*Early Development and Parenting*, Vol. 6, 171–178 (1997)

# *The Conditioned Head Turn Procedure as a Method for Testing Infant Speech Perception*

**Janet F. Werker[1]*, Linda Polka[2] and Judith E. Pegg[3]**
[1]*University of British Columbia, Vancouver, Canada*
[2]*McGill University, Montreal, Canada*
[3]*B.C. Research Institute for Child and Family Health, Vancouver, Canada*

**The purpose of this paper is to present and describe the Conditioned Head Turn procedure, with primary focus on its use as a method for testing infant speech perception. The paper begins with a brief history of the Conditioned Head Turn Procedure followed by a fairly detailed description of how the procedure is currently implemented. We then briefly outline the methods of analysis that are best suited for data obtained with the Conditioned Head Turn procedure. Next discussed are variations in the Conditioned Head Turn procedure when it is used with subjects of different ages. Then, some of the kinds of findings that have been revealed in the area of infant speech perception are presented to give the reader a sense of the range of questions that can be answered using this procedure. Following this, the strengths and limitations of the procedure are discussed frankly. We end with a presentation of new variations to the procedure that have been developed in recent years, and note how these new variations are expanding the range of questions the procedure can address. ©1997 John Wiley & Sons, Ltd.**

*Early Dev. Parent.* **6**: 171–178, (1997)
No. of Figures: 2. No. of Tables: 0. No. of References: 30.

*Key words:* infancy; speech perception; method

The Conditioned Head Turn procedure is one of the most versatile procedures for helping us understand infant speech perception capabilities and how these capabilities change as a function of experience and development. In this procedure, the infant is taught to turn his/her head to a sound or to a change in sounds. The procedure was originally developed from 'the peep show audiometry' designed by Dix and Hallpike (1947) and Suzuki and Ogiba (1960) for assessing auditory perception in children. In 'peep show audiometry' children were reinforced with a live model for correctly detecting the presentation of a sound. In this way, auditory thresholds could be assessed. The procedure was subsequently modified by Eilers *et al.* (1977) and later Kuhl (1985) for assessing auditory and speech perception in infants (see also Polka *et al.* 1995).[1] The Conditioned Head Turn procedure is based on

*Correspondence to: J. F. Werker, Department of Psychology, University of British Columbia, Vancouver, BC, Canada V6T 1Z4.
Contract grant sponsor: National Science and Engineering Council of Canada
Contract grant number: OGP 0001103
Contract grant number: OGP 0105397

CCC 1057-3593/97/030171–08$17.50


*Received 1 August 1996*
*Accepted 1 September 1996*

the premise that we will be able to obtain a more accurate picture of sensory and perceptual capabilities if we engage infants in a task that is fun, and one that rewards them for correct responses.

In the basic version of this procedure, the infant sits on the caregiver's lap across the table from an experimental assistant. To keep the infant entertained, the experimental assistant quietly shows the infant brightly coloured toys. An audio speaker and dark plexiglass box are located to one side of the parent/infant. Speech stimuli are presented over the speaker. The infant is taught to turn his/her head in the direction of the plexiglass box whenever he/she detects a change in a speech stimulus (or stimuli). When the baby makes a correct head turn, the dark box is illuminated and animated toy animals are displayed. In addition, the experimental assistant smiles and praises the infant. Incorrect head turns are not reinforced.

In this procedure, the mother/infant pair and the experimental assistant (E1) are seated inside a sound-attenuated booth. A second experimenter (E2), situated outside the booth, operates the computer and observes the infant through either a one-way glass or a closed circuit television (see Figures 1 and 2).

The parent and E1 both wear headphones delivering music so they cannot hear the stimuli being presented to the infant. E2 presses a button whenever the infant is in a state of readiness (watching, but not totally engaged in the toys being shown by the experimental assistant). The computer is then programmed to select either an experimental trial (a change in the speech stimulus) or a control trial (no change in the stimulus). E2 monitors the infant's behaviour, and pushes a button if a head turn occurs. In our instrumentation of the procedure, this button press is recorded by the computer.

