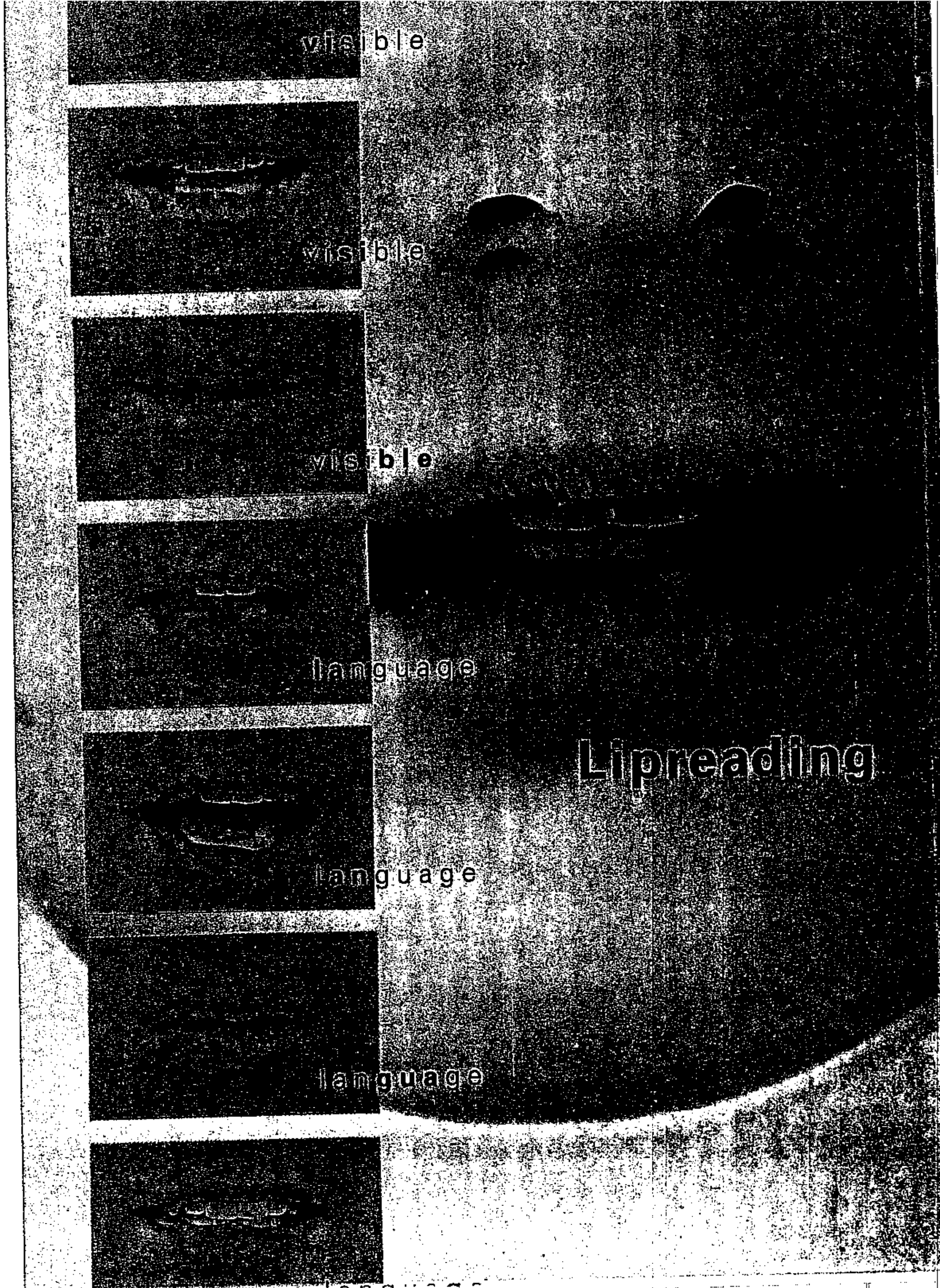
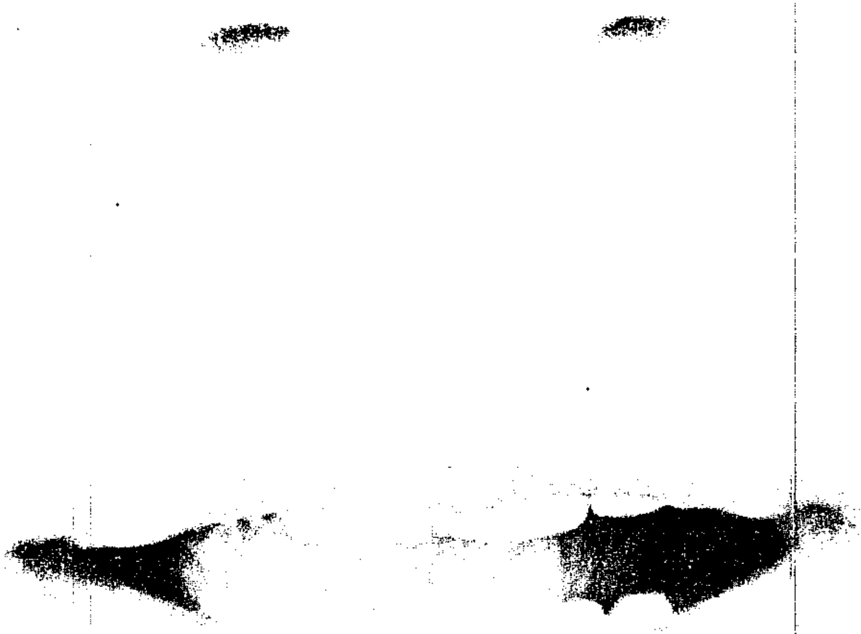
Lipreading





Perception of Facial Movements in Early Infancy

Perception of Facial Movements in Early Infancy: Some Reflections in Relation to Speech Perception

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Some aspects of the literature dedicated to the study of perception of facial features and movements by infants are examined. More particularly, we try to analyze the kind of visual information infants can process at different ages, and how this may be linked to their developing speech perception. Empirical data related to imitation of facial movements, to pre-speech activity, to lip-reading ability and auditory-visual integration are reviewed. These data show that the ability of young infants to encode face features and process facial information undergoes a complex development in the first year of life. In the final part of this paper, we discuss briefly the relationships between face perception processes and visual speech perception within a developmental and cognitive framework. A central concern in this discussion is related to the "segmentation" problem, i.e. to the nature of the unit of perception used when speech is processed.

