time. If this had been possible, infants' cardiac processing might have more accurately resembled those phases defined in Richards' model and ultimately yielded differences in the amount of time infants spent in the sustained attention phase as a function of speech type. In order to assess if this phenomenon was occurring, an analysis more sensitive to transient changes (more than those just in a specified block) could help resolve the differences attributable to the variations of individual look durations.

Based upon previous work with 4-month-olds, the first hypothesis predicted that infants would look longer to ID-Slow speech compared to ID-Normal speech. In contrast, this study did not find significantly longer looking times to a visual target when looking resulted in the presentation of ID-Slow speech. This was surprising, especially since the same speech recordings from previous studies were used in the present investigation and there were no differences in the experimental design of the study. Importantly, there may have been differences in the experimental set up that could have affected the results. This study required a longer period of time to set up and begin testing after the infants had arrived in the lab, due to the utilization of heart rate measures. It was during this extra period of time that the infants had electrodes placed on their chests and we confirmed that

the heart rate signal was clean and free of interference. Consequently, the infants had more time to become acclimated to their surroundings.

Comparatively, the previous investigation did not have such a delay and the infants were tested shortly after they arrived in the lab. It could be hypothesized that these infants' were more highly aroused when the testing began (as new places, people and events can be stressful). If this were the case, the slow speech stimuli may have been able to impact infant attention more dramatically, as a slower rate of speaking is thought to be more calming, soothing and serve to maintain attention (Stern, Speiker, Barnett & McKain, 1982). This feature may have been able to elicit longer periods of attention by helping infants' to regulate their level of arousal.

In young infants (younger than 3 months), attentional responding is heavily influenced by their ability to regulate their arousal levels, with arousal and attention initially working together in the same homeostatic system but becoming independent from one another with development (Karmel, Gardner & Magnano, 1991). This arousal modulated attention is thought to undergo developmental change sometime between birth and 5-months of age (Garner & Karmel, 1995). An alternative explanation for the previously observed preference for ID-Slow speech in 4-month-old infants could be attributable to the arousal modulation of attention, if infants were experiencing heightened levels of arousal prior to the beginning of testing. If this was the case, then perhaps infants looked longer at the visual display when it was paired with ID-Slow speech because that feature may have served a function of helping to regulate their internal state.

In the current study, it could be that infants were not as highly aroused when testing began, as they had a longer period of time to acclimate themselves to the new environment. As a result, slowed speech may not have been able to impact them to the same extent. If there was a difference in the infants' arousal levels at the beginning of the test, it could account for the differences in attention to slow speech between the two studies. This hypothesis suggests a need for future investigation to establish a baseline

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measure and then consider the time of acclimation as a potential factor influencing the infants' arousal level prior to the beginning of testing.

It may be important to note the difference in the effect sizes observed within previous studies for ID-Slow speech, the effect size for the 4-month-olds was moderate (.45) compared to the large effect (.72) in the 1-month-old sample. This implies that the impact of ID-Slow speech was of a lesser magnitude in the 4-month-old sample (compared to that observed in 1-month-olds) accounting for less of the variance in the sample. Although the effect size was moderate and would be expected to generate similar findings, it was still not as strong as that found in the younger sample. Currently within our lab, a comparable study with 1-month-olds is being conducted.

Why did a behavioral preference not emerge within the looking data? One possibility is that the perceived novelty of the ID-Slow speech was not enough to elicit longer looking times over the familiar, ID-Normal speech. It could be that within a session, infants were equally attracted to the novel and familiar characteristics of the respective stimuli, thus preventing the emergence of a behavioral preference. This does not suggest that infants could not discriminate the difference between the two speech types, but that perhaps, since infant directed speech is already slowed by definition, the degree that it is slowed may not be salient enough to override a preference for the normal rate of speech. However, this does not appear to be the case, as differences were observed in HR, suggesting that ID-Slow speech was being perceived as more novel than ID-Normal speech. Although Cooper (2001) did not observe a preference for ID-Slow speech in one of his conditions (the structured stimuli utilizing a schematic face), the mechanism that moderates the effect in his study does not seem attributable to the same source (as there were no visual manipulations in this study).