The procedure typically involves several stages. There is an initial training stage (designed to familiarize the infant with the reinforcer) wherein the visual reinforcer is activated immediately after the first presentation of a new stimulus. Following some criterial number of trials in this first stage (typically 3–8), the conditioning stage begins. During conditioning, every trial is a 'change' trial. It is E2's job to gradually 'condition' or 'shape' the infant to turn towards the reinforcer. Thus, during the first few trials, E2 will turn the reinforcer on immediately following presentation of a change trial, and then will gradually increase the delay across trials to give the infant an opportunity to initiate a head turn on his/her own. Once the infant has performed a criterial number of anticipatory head turns (we require three in a row), the testing phase begins. During the testing phase, the computer randomly presents experimental and control trials. E2 does not know

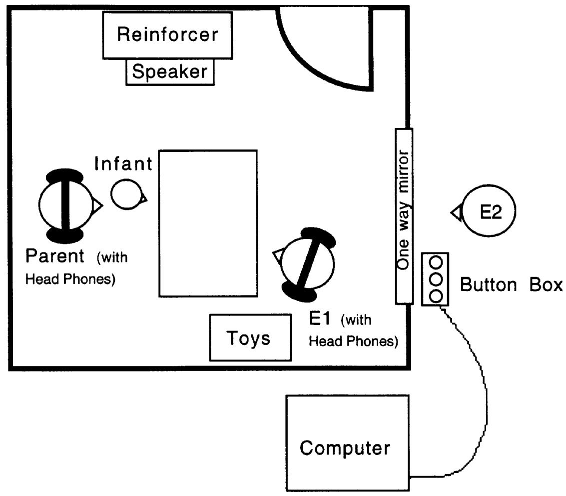


Figure 1. A schematic diagram of the Conditioned Head Turn procedure.

Figure 2. Madeleine performing in the Conditioned Head Turn procedure.

[1]In the clinical context the procedure is often referred to as VRA (visual reinforcement audiometry) and VRISD (visually reinforced infant speech discrimination).

 

the trial type during any observation interval: his/her task is to monitor the infant's behaviour and push a button when the infant makes a head turn. If that button press has occurred within a criterial window (4–6 seconds allowing the infant to hear three change stimuli), the reinforcer is activated and a 'hit' is recorded. 'Correct rejections' occur when an infant inhibits a head turn during a control trial, and 'false alarms' occur if the infant turns her head during a control trial.

Data can be analysed in many different ways. The data can be treated as continuous, allowing analysis of overall per cent correct or simply per cent correct to change trials. Using either of these dependent variables, *t*-tests or analysis of variance can be conducted to look for group differences. Single group *t*-tests can also be used to ascertain whether the performance of any particular group of subjects is greater than chance. To correct for different response strategies between infants, responses to hits in comparison to false alarms can be computed in a variety of ways (we have typically used an A′ calculation), and A′ scores can also be analysed using *t*-tests or ANOVAs. In addition, the data can be treated as discrete by setting a criterial performance level for ascertaining whether individual infants can or cannot discriminate a particular stimulus set. (We typically use seven out of eight contiguous correct responses achieved at some point during a sequence of 25 test trials.) The resulting categorical data can be analysed using techniques such as $\chi^2$, analysis of proportions, or randomization tests. Also, the question of whether individual differences in speech perception are related to other developmental events can be investigated by entering criterial data in some sort of prediction or causal modelling analysis (see Lalonde and Werker, 1995, for an example).

As you might imagine, many infants really enjoy this procedure. Unlike many other procedures where the infant is a passive observer, in this procedure the infant is able to make things happen. Infants who are interested in participating quickly learn the association between the sound change and activation of the reinforcer. Some infants quickly lose interest in the reinforcer, but still seem to enjoy their ability to 'make it come on' by turning their head at the right time. These infants simply swing their head around when the sound changes, and immediately look right back to E1 for that smile and praise. Other infants point in the direction of the toy animals at the same time as they turn their heads, and still others clap for themselves following successful head turns! On the other hand, some of the infants we test are not at all interested in this game and thus refuse to participate (see Strengths and Limitations section below). In addition, on occasion, we test an infant who finds the animated toy animals frightening rather than rewarding. For these infants, we keep a still toy animal in one compartment of the plexiglass box. This animal is illuminated, but does not perform following correct head turns.