Recently people working on language have started to focus their attention on the fact that to produce speech one has to move the lips, and that some information about what is actually said may be derived from these movements. Of course the auditory/acoustic characteristics of language have attracted the major interest of (developmental) linguists and psycholinguists; for blind infants tend to develop normal speech, while deaf infants experience major difficulties in acquiring language. But, as a matter of fact, Mills (1987) reports that blind children do not show normal phonemic production development, but in their own speech, tend to confuse sounds that "look alike" (with regard to lipread information), for a more protracted period than hearing children. They also babble less than sighted infants, which may be indicative of the role that lipread information plays in speech production. Moreover, as mentioned by Dodd (1983), it is a current practice among teachers of deaf children to start to emphasize lipreading when infants are of a very early age, recognizing in this way the role of vision in speech perception. Such a practice seems to take for granted that young infants are able to process lipread information.

In this paper, we will examine some aspects of the literature dedicated to the study of perception of facial features and movements by infants. We will try to analyze the kind of visual information they can process at different ages and that may be related to their developing language perception. This paper will be closely focused on data indicative of the pre-linguistic infant's ability to discriminate visual information in faces. Moreover, when available, developmental data will be presented. The final part of the paper will speculate about the relationships between facial movements and language perception.

Different behaviors are meaningful with regard to the infant's ability to perceive facial movements, associated or not with speech:

Imitation of Facial Gestures: the repertoire of facial movements that have been used in imitation studies includes the tongue protrusion, lip protrusion, mouth opening-closing, eye blink, eye opening-closing and cheek movements.

Pre-Speech Movements: these refer to the infant's facial and manual movements when she is confronted with a talking partner.

Lipreading Behavior: these are some studies which have directly investigated the infant's ability to integrate visual and auditory information from lip movements.

In addition, it is worth analyzing the studies that show the infant's more general ability to coordinate vision and audition in relation to the face, as for instance to conceive that face and voice share a common spatial location.

Gaze Co-Orientation or Reciprocal Gaze Between Infant and Adult: this seems mainly related to pragmatic aspects of language, which is of minor interest; we will report this ability to interpret adult gaze only very briefly.

But before considering these different behaviors, it may be interesting to briefly mention some data on the infant's visual preferences with respect to faces as well as some indications on the developing psychophysical sensitivities of the infant's visual skills.

The Infant's Visual Preferences and Visual System Maturation

From a very early age, infants seem to prefer faces to other stimuli.

A summary of the main research results on early visual preferences follows. We will assume that these preferences indicate which stimuli are more efficiently processed by young infants (see Fantz, 1966; Banks, 1985). From a very early age, infants seem to prefer faces to other stimuli (see Vinter et al., 1986 for a review). Newborns track a moving schematic face in preference to other similar stimuli (Goren et al., 1975), and 2-week-old infants prefer to look at a still human face rather than at other stimuli (Fantz, 1966).

The stimuli which are attended to most by newborns are large, of high contrast, and with sharp contours (Fantz & Fagan, 1975; Fantz et al., 1975; Karmel, 1969; Salapatek, 1975). The hairline and the eyes are the most distinctive or high contrast features of the face, and seem to be the first features to be discriminated. In fact, habituated with a schematic face, 4-month-olds do not notice modifications in the mouth-nose configuration but do notice those of hairline-eyes, suggesting that, at this age, the lower part of the face is not well discriminated probably because of lower contrast and softer contour. Changes in nose and mouth are noticed later, at 5 months (Caron et al., 1973).

Given patterns with a fixed number of elements, infants prefer larger to smaller elements, and given patterns of fixed element size, they prefer the one with more elements in it. Later the number of elements in a pattern, in comparison with the size, becomes a more salient feature. At birth, a flat representation of an object is preferred to a three dimensional object and to photographs. Preferences for photographs and then for the real three dimensional object appear later. Newborns prefer schematic faces to photographs of faces. The preferences are reversed at 5 months. Finally a preference in curvature of external contour also exists at birth. This preference seems to decrease to a minimum at 4 weeks and increases again by 7 weeks. Specific curvatures do in fact characterize the external contours of the face, such as either the border of the face, which may be the first attended to, or in a less pronounced way, the eyes or the mouth.

In short, these data give support to the view that, from birth, infants are attracted by the human face, are senstive to different optical-perceptual parameters at different times, and do spend time observing faces. They also suggest that, in a static face, the mouth is discriminated relatively late in development, not before 4 months.