The last hypothesis predicted a negative relationship between look duration and heart rate activity. More specifically, as looking durations increased it was expected that heart period would increase (i.e. become slower). Surprisingly, there was no significant correlation between these measures. Perhaps this is because the times were different

between the two measures, as the entire length of the trial was used for the looking data compared to the first five seconds in heart period. Therefore there were no differences in behavior occurring despite the observation of differences in the physiological data, as a result, a direct correlation did not emerge between the two dependent measures. In order to better address this question, examining the length of the sustained attention phase in the heart rate record corrected for the length of the trial may produce better concordance between measures (as longer periods of sustained attention should result in longer looking trials). Again, being able to more finely define the phases of attention in the heart rate record may help to better establish the relationship between looking behavior and heart rate.

Another alternative explanation is that infants at four-months of age still do not have well synchronized behavioral and heart rate indices of attention. It has been established, with regard to infants' sustained attention phases, that younger infants (e.g., 8 weeks) show less coupling of behavioral and physiological indices than older infants (Hicks & Richards, 1998; Hunter & Richards, 1999, 2000; Richards, 1989b). The age related changes in heart rate during sustained attention may imply that the development of a general arousal system has not yet begun to effectively function at this age. Therefore, the observed lack of concordance between measures in this study may not be entirely reflective of measurement limitations but rather of infants' lack of integration abilities among sensory systems.

Overall, future research within the field of infant speech perception would be enhanced by the addition of a physiological measure, such as heart rate, because it is informative of how speech is impacting infants' attentional responses and arousal modulation abilities, which may not manifest themselves behaviorally. More specifically, in regard to the investigation of the perceptual feature of rate, this study suggests a need for the exploration of heart rate responses at different ages across the first postnatal year. This would allow for a more complete understanding of how the feature of rate may differentially impact infants across ages, illuminating patterns of developmental change over time. Additionally, similar manipulations of other features of infant directed speech

(i.e. increased pitch, increased pitch variability), may differentiate the ways in which specific features are most effectively impacting infants' attentional capacities.

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Appendix A

**INFANT PERCEPTION LABORATORY
DEPARTMENT OF PSYCHOLOGY
VIRGINIA TECH**

Dear Parent(s):

Soon after infants are born, they can recognize many different sounds and voices. For instance, we now know that babies only a few days old would rather listen to their own mother's voice than that of another woman. Even though babies are not yet talking, we believe that they are actively listening to the speech of their parents and others around them. In the Department of Psychology at Virginia Tech, we are interested in studying how different speech types affect infant attention. This information is very important for our understanding of how infants learn about the world around them.

Currently, we are investigating infants' attention to infant-directed speech. Specifically, we would like to measure the changes in infants' heart-rate occurring as they listen to a female voice talking to a baby. Your participation would involve one visit to the Infant Perception Lab, located next door to Bogen's restaurant in downtown Blacksburg (a map is enclosed for your convenience). This visit would be scheduled when your baby is **16-18 weeks old** and at a time that is convenient for you both (nights and weekends are available if you prefer). Our entire procedure lasts for approximately 35 minutes, but we schedule a full hour appointment with you and your baby to give you time to get settled and not feel rushed. If there are older children in the family and you would like to bring them along, we offer free babysitting in the waiting room right next to the observation room.

If you are interested in scheduling an appointment for your infant or like to find out more about our work, please feel free to call us at 231-3972 or visit us at http://www.psyc.vt.edu/infant_speech/. We hope to see you and your baby very soon!

Sincerely,

Robin Panneton Cooper, Ph.D.   Megan McIlreavy
Associate Professor   Graduate Researcher
Department of Psychology   Department of Psychology
Virginia Tech   Virginia Tech
cooperr@vt.edu   mmcilrea@vt.edu

Appendix B

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

INFORMED CONSENT

TITLE: 4-Month-Old Infants' Responses to Different Rates of Infant-Directed Speech
PRINCIPLE INVESTIGATORS: Dr. Robin Panneton Cooper
Megan McIlreavy

I. RESEARCH PURPOSE AND BENEFIT

The purpose of this project is to investigate 4-month-old infants' pattern of heart rate activity as they listen to different speech recordings. Your participation in this study benefits the study of early auditory perception, particularly our understanding of infant speech recognition.