## AGE VARIATIONS

The Conditioned Head Turn procedure is used most widely with infants between 5.5 and 18 months of age, but it is ideally suited for infants between roughly 6 and 10 months of age. At 6–10 months the infant is a 'captive audience' and is not easily bored with the reinforcer. Beginning at roughly 11 months, infants' mobility increases and they are less content to just sit quietly on the parent's lap for a very long time. These older infants often become bored with the visual reinforcer and thus appropriate social reinforcement becomes more critical. Varying the visual reinforcer across the test session can also help maintain interest in the task with infants this age.

The basic head turn procedure can be adapted to test older children and adults as well as younger infants. To test adults and older children (roughly 5 years and up) the head turn response is generally replaced with a hand signal. Minimal instructions are given if direct comparison with infants is of interest. With younger children (between roughly 2 and 5 years) the head turn response can be replaced with a button or bar press. The visual reinforcer may be adequate to engage some young children in the task. However, especially with the younger child, success depends on age-appropriate social praise and encouragement provided by an assistant. In addition, a tangible reward (small toy or sticker) given after a block of trials may be needed to maintain cooperation in the task. These adjustments make the Conditioned Head Turn procedure a useful tool for studying both infant perceptual abilities and developmental change.

It is also possible to test younger infants using the same basic procedure by adapting the responsibilities of the experimenter instead of the subject. Babies typically cannot be conditioned to perform reliable short-latency head turns before they are about 5 months of age. However, there are behaviours that infants 5 months and younger display in response to sound such as eye-widening, eyebrow movements, or a global pause in ongoing activity. Recent studies show that these behaviours, like the head turn response, can also be conditioned (e.g. Olsho *et al.*, 1987). To do so, the experimenter is trained to judge whether the baby has heard a change (experimental trials) or no change (control trials) by attending to any behaviour emitted by the baby. The basic procedure is very similar from the babies' perspective in that a baby must make some response that the observer can detect when the sound changes. Responses made (and detected) on change trials are reinforced with a visual reinforcer and social praise while not responding on control trials is not reinforced.[2] The procedure differs from the experimenter's perspective. The experimenter outside the test chamber (E2) must learn to correctly detect the behaviours made by the baby when a sound change occurs. To do so, feedback on both change and control trials is provided to the observer. In some labs a longer trial duration (10 seconds) is used (compared to the 4–6 seconds used in the standard procedure) and the assistant inside the booth listens to the stimuli during the training phase and gives the observer (E2) advice on what behaviours to look for. Several researchers have successfully employed this observer-based technique with non-speech stimuli to assess basic auditory acuity in infants between 1.5 and 12 months (Olsho *et al.*, 1987; Morrongiello *et al.*, 1990; Trehub *et al.*, 1991). A recent study conducted by Marean *et al.* (1992) has shown that this approach also holds promise for studying speech discrimination in infants between 2 and 6 months of age.

## QUESTIONS ADDRESSED USING THIS PROCEDURE

The Conditioned Head Turn procedure originated as a technique for conducting audiological assessment with infants and continues to serve as a standard technique for clinical evaluation of auditory acuity in infants and for psycho-physical research in infant audition. The procedure has been adapted for assessing infants' perception of musical structure by Trehub *et al.* (1984). As mentioned above, and of particular interest to us, this procedure has also allowed researchers to investigate infant speech perception. One such speech perception phenomenon involves discrimination: the ability to detect differences between speech stimuli (e.g. consonant and vowel syllables). For example, to determine if infants can discriminate syllables, a background (or referent) syllable is presented repeatedly to the infant (e.g. /da, da, da, da/) and when the infant is in a ready state the presented signal changes to a different syllable (e.g. /ta, ta, ta/). If the infant can hear the difference between the two syllables, he/she will learn to make a head turn when the syllable changes. This procedure could also be used to determine if infants discriminate any two sounds such as two different frequencies, different melodies, and even different voices. Early research that implemented the Conditioned Head Turn procedure using this simple discrimination paradigm was important in revealing the remarkable speech perception abilities of young infants (see Kuhl, 1987, for a review).