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Several aspects of developing visual capacities may be important with regard to these visual preferences. Development of the oculomotor systems might explain the appearance of the ability to detect a small pattern, to explore many details successively, and to hold foveal fixation with both eyes. Such abilities are important for the exploration of the fine internal features of the face. Development of visual acuity is also relevant for an understanding of face perception development, since pattern elements which are smaller than the resolution limit of the visual system cannot be detected. At birth the resolution power of the infant's visual system is low (around 2c/deg) and increases steadily for at least the first 6 months of life (Banks & Salapatek, 1978; Marq et al., 1976). Fine facial details are therefore unlikely to be discriminated in the very first months of life. Finally the development of contrast sensitivity appears to be another important factor of the developing ability to recognize pattern. The CSF (contrast sensitivity function) plots the minimal contrast necessary to just detect a sine wave grating with the grating's spatial frequency. Sensitivity to middle and high spatial frequencies undergoes a marked development during the first months of life (Banks & Salapatek, 1981; Banks, 1982). Atkinson et al., (1977) showed a large increase in contrast sensitivity from 1 to 2 months mostly at high spatial frequencies. By contrast, no noticeable change occurs between 2 and 3 months (Banks & Salapatek, 1978).

According to Bank's visual preference model (Banks, 1982), the linear systems model, the most preferred pattern is that one which best fits the infant's visual "window". This model uses the CSF as the description of this window, and can be summarized by a very simple rule: infants aged less than 3 months look at the pattern whose filtered output is greatest. After 3 months, other dimensions (perceptive-cognitive, attention-memory) also become important to account for visual preferences. In fact, as pointed out by Banks (1985), the linear-systems model is completely insensitive to the meaningfulness of a visual pattern, whereas it is very likely that as the complexity of visual perception grows with age, what a visual pattern "tells" to the infant may become a major determinant of his visual perception or preference.

A review of some specific behaviors that demonstrate that infants are sensitive to facial information at a very early age follows.

Perception of Facial Movements in Infancy

Imitation of facial movements

Following Piaget (1946), it has long been assumed that very young infants are poor at imitating gestures, either manual or facial. Yet, the first experimental study of early imitation, was carried out as early as 1928 by Guernsey. She observed 214 infants aged from 2 to 21 months, and analyzed their imitations of different models. Of interest are what she called "expressive mimic movements", which include the mouth opening–closing,a large open-

ing of the mouth, the tongue protrusion, and which are contrasted with models such as vocal models or movements performed with objects, toys and so on.
She concluded that (ibid, p.143):

"Die einzigen wirksamen Nachahmungsreize unter 4 1/2 Monaten sind mimische Ausdrücksbewegungen. Die Reaktionen sind vorherrshend reflexartig and bleiben es auch während des ganzen Lebens".

"The only items which are effectively imitated under 4 1/2 months of age are the expressive mimic movements. The reactions are mainly reflex, and remain so throughout life" *(our translation).*

The mimic movements which are reproduced from the age of 2 months onwards are essentially the large opening of the mouth, the mouth opening-closing, the tongue protrusion, and a lateral rotation of the head. Moreover she observed a progressive disappearance of these imitative responses between 4 and 6 months, whereas imitation of other kinds of movements progressively develops after 6-7 months of age. Even if she considered these early imitations as reflex, it is astonishing to realize that she identified as first imitative behaviors imitative responses to the "Aüsdruckbewe-gungen", i.e. facial gestures.

Finally, several anecdotal reports have accumulated during the last three decades of observation of early imitation occurrences (Brazelton &Young, 1964; Gardner & Gardner, 1970; Zazzo, 1957).

Current knowledge of early imitation has not progressed very much since 1928! Maratos' experiment (1973, 1982) marked the beginning of a new line of research in infancy but basically confirmed Guernsey's results. At 1 month, infants imitate a tongue protrusion movement, an opening–closing of the mouth, and a lateral head movement. Furthermore, imitation of the tongue protrusion movement disappears between 2 and 3 months, and that of the mouth opening-closing at around 3 months. But now, our American cousins, with their high technology and sensitive methods, have considerably complicated the situation! Some authors have argued in favor of the existence of early imitation ability and have extended the repertoire of facial movements that very young infants are able to reproduce: lip protrusion at 2-3 weeks (Meltzoff & Moore, 1977), facial expressions of sadness, surprise and happiness at less than 1 week (Field, et al., 1982), eye blink and cheek movement at 2 months (Fontaine, 1982), opening-closing of the eye within three-quarters of an hour of birth (Kugiumutzakis, 1985a, 1985b). On the other hand, others have denied that young infants can imitate facial movements, after failing to replicate Meltzoff and Moore's results (Hayes &Watson, 1981; McKenzie & Over, 1983). Lewis and Wolan-Sullivan (1985) did not observe any facial imitation either at 2 weeks, 3 months or 6 months. Finally, whereas Abravanel and Sigafoos (1984) described a very restricted capacity to imitate the tongue protrusion movement, the specificity of this task may be put in doubt by Jacobson's (1979) finding that tongue protrusion is elicited no more frequently by a person's protruding tongue than by a pen moving toward and away from the infant's mouth.

Despite some inconsistencies, then, (see Vinter, 1985, for further discussion), these studies attest quite well to the capacity of newly born infants to reproduce at least two facial movements: that of tongue protrusion and that of mouth opening-closing. It is worth mentioning that one cannot conceive of imitation without postulating the existence of some selective perceptuo-motor linkage, which integrates different sensory modalities and permits an identification of some facial features. Further research is needed to confirm the neonate's ability either to imitate facial expressions or to selectively imitate facial gestures other than tongue protrusion or mouth opening and closing.

Up to now, we have little understanding of which features or combination of features infants respond to when they imitate. Jacobson's study suggests that properties of shape and movement are fundamental to the elicitation of imitative responses, which has been confirmed by Vinter (1986) with regard to the role of movement in neonatal imitation. Infants exposed to kinetic (dynamic) facial and manual actions emitted higher rates of the modeled acts in the interval during which it was modeled than in any other condition. In contrast, infants exposed to the static

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tive reproduction of the modeled behavior; they did, however, spend relatively more time visually fixating both the facial and the manual positions. This suggests that, at this age, a static face is more likely to elicit visual exploration than imitation, and that the role of movement may be a fundamental criterion that differentiates early imitation from late imitation.