II. PROCEDURES

Your infant will be tested for approximately 20 minutes, provided that he/she is quiet and awake. The baby will be held by the experimenter in her/his lap, facing a black panel. The baby will view a video screen on which a colored bullseye will appear. When the infant looks at the screen, a recording of infant-directed speech will begin. The infant can hear this speech as long as he/she looks at the screen. The loudness of the speech played to the infant is no more than that heard by infants in their typical home environment. While the infant is listening to speech, we will be recording his/her heart rate as a measure of interest in the speech. This heartrate measure involves placing three electrodes on the infant's chest, using small adhesive strips that capture the recording. Also, each infant will be videotaped during his/her session for subsequent coding of their facial expressions. If for any reason, your infant cries or falls asleep, testing will be discontinued. There are no apparent risks to your infant or to yourself for participation in this study. However, you have the right to terminate your involvement in this study at anytime and for any reason, if you so choose.

III. CONFIDENTIALITY

All of the information gathered in this study will be kept confidential and the results will not be released without parental consent. However, the results of this project may be used for scientific and/or educational purposes, presented at scientific meetings, and/or published in a scientific journal. You will be sent a summary of the work when this project is completed.

IV (a). RESEARCH APPROVAL

I have been given an opportunity to as further questions about this procedure and I understand that I have the right to end this session for any reason if I so choose. This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech. If I have any questions regarding this research and its conduct, I should contact one of the persons named below. Given these procedures and conditions, I give my permission to Dr. Cooper and her co-workers to test my son/daughter.

IV (b). RESEARCH APPROVAL (parent's copy)

       I have been given an opportunity to as further questions about this procedure and I understand that I have the right to end this session for any reason if I so choose. This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech. If I have any questions regarding this research and its conduct, I should contact one of the persons named below. Given these procedures and conditions, I give my permission to Dr. Cooper and her co-workers to test my son/daughter.

Dr. Robin Panneton Cooper, Principle Investigator   231-5938
Megan McIlreavy, Graduate Assistant   552-7185
Dr. David Harrison, Chair, Human Subjects Committee   231-4422
David M. Moore, DVM, Assistant Vice Provost for   231-4991
                        Research Compliance

_____   _____

Signature of Parent   Date

Appendix C

Family Information Sheet
(All information is strictly confidential)

Mother's Age: _____

Mother's Occupation: _____

Father's Occupation: _____

Mother's Education (in years): _____

Father's Education (in years): _____

Estimated Family Income: _____

Race: White/Caucasian   African American   Hispanic   Asian   Native American
Other

Marital Status: Married   Separated   Divorced   Single

For your most recent pregnancy, please note the following:

Method of delivery: Vaginal   Cesarean

Method of feeding: Breast   Bottle

Estimated Gestational Age in Birth (in weeks):
_____

Please list the gender and age of your older children (if any):

_____   _____

_____   _____

How long has it been since the baby late ate?   _____

How long has it been since the baby last slept/napped?   _____

Appendix D

Infant Questionnaire

For the following questions, please circle the number that is most typical of your baby.

1. How easy is it for you to calm or soothe your baby when he/she is upset?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

2. How easy is it for you to predict when your baby will go to sleep?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

3. How easy is it for you to know what's bothering your baby when he/she cries or fusses?

1	2	3	4	5	6	7
very easy			*about average*			*difficult*

4. How many times per day, on the average, does your baby get fussy and irritable-for either short or long periods of time?

1	2	3	4	5	6	7
never	*1-2*	*3-4*	*5-6*	*7-8*	*10-14*	*over 15*

5. How much does your baby cry and fuss in general?

1	2	3	4	5	6	7
very little			*about average*			*quite often*

6. How easily does your infant get upset?

1	2	3	4	5	6	7
not easily			*about average*			*very easily*

7. When your baby gets upset, how vigorously or loudly does he/she cry?

1	2	3	4	5	6	7
very mildly			*about average*			*very loudly*

8. How much does your baby want to be held?

1	2	3	4	5	6	7
very often			*sometimes*			*not very often*

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Department of Communication Studies:
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McIlreavy, M., Hoffman, K., & Cooper, R. P. (April, 2003). Father recognition in 9-12-month-old infants.
Poster presented at the Society for Research in Child Development, Tampa, Florida.

McIlreavy, M.E., Cooper, J.S. (April, 2001). Infants' preference for slow rates of Infant-directed speech
diminishes with age. Poster presented at the Society for Research in Child Development, Minneapolis,
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Student Member of the Society for Research in Child Development
Student Member of the International Society for Infant Studies

Honors/Awards:
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Galper Fund, 2001
Graduate Student Assembly Research Travel Award, 2001