Another speech perception phenomenon investigated using this procedure involves categorization: the ability to treat exemplars from within one category as similar to each other and as different from exemplars from another category. To determine if infants can group speech stimuli in the same manner as adults, we present them with several different members of one category as the background stimuli, and on change trials we present several different exemplars of a new category. If infants treat the within-category variants as similar and the cross-category variants as different, they will only turn their heads on change trials. Several studies have clearly demonstrated that infants can discriminate on the basis of category identity even when they are able to discriminate the within-category variants. Such findings show that infants can form equivalence classes that match adult perceptual categories. For example, using synthesized speech Kuhl (1983) showed that at 6 months infants can treat multiple exemplars of /i/ as similar to each other and different from a set of exemplars of /a/, even though each set consisted of different pitches (rising, falling) and voices (male, female, child) that were discriminable to these infants. In contrast, infants of this age failed to detect arbitrary categories that were constructed using the same stimuli. In a recent study Bohn and Polka (1995) used the category change paradigm with modified natural syllables to explore the acoustic determinants of vowel identity in young infants.

[2]One published study has used this procedure successfully without implementing a visual reinforcer (Trehub *et al.*, 1991).

Kuhl (Grieser and Kuhl, 1989; Kuhl, 1991) has used the procedure in a slightly different way to examine the internal structure of phonetic categories. She has found that for at least some synthesized stimulus sets, subjects show differences in their ability to discriminate instances from the same category depending upon whether a 'good' or a 'bad' exemplar of the category is presented as the background or the referent. Adults are initially presented with several examples of a category and are asked to judge the quality of each exemplar on a numerical scale. Those exemplars judged as better examples of the category are considered 'good' exemplars. Next, adults are tested in the head turn procedure controlling order of presentation of two exemplars. Evidence of a perceptual magnet effect is provided when adults more easily discriminate variations in the two exemplars of the vowel /i/ when a 'poor' instance of /i/ is presented as the referent than when a 'good' instance of /i/ was used as the referent. The greater generalization (i.e. poorer discrimination) associated with the 'good' reference was taken as evidence that, within a vowel category, a 'good' exemplar acts like a perceptual magnet to organize the phonetic category. Because infants showed the same pattern of discrimination results as adults, it can be inferred that the phonetic category for this vowel is similarly structured for infants as it is for adults (Kuhl *et al.*, 1992; and see Polka and Werker, 1994, and Polka and Bohn, 1996 for a related approach using natural speech).

Because the procedure can be used across the life span, it can also be used to assess age-related differences and similarities in discriminative capacity. For example, we have used the procedure to examine experimental influences on non-native speech perception by comparing younger infants, older infants, children, and adults on their ability to discriminate non-native consonant and vowel distinctions. Using the procedure, we have found that 6- to 8-month-old infants perform better than 10- to 12-month-old infants and adults on their ability to discriminate non-native phonetic distinctions (Pegg and Werker, in press; Polka and Werker, 1994; Werker and Tees, 1984; Werker and Desjardins, 1995). This finding of a developmental progression from greater sensitivity in younger than in older infants suggests that infants begin life with language-general speech perception capabilities and gradually come to focus selectively on the specific variation that characterizes speech sounds in their native language.

## STRENGTHS AND LIMITATIONS OF THE PROCEDURE

A number of positive features contribute to the status of the Conditioned Head Turn procedure as a classic method for assessing perception of auditory information in infants. First, many procedures used to assess auditory perception in infants, such as the auditory brain stem response or ABR, measure electrophysiological responses. Such measures are informative but, at present, provide a restricted view of auditory function. Also, we cannot be confident that electrophysiological measures can be equated with functional hearing (see Hecox and Burkard, 1982, for a review). In contrast, the information gathered using the Conditioned Head Turn procedure relies on behavioural responses from infants and can readily be accepted as an index of functional hearing.

Of course, it is imperative that the procedure be performed under conditions that control for test bias. Thus, it is essential that parent and E1 both wear headphones delivering music so they cannot hear stimulus changes and potentially influence the infant to turn his/her head. It is essential, also, that E2 be unable to hear the stimuli and have no knowledge of whether a particular trial is a control or experimental trial.