It would also be interesting to know to what extent the "faceness" of the model plays a role in this phenomenon, and whether, for instance, the presence of features such as the eyes or the nose are also important in eliciting imitation of mouth movements.

The fact that newborn infants can reproduce mouth movements such as tongue protrusion and mouth opening-closing may appear to contradict data on how they process the features of the face. It has in fact been claimed that infants do not initially discriminate internal fea-tures of the face. Studies of infant eye movements show that 1-month-olds examine only the external contours of a real face (hairline, chin, ear) whereas 2-month-olds also scan the internal features, particularly the eye region (Maurer & Salapatek, 1976; Hainline, 1978). But this "externality effect", which is also observed with a compound figure, appears to be influenced by at least three parameters: the size of the internal figure, its salience, and the presence of relative motion (Banks & Salapatek, 1983; Milewski, 1976). This last parameter is of interest to us here. Bushnell (1979) showed that infants at 1 month discriminate changes of the internal figure when it flickers or is moved within the external figure, but not when both move together or when the component is static. In the imitation studies, an "internal feature" of the face (the mouth) is in fact in motion. Thus there is sufficient evidence to support the view that infants in the very first month of life are able to process visual information related to internal features of the face, in particular to mouth movement (if not to a still mouth).

Interestingly, the developmental studies of early facial imitation all report a gradual disappearance of this ability during the first months of life (Dunkeld, 1978; Maratos, 1973; Fontaine, 1982; Vinter, 1985). Imitation of the tongue protrusion movement is no longer observed at 3 months, that of mouth opening-closing disappears at around 3-4 months (Vinter, 1985). Also Jacobson (1979) who did not agree on the existence of a selective imitative capacity at birth since "imitative" movements are equally elicited by inanimate models sharing some characteristics with human models, observed a "disappearance" of matching responses between the inanimate model's movements and the infant's movements after 2 months. Simultaneously, some authors described the progressive appearance of a new imitative ability, essentially related to vocal imitation, in the period between 2 and 6-8 months (Papousek & Papousek, 1979, 1982; Kugiumutzakis, 1985b).

In relation to this later period of development, Razran (1971) quoted a very interesting Russian study of imitation carried out by Lyakh (1968a and b). In this experiment, infants aged from 2 to 8 months are confronted with an adult performing two mouth movements: one corresponds to the articulatory movement typical of the vowel "a" (similar to a mouth opening-closing), and the other of the vowel "o" (close to a lip protrusion movement), but both were produced without sound. The author reported that imitation of these movements is more frequent in the 2-to 4-months age group than in the 4-to 8-months age group, but does nevertheless exist in the latter group.

The loss of selective imitative responses corresponds with the appearance of new selective reactions to the modeled acts, either facial or manual. As far as facial imitation is concerned, several authors report that the infant tries to reach for the experimenter's tongue (Fontaine, 1983; Kugiumutzakis, 1985b).

Social reactions also are obtained. Vinter (1985) has shown that 3-month-olds smile and vocalize in response to the facial model (tongue protrusion), but look at their own hand in response to the manual model. She has called these reactions "analogical imitations" in the sense that, to some extent, the infant takes into consideration the body part involved in the modeled act. These reactions also make clear that during the first months of life, the infant seems to be involved in a process of (re)discovery or (re)identification of his body parts. This process is necessary for an intentional imitative ability to occur.

The way in which facial imitation develops later in childhood has been well analyzed by Piaget (1946), and confirmed by Uzgiris & Hunt (1975). Successful imitation of mouth movements (such as mouth opening-closing or tongue protrusion) seems to appear again between 9 and 14 months. In this period, there seems to be great interindividual variability in the order of acquisition of these facial imitative responses.

Pre-speech movements

With regard to language as both auditory and visual input, some astonishing kinds of imitative behavior have been described.

With regard to language as both auditory and visual input, some astonishing kinds of imitative behavior have been described. Condon & Sander (1974) showed that a precise temporal and rhythmical synchrony can be established between the infant's movements (arm-hand) and adult speech when talking to the infant. They showed that arm displacement by the infant coincided with syllable or word pronouncement by the adult. Furthermore, infants tend to move when the speech sounds are modified and keep their posture constant all the time that a speech sound is produced. According to the authors, this ability to synchronize one's own movements with heard speech units may account for the relationships between articulation and audition, in particular the fact that speech stream is perceived in discrete units. At the least, it suggests a general sensitivity to spoken syllable structure in the prelingual child. Infants aged 2-4 months also seem to mimic lip and tongue movements associated with speech articulations when stimulated to communicate with an adult partner. These movements have been called "pre-speech" movements (Trevarthen, 1974, 1984), and are often produced without vocalisations. If the imitative nature of such movements could be established, this behavior might show that young infants are sensitive to visual information derived from adult mouth movements when talking. Sensitivity of infants as young as 2 months to the mother's facial expressions as a whole (not just the mouth) has been noted by several authors (see Schaffer, 1977; Trevarthen, 1980). The more often the mother smiles, vocalizes, looks at her infant, the more frequent are infant's smiles, vocalizations, positive

orientations to the mother. In complementary fashion, a blank or silent mother's face elicits negative reactions or responses of avoidance from her infant.