A special feature of the Conditioned Head Turn procedure is that, unlike many other behavioural procedures (such as habituation), the stimulus and the reinforcer are independent events. This means we can evaluate an infant's response to the test stimuli independently of his/her response to the reinforcer. Thus, we can more easily determine when the infant is having perceptual difficulty versus showing general disinterest or non-cooperation. This is a tremendous advantage because it provides a way to design experiments that allows interpretation of the meaning of an infant's failure to detect or discriminate auditory information.

Another important feature of the Conditioned Head Turn procedure for both auditory assessment and perceptual research is that with this technique we can present multiple test trials to the same infant, making it possible to ascertain whether an individual infant can or cannot reliably detect or discriminate particular stimuli. Data on the perceptual abilities of individual infants contribute to the meaningfulness of the findings. It allows the researcher to identify infants at risk for hearing loss or perceptual difficulties. It allows identification of potential developmental delays or aberrant patterns of development. It permits the implementation of a wide range of research designs. And it allows the researcher to study how performance on auditory or speech perception tasks patterns with performance on other tasks or whether it predicts later emerging competencies (see, for example, Lalonde and Werker, 1995).

A third advantage associated with the Conditioned Head Turn procedure is that, with slight modification, it is possible to use this procedure across the entire life span. The several strengths outlined above make the Conditioned Head Turn procedure a useful instrument for both cross-sectional and longitudinal studies of perceptual development.

Despite the significant strengths of the Conditioned Head Turn procedure, this methodology is not without its weak spots. At present, three major limitations can be identified, each of which may be overcome with further developments in the procedure. First, this procedure, like other infant procedures, is characterized by variable attrition rates (varying from 5% to 50%). Attrition rates can be kept lower if the researcher ensures that the reinforcer and behavioural response are age appropriate. Nevertheless, individual infants differ in the ease with which they can be conditioned in the task. Thus it is critical that the team of researchers testing the infants (E1 and E2) be carefully trained, and be able to modify the timing of trials and intensity of the social feedback in response to the needs and interests of each individual infant. Also, attrition rates are higher when infants are tested with background and target stimuli that are difficult to discriminate.

A second limitation concerns the type of stimuli that can be studied using the methodology. The Conditioned Head Turn procedure has proven to be a superb method for studying perception of relatively short speech patterns, such as syllables, single and multi-syllabic words, short melodic patterns, or brief trains of noise. However, it is generally not the method of choice to investigate discrimination or categorization of speech patterns that are inherently longer in duration, such as intonational phrases, sentential stress patterns, or discourse samples.

Finally, there are some inherent restrictions in the interpretations that can be drawn from studies using the Conditioned Head Turn procedure. With this tool researchers have cleverly designed experiments from which we can draw inferences about more sophisticated abilities such as categorization. However, it is important to realize that such results cannot directly inform us about 'what' the infant perceived in the test procedure. Therefore, the issue of whether the infant recognized or identified the target and background stimuli in the same way as the adult experimenter or has attached a specific meaning to the stimuli can be debated.

## NEWER VARIATIONS ON THE PROCEDURE

Several laboratories have attempted to modify this procedure to change it from a discrimination task into an identification task. The basic approach has been to attempt to teach infants or children to make two different responses to two different kinds of stimuli (e.g. Burnham *et al.*, 1987; Kubaska and Aslin, 1985; Murphy *et al.*, 1989). For purposes of illustration, we will briefly present the two-choice version of the procedure used by Murphy *et al.* (1989) with 3-year-old children. In this variation, 3-year-old children are seated either alone or with a parent, again in a sound-attenuated room. An audio speaker is situated directly in front and slightly above the child. Two television monitors are in the room, one 45° to the left and one 45° to the right of the audio speaker. Short video clips, rather than animated toy animals, are used as reinforcers. The child is taught to point to one television monitor when he/she hears one kind of stimulus (e.g. a particular vowel) and to the other television monitor when he/she hears a contrasting stimulus (e.g. a different vowel). (See also Burnham *et al.*, 1991, for a similar kind of procedure used with slightly older children.)

There have also been attempts to assess identification abilities in infants by extending two-choice procedures to this younger age group. The response involves requiring the infants to turn their head to one side in response to one particular sound, and to the other side in response to a second particular sound. These attempts have met with mixed success, however, and there is disagreement as to their validity with infants (see Burnham, *et al.*, 1986, for a discussion of some of the problems).