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We lack the experimental studies that would give us a real understanding of these phenomena. We need to know to what aspects of adult speech these pre-speech movements are related, for example, whether they can be elicited by hearing or vision alone. Similarly, it may be important to establish whether responsiveness of the infant to the mother's facial expressions is based upon a wholistic perception in which kinetic information is essential (the infant would react by a moving face to a moving face) or is more dependent on static face features (the infant may smile at a wide mouth for instance). In addition, indications about the development of this ability to mimic speech activity are required; in particular the age at which it appears and whether or not its development follows a course similar to that of early imitation.

Lipreading ability and auditory-visual integration

A large number of experiments have been dedicated to the study of how infants can integrate auditory with visual information. Some of them are specifically related to speech perception (experiments on lip reading for instance– see Campbell, 1986, for a review), others are aimed at a more general understanding of how infants conceive of the relationships between face and voice (see Butterworth, 1980, for a review).

Aronson & Rosenbloom (1971) have shown that 1-month-old infants are distressed when confronted with a voice coming from a spatial location different than that of the face, as if they expected face and voice to share a common location. Other authors described other kinds of behavior in this situation of spatial discordance. According to Castillo & Butterworth (1981), neonates systematically orient to the face and thus seem to "resolve" the spatial conflict in favor of vision. Vinter et al. (1984) showed that neonates orient more frequently face after having turned their head toward the voice than toward the voice after the face has been the first preferred vice-versa. These studies demonstrate that infants younger than 1 month are sensitive to a spatial discordance between vision and audition. But so far, data are lacking in order to know to what extent this sensitivity may be specific to face perception, in contrast to perception of any audible object, as far as very young infants are concerned. At around 3-4 months, it seems established that a similar sensitivity can be observed both with human faces and inanimate displays (see Spelke, 1976, 1985).

An intriguing developmental course has been revealed both with regard to the ability to integrate vision and audition from face perception and to orient toward a voice (see Muir & Clifton, 1985, for further discussion). Muir et al. (1979) found that at around 2 months, a response of orientation to sound is very difficult to elicit, whereas it is much easier to obtain either at birth or at 3-4 months. Similarly, Vinter et al. (1984) described a U-shaped development in infant's response to spatial discordance between face and voice. In particular, two-month-olds did not seem to notice when face and voice were displaced, since they rarely, if ever, turn their head in the direction of the voice. This change in responsivity at 2 months recalls a similar failure to react which was noted in the imitation studies (see above).

While attention to a single face or voice is one way to study sensitivity to their concordance, a preferential looking paradigm can provide more detailed information. In such studies, the experimental procedure consists of neighbouring presentation of two films (or slides) with a central soundtrack that correctly matchs one of the films. Relative durations of the infant's looking at the two films are measured. Confronted with the mother's face and a strange female face, 8-month-olds look at the mother when the central sound corresponds to the mother's voice, at the stranger when the sound emits her voice, whereas 5-month-olds do not look preferentially to one of the faces according to the voice heard (Cohen, 1974). This study suggests that it is rather late in development that infants are sensitive to shared identity of face and voice. But other experiments seem to demonstrate that such an ability exists earlier. In Spelke & Owsley's study (1979), the mother's face was contrasted to the father's face whereas either the mother's voice or the father's voice was centrally emitted. Three-month-olds are able to associate the face with the voice correctly in this situation. But it is true that mother and father are auditorally and visually more different than mother and female stranger. This difference in the degree of similarity of the two streams of information may account for the difference observed between Cohen's and Spelke & Owsley's studies. In sum, Spelke's research (1976; see Spelke, 1985, for a review) suggests that 3 or 4-month-olds are able to coordinate auditory and visual information correctly from very different displays, not uniquely from faces.

Infants can be shown to be aware of an even more precise concordance between face movements and voice. Dodd (1979) demonstrated that 10 to 16-week-old infants can detect that a voice is in or out-of-synchrony with respect to the mouth's movements. Spelke & Cortelyou (1981) confirmed that 3-month-olds look more at the face whose mouth movements are synchronized with the heard voice. Moreover 5-month-old infants look preferentially at the face that matches a heard voice in expressed emotion, rather than one that does not match (Walker, 1982).

From these studies, it may be inferred that what the face is saying can in some way be processed at an early age. Kuhl and Meltzoff's study (1982, 1984) is a first attempt to indicate how speech-specific such abilities may be. They first showed that 18 to 20–week–olds looked longer at the face whose lip movements matched either the heard vowel "a" or "i" than at the face which articulated the other vowel. They then asked whether this ability is due simply to the detection of temporal asynchronies between the onset and offset of acoustic input with lip opening and closing or is specific to the recognition of particular correspondences between a speech sound and its precise articulatory format. By removing the sound-spectral information from the same vowels "a" and "i" but preserving their temporal properties, these authors showed that purely temporal factors were insufficient to produce the preference patterns for seen and heard suggests that when infants distinguish lipread /a/ and /i/, they are sensitive to the acoustic correlates of these speech sounds. These authors conclude that speech is likely to be supramodally represented, i.e. that auditory and visual speech information are related to a common supramodal phonetic representation (see Studdert-Kennedy, 1983).

MacKain et al. (1983) also demonstrated a sensitivity of 5 to 6-month-old infants to auditory and visual correlates of speech structures. They showed that infants looked longer at a woman's face articulating CVCV syllables to which they were listening (e.g. "mama") than to the same woman repeating a synchronized competing CVCV ("lulu" in this case), but only when infants were looking at the video display on their right. They concluded that left hemisphere activation facilitated perception of auditory-visual speech correspondences, and argued for the existence of a left hemisphere perceptuo-motor mechanism.