One modification to the Conditioned Head Turn procedure, which functions somewhat like an identification procedure but can be used successfully with infants, is the noise detection technique (Morgan, 1994). The set-up for this procedure is identical to that used in the Conditioned Head Turn procedure, and the logic of progressing through shaping, conditioning, and testing phases is maintained. However, in this procedure, infants are taught to turn their head to one side whenever they detect a particular sound (such as buzz or click inserted into speech) rather than whenever they detect a change in the sound stimulus. Correct head turns are reinforced, again, typically with animated, illuminated toy animals. Morgan used not only correct head turns, but also response latency as a dependent variable. Unlike the two-choice procedure described above, however, infants need only learn to turn their head in one direction in response to a sound of a particular type. The fact that they need not learn two distinct responses for two different kinds of sounds may account for the greater success with this procedure. It should be noted, however, that learning a single response to a single sound is more easily understood as simple conditioning than as an ability to identify or 'label' a particular sound.

This technique allows researchers to investigate whether some stimuli or stimulus sequences are more coherent than others. The logic, following from the click detection methods used in adult sentence processing, is that infants will more readily detect a click at a boundary (e.g. a clause or phrase or syllable boundary) than they will detect a click inserted within a perceptual grouping. This technique can thus expand the range of questions that can be investigated with the Conditioned Head Turn procedure. For example, using Morgan's modification, Morgan and Saffran (1995) showed there to be developmental changes between 6 and 9 months of age in the contextual variables that influence click detection.

This modification will allow researchers to investigate the influence of sentential-level prosody, phrasal structure, and other grouping properties on infant speech processing. Also, if infants can be taught to detect clicks, they may also be able to be taught to monitor for particular syllables or particular words. In this way, the technique may be used as something closer to an identification task in ascertaining not just when infants can hear a change, but when they notice a particular syllable or word.

## CONCLUSION

The Conditioned Head Turn procedure is a very useful procedure for assessing infant perceptual capabilities. It can be used to assess basic auditory sensitivities, perception of music and rhythm, and perception of speech. It provides data on detection, discrimination, categorization, and perceptual grouping. Because it can be implemented in subjects of very different ages it can be used to study developmental change, and because it can provide data on individual subjects it can also be used to assess individual differences. Using this technique we have greatly increased our understanding of infant speech perception. With ongoing refinements and exciting new variations of the basic technique we can expect the Conditioned Head Turn procedure to remain one of the essential tools for the perceptual researcher and clinical audiologist.

## ACKNOWLEDGEMENTS

This work was supported in part by grants from the Natural Science and Engineering Research Council of Canada to J. F. Werker(OGP0001103) and to L. Polka (OGP0105397).

## REFERENCES

Bohn, O.-S. and Polka, L. (1995). What defines vowel identity in prelingual infants? *Proceedings of the International Congress of Phonetic Sciences*, Stockholm, Sweden, Vol. 1, pp. 130–133.

Burnham, D. K., Earnshaw, L. J. and Clark, J. E. (1986). Categorical identification of phonemic and non-phonemic bilabial stops by infants, children, and adults. *Speech and Language Research Centre Working Papers*, **4**, 53–73.

Burnham, D. K., Earnshaw, L. J. and Quinn, M. C. (1987). The development of the categorical identification of native speech. In B. E. McKenzie and R. H. Day (Eds), *Perceptual Development in Early Infancy: Problems and Issues*. Hillsdale, NJ: Erlbaum.

Burnham, D. K., Earnshaw, L. J. and Clark, J. E. (1991). Development of categorical identification of native and non-native bilabial stops: infants, children and adults. *Journal of Child Language*, **18**, 231–260.

Dix, M. R. and Hallpike, C. S. (1947), The peep shows: new technique for pure-tone audiometry in young children. *British Medical Journal*, (2), 719.

Eilers, R. E., Wilson, W. R. and Moore, J. M. (1977). Developmental changes in speech discrimination in infancy. *Journal of Speech Hearing Research*, **20**, 766–780.