There is considerable experimental evidence that young infants discriminate auditorilly presented phonemes and treat discriminably different members of the same vowel category as equivalent (Eimas et al., 1971; Kuhl, 1983). No similar categorization ability has yet been shown with respect to language as lipread visual input (but for a discussion of this notion of categorization, see Massaro & Cohen, 1983) . Yet it would be very interesting to investigate whether infants are able to differentiate visually discriminable phonemes categorically, i.e. phonemes that differ with respect to the place of articulation feature, when no auditory information is provided.

To investigate this issue further, it may be important to know if infants are subject to auditory-visual illusions as adults and children are. With regard to lipreading, two forms of illusion have been revealed in adults and children; one is often called the McGurk effect, the other the blend illusion (McGurk & MacDonald, 1976; MacDonald & McGurk, 1978; Dodd, 1977; Massaro, 1984, and see Massaro, this volume). Such an experiment is currently in progress (Dodd & Dennis, personal communication), and it should indicate the innate basis of lip reading ability.

The role of lipreading with regard to language acquisition has been explored by Dodd (1987), who reported that access to lipread information has an effect on some aspects of babbling (increase of the number of utterances containing consonants) in 9 to 12-month-old infants.

With regard to the question of how heard and seen speech are integrated, it is interesting to note that the candidate hypotheses are of the same kind as those suggested to account for gestural imitation. Dodd (1983) discussed three possible alternatives and argued in favor of the existence of a nonmodality specific phonological code, i.e. of a common code for processing auditory-visual as well as articulatory speech information from early infancy. Summerfield (1979) also argued that lipreading ability constitutes a convincing argument for information used is essentially provided by articulatory movements. This theoretical position corresponds to that of Spelke with regard to auditory-visual coordination, and more generally has to do with some basic Gibsonian principles in perception. In such a line of reasoning, it would be necessary to demonstrate that visual and articulatory speech perception processes are similar to those that govern auditory speech perception.

Gaze co-orientation between infant and adult

One specific facial act, gaze orientation, is often used by children and adults as a valid cue of the act of " referring", i.e. act by means of which we make use of words or gestures in order to communicate or share a particular knowledge or state of affair. Recent interest in the pragmatics of communication, in particular in the study of the pre-linguistic period as a preparatory period for linguistic communication, has led some authors to examine at what age infants are able to understand the adult's gaze direction (Bruner, 1975; Scaife & Bruner, 1975). The comprehension by infants of the uses of pointing as a referential gesture has also been studied within the same perspective (Bates et al., 1975; Pechman & Deutsch, 1982).

In natural settings the mother very often tracks the gaze of her infant and tries to establish in this way moments of gaze co-orientations (Collis & Schaffer, 1976). Scaife

& Bruner (1975) showed that the gaze direction of infants as young as 4 months can be influenced by the gaze direction of the adult. The role of different spatial indicators in determining this ability, such as landmarks located in the infant's environment, has been analyzed in infants in their first year of life (Butterworth & Cochran, 1980; Butterworth, 1982; Churcher & Scaife,1982; Lempers, 1976). It appears that at first the young infant has only a roughly differentiated notion of where his mother is looking, turning to look to one side only, and not precisely where the mother looks. More finely differentiated reactions are not apparent before 10 or 12 months, more or less at the same time that the hand pointing gesture begins to be used and understood. What is of interest is the fact that from around 3-4 months, infants are able to get information from eye direction whose meaning goes beyond the actual behavior and is related to interindividual communication.

Reflections in Relation to Speech Perception

Imitation, perception of facial gestures and lipreading

The reviewed data shows that the ability of young infants to encode face features and process facial information undergoes a complex development in the first year of life. Moreover , the data is contradictory at least at first glance. In brief, neonates and infants aged less than 2 months can imitate some facial gestures and expressions, they are sensitive to the fact that a face and a voice should share a common spatial location, and can mimic the lip movements of a speaking person. Movement of the seen face plays an important role in eliciting these performances. From a developmental point of view, two of these abilities, coordination between vision and audition imitation — "disappear" between 2 and 3 months to reappear later (at around 4 months for the former ability, 9-14 months for the latter). Other kinds of behavior, not specifically related to face perception, such as reaching, also "disappear" in the first months of life.

Different hypotheses can be suggested to account for such a developmental trend, focusing on changes in peripheral processes (as, for instance, an asychronical development between modifications of the weight of some body parts and of their muscular strengths, see Thelen & Fisher, 1982) or focusing on changes in central processes (Mounoud, 1979).

Our proposal is to radically differentiate between the neonatal level of behavioral organization, called sensori-motor organization, and the new behavioral organization, called perceptuo–motor organization, that develops progressively in the first two years of life. These organizations differ with regard to the code used to process incoming information (sensory versus perceptual code).

Our proposal (Mounoud &Vinter, 1981) is to radically differentiate between the neonatal level of behavioral organization, called sensori-motor organization, and the new behavioral organization, called perceptuo-motor organization, that develops progressively in the first two years of life (Mounoud, 1984; Vinter, 1986b). These organizations differ with regard to the code used to process incoming information (sensory versus perceptual code).

In this theory it is postulated that neonates possess an innate body representation (or schema), in which information is coded by means of the sensory code. They then construct new representations, a new body representation for instance, by means of the perceptual code. "Representation" or "schema" is defined as an internal organization of contents, of the different properties of objects, situations or events, i.e. as the result of a top–down process. It can also be seen as the result of information selection and information-processing processes. The term "code" is used to mean the set of formal operations or rules that transform or translate the information related to objects or actions. And a representation is understood as a translation of information by means of a particular code.