Grieser, P. and Kuhl, P. K. (1980). Categorization of speech by infants: support for speech–sound prototypes. *Developmental Psychology*, **25**, 577–588.

 

Hecox, K. and Burkard, R. (1982). Developmental dependencies of the human brainstem auditory evoked response. *Annals of the New York Academy of Sciences*, **388**, 538–556.

Kubaska, C. A,. and Aslin, R. N. (1985). Categorization and normalization of vowels by 3-year-old children. *Perception and Psychophysics*, **37**, 355–362.

Kuhl, P. K. (1983). Perception of auditory equivalence classes for speech by infants. *Infant Behavior and Development*, **6**, 263–285.

Kuhl, P. K. (1985). Methods in the study of infant speech perception. In G. Gottlieb and Krasnegor, N. A. (Eds), *Measurement of Audition and Vision in the First Year of Postnatal Life: A Methodological Overview*. Norwood, NJ: Ablex.

Kuhl, P. K. (1987). Perception of speech and sound in early infancy. In P. Salapatek and L. Cohen (Eds), *Handbook of Infant Perception*, Vol. 2. New York: Academic Press, pp. 275–382.

Kuhl, P. K. (1991). Human adults and human infants show a 'perceptual magnet effect' for the prototypes of speech categories, monkeys do not. *Perception and Psychophysics*, **50**, 93–107.

Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N. and Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, **255**, 606–608.

Lalonde, C. E. and Werker, J. F. (1995). Cognitive influences on cross-language speech perception in infancy. *Infant Behavior and Development*, **18**, 459–476.

Marean, G. C., Werner, L. A. and Kuhl, P. K. (1992). Vowel categorization by very young infants. *Developmental Psychology*, **28**, 396–405.

Morgan, J. L. (1994) Converging measures of speech segmentation in preverbal infants. *Infant Behavior and Development*, **17**, 389–403.

Morgan, J. L. and Saffran, J. R. (1995). Emerging integration of sequential and suprasegmental information in preverbal speech segmentation. *Child Development*, **66**, 911–936.

Morrongiello, B. A., Fenwick, K. D. and Chance, G. (1990). Sound localization acuity in very young infants: an observer-based testing procedure. *Developmental Psychology*, **26**, 75–84.

Murphy, W. D., Shea, S. L. and Aslin, R. N. (1989). Identification of vowels in 'vowelless' syllables by 3-year-olds. *Perception and Psychophysics*, **46**, 375–383.

Olsho, L. W., Koch, E. G., Halpin, C. F. and Carter, E. A. (1987). An observer-based psychoacoustic procedure for use with young infants. *Developmental Psychology*, **23**, 627–640.

Pegg, J. E. and Werker, F. (in press). Adult and infant perception of an English phonetic distinction. *Journal of the Acoustic Society of America*.

Polka, L. and Bohn, O.-S. (1996). A cross-language comparison of vowel perception in English-learning and German-learning infants. *Journal of the Acoustical Society of America*, **100**, 577–592.

Polka, L. and Werker, J. F. (1994). Developmental changes in perception of non-native vowel contrasts. *Journal of Experimental Psychology: Human Perception and Performance*, **20**, 421–435.

Polka, L., Jusczyk, P. W. and Rvachew, S. (1995). Methods for studying speech perception in infants and children. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues in Cross-Language Speech Research*. Timonium, MD: York Press.

Suzuki, Y. and Ogiba, Y. (1960). A technique of pure tone audiometry for children under three years of age: conditioned orientation reflex (C.O.R.) audiometry. *Revue de Laryngologie*, **81**, 3–43.

Trehub, S. E., Bull, D. and Thorpe, L. A. (1984) Infants' perception of melodies: the role of melodic contour. *Child Development*, **55**, 821–830.

Trehub, S. E., Schneider, B. A., Thorpe, L. A. and Judge, P. (1991). Observational measures of auditory sensitivity in early infancy. *Developmental Psychology*. **27**, 40–49.

Werker, J. and Desjardins, R. N. (1995). Listening to speech in the first year of life. *Current Directions in Psychological Science*, **4**(3), 76–81.

Werker, J. F. and Tees, R. C. (1983), Cross-language speech perception: evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, **7**, 49–63.

 