Within this framework, we claim that the perception of facial movements at birth is qualitatively different from the perception of facial movements appearing later (Vinter, et al., 1986). This is how we explain why neonates are able to process information coming from internal features of the face, as evidenced by the imitation ability, whereas other studies suggest that internal features of the lowerpart of the face are not discriminated before 4 months. In our view, imitation at birth is based on a sensorial coding of information, in which kinetic information is of prime importance, and which does not permit any facial movement to be produced in isolation. Mouth movements for instance are integrated in a more complex sequence in which head movements (and probably arm-hand movements) also intervene

(Vinter, 1985b). By contrast, the ability to perceive facial features demonstrated in a 3 to 4-month-old infant by scanning or preferential studies is based on a perceptual coding of facial information. With this code, movement is not a crucial determinant of feature detection. A specific facial movement can be reproduced in isolation, without other associated movement. Thus the same part of the face may be processed by different codes, and it may be that at the beginning of life, both processes can occur, which may explain some apparent contradictions in the literature. Within such a view, it is crucial to define precisely the specific elicitators of each code. This has yet to be done.

In relation to lipreading ability, we do not yet know whether or not it is present from birth, and we are also ignorant about how it develops. Sensitivity of infants to the integration between lip movements and the sound produced seems to be evident at around 4 months. Whatever its developmental course may be, it is intriguing that lip reading is present when imitation of facial movements has disappeared. More precisely, at the age when infants are able to match the lip movements that produces an "a" (i.e. more or less an opening closing of the mouth) with the sound "a", and moreover are able to produce the sound "a", spontaneously as well as in response to the same auditory input (occurences of vocal imitation are reported by Kuhl & Meltzoff's study), they are at the age when they seem to be unwilling or unable to imitate that movement of mouth opening-closing. By contrast, while some mouth imitation is present at birth (i.e. under 3 weeks of life), speech imitation as a visual-auditory input (i.e. mouth movements and sound) has not been reported*.

Campbell (1986) discusses another provocative contrast by pointing out that the age at which imitation of facial movements is no longer elicitable is precisely the age at

* Kugiumutzakis (1985a) mentioned some cases of imitation of the vowel "a" but without any analysis of the neonate's vocal emission, which appears very doubtful.

4-month-olds can be characterized by a complex behavioral panorama. They can discriminate acoustically different speech units, vocally imitate, lipread, but they no longer imitate a visually perceived mouth or lip movement.

which infants are very sensitive to auditory phonetic contrasts (Eimas et al., 1971). In short, to the extent that the data are reliable**, 4-month-olds can be characterized by a complex behavioral panorama. They can discriminate acoustically different speech units, vocally imitate, i.e. associate a heard sound with an articulatory movement, lipread, i.e. visually perceive that a particular lip shape goes together with a heard acoustic input, but they no longer imitate a visually perceived mouth or lip movement, i.e. produce an articulatory movement that conforms to the perceived model. Infants are about 10 to 14-months before they can again imitate a visually perceived mouth movement, while it seems established that lipreading occurs around 4 months earlier. Thus a dissociation at least partial and temporary between lipreading and imitation must be postulated.

These contrasts raise different fundamental questions which refer to the relationships between perception (auditory perception, visuo-auditory perception of speech), production (speech production, articulatory speech and nonspeech movements production) and imitation (of speech or nonspeech movements). Imitation constitutes a very particular ability since perception and production must closely interact for precise imitation to occur.

The question that arises now is, in what way does the ability to derive speech from seen faces depend on, and relate to, the various mouth imitative skills of the youngest infants, and the demonstrated sensitivities of slightly older ones.

It may first be argued that although both are closely linked to perception of facial movements and are based on intermodal coordination, lipreading ability and facial imitation do not share any common process. A basic

** Experiments on imitation of speech movements produced without associated sounds in comparison with vocal imitation are still needed for a valuable understanding of these questions. Moreover it would be interesting to know if infants of this age are able to visually discriminate different articulatory movements, for instance the visual form associated to the production of "ba" from that associated with "da" or "ga".

difference may be that differentiated face schema in which the mouth and its movements are represented is a necessary condition for imitation, but not for lipreading. If this is so, it is what infants at 4 months lack. Three-month-olds, who no longer reproduce a facial movement, do nevertheless react to such a movement in a specific way, by smiling and vocalizing, i.e. in the same manner that they re-spond to any human moving face. On the other hand, to a manual movement, they respond by looking at their own hand (Vinter, 1986). These reactions have been interpreted as demonstrating that the infant, at this age, is progressively discovering his body.

To what extent can we support the view that lipreading does not require the existence of an abstract face representation, through which one's own mouth may be conceived of as corresponding to another person's mouth? In fact, such close correspondence between one's own body and the body of another may not be necessary for lipreading to occur.

Within a different framework, Campbell (1986) also proposed that lipreading ability must be distinguished from other skills related to face perception. Campbell et al. (1986) showed a complete dissociation between face recognition and classification processes and lipreading in two unilaterally lesioned patients. They concluded that most aspects of lipreading are likely to be more related to language processes than to processing of non- linguistic properties of faces, and as a consequence are likely to be left-hemisphere lateralized.

A different distinction between lipreading and imitation may reflect their different relationship with perception and action. Lipreading may not require an integration between perception and production, i.e. between vision and proprioception (articulatory processes). Lipreading ability would be essentially a perceptual act. This hypothesis does not fit one interpretation of the Motor Theory of speech perception (Liberman & Studdert-Kennedy, 1977), which has been suggested by MacDonald & McGurk (1978) to account for audition-vision fusion "illusions". Within this theory, lipread information is processed in a code derived from articulatory feedback, and thus speech perception cannot be dissociated from speech production.

But such a theory cannot apparently easily account for the differences between lipreading and imitation of facial movements on which we are focusing, since these theorists also reject any idea of mediated perception through internal schemas. Lipreading and imitation could not thus differ with respect to the necessary presence of a differentiated face schema for the latter. By contrast, Straight (1980) favors a theory that would distinguish different mechanisms and different representational basis for speech perception processes on one hand and speech production processes on the other. He suggested a distinction between auditory phonological processes (we could add visual phonological processes) and articulatory phonological processes, imitation being an essential mechanism for the latter processes. Within such a framework, we expect to observe a dissociation during development between lipreading ability as a perceptual process and imitation of mouth movement as a productive process.

Speech perception within a developmental and cognitive model.

In conclusion we will discuss briefly the relationships between face perception processes and visual speech perception within a developmental and cognitive perspective. An account of lipreading ability requires an understanding of how heard and seen speech can be integrated, and we may ask ourselves to what extent speech may be a special phenomenon, i.e. to what extent such auditory-visual integration is special with regard to similar intermodal coordinations governing object perception. In relation to somewhat different problems, we have argued elsewhere that speech constitutes a cognitive system among others, no more specific than others (Mounoud, 1986; Vinter, 1987). This means that the development of lipreading might be described by the same cognitive model that is used to understand the development of face perception (Vinter et al., 1986).

Different hypotheses about visual-auditory speech integration can be generated from this model (see Mounoud (1984) or Vinter (1986b) for a presentation of the model):

- integration between seen and heard speech in the neonatal period (0-1 month) should be based on physical, i.e. acoustic and visual properties of heard speech and seen faces and not on more cognitively mediated perceptual properties such as phonemic categorisation;

- this ability may follow a U-shaped development, between birth and 6 or 8 months, i.e. may disappear sometime after the first month of life, and reappear later;
- when infants are again sensitive to seen and heard speech in the middle of the first year, this visual-auditory speech integration is likely to be qualitatively different from the form present at birth, and is possibly based on spectral information, as demonstrated by Kuhl & Meltzoff (1984). It means that an experiment such as Kuhl & Meltzoff carried out with infants aged less than 1 month may demonstrate their sensitivity to sound-face synchrony, but *not* to specific vowels (not on the basis of spectral information);
- as far as a complex visual-auditory speech integration such as the McGurk effect requires that the phonemes are perceived as interrelated units, and not as independent speech units (Massaro's model argues against this assumption), we might not expect to observe it before the end of the first year or the second year of life.

If such hypotheses can be empirically validated, it may be possible to sustain the idea of the nonspecificity of speech perception processes, at least in infancy and with regard to processing of visual-auditory information.

Generally, we argue that lipreading ability, as a particular speech perception skill, qualitatively changes during the first years of life, and its relationships with imitation or other speech perception processes may also vary during development. With regard to speech perception, MacKain (1987) discusses in a very interesting way three theoretical alternatives that are currently being taken up by psycholinguists:

- the phonetic view, which claims that infants perceive phonetic structures, i.e. are sensitive to the abstract phonetic features of phonetic segments (Eimas, 1975);
- the auditory view, which postulates the existence of an auditory mechanism, not specific to human speech but common to all mammals, and which considers that infants are sensitive to the acoustic attributes that distinguish phonetic features without having an abstract phonetic code at their disposal (Stevens, 1975). We think that this view may very well be extended to visual information related to speech: infants may recognize visual speech patterns through a general mechanism of visual pattern recognition. Both sensory information sources may then be integrated on the basis of the principles described by Massaro & Cohen (1983) for instance;

Generally, we argue that lipreading ability, as a particular speech perception skill, qualitatively changes during the first years of life, and its relationships with imitation or other speech perception processes may also vary during development.

- the perceptuo-motor view, which closely links speech perception processes with the motor activity of speech production (articulation) and thus suggests that infants are sensitive to the phonetic articulatory information in the speech spectrum, i.e. that auditory and visual speech information provide directly information about the underlying articulatory gestures (Studdert-Kennedy, 1986).

To be able to argue for or against any one of these views, which suggest different levels of speech processing, it appears essential to know the unit of perception with which infants process speech (e.g. syllable, word, phoneme), and whether or not this unit changes with development.

Such questions are in no way language-specific. We are confronted with exactly the same questions when trying to analyze the development of a psychomotor ability, such as reaching (Vinter, in press *a*). We need to briefly develop this point before going back to speech perception. With regard to reaching (see Mounoud, 1983), we have suggested that three different levels of processing (or "codes") can be distinguished between birth and 2 years, and which are successively predominant without ever disappearing: a sensory level (predominant from birth until around 4 months), a perceptual level (from 1 month to 24 months), and a conceptual level (from 16 to 18 months until 10 years). The crucial dimension of differentiation between the sensory and perceptual levels is related to the "referential relationship" between object, subject and meaning; this relationship is necessarily undifferentiated at the sensory level (for example, incoming information cannot be related to the object's

properties by the subject) but is differentiated at the perceptual level. Moreover, the unit of perception (the "segmentation problem") evolves with development and always through the same steps, whatever the level of processing:
1. uncoordinated and partial segments;
2. wholistic and nondecomposable units; 3. units partially and then completely decomposable in their constitutive segments.

Within this framework, it maybe suggested that:

- speech is initially (at the beginning of life) processed at a sensory level, i.e. at the acoustic auditory or auditory-visual level. Infants can discriminate auditory speech contrasts, independently of any segmentation specific to their language, without any meaning associated to these sound contrasts. Auditory perception maybe categorical, as held by Eimas (1975), without involving the existence of a phonetic code.

- speech will then be progressively processed at a perceptual level, and different steps in the processed units of perception can be distinguished. The kind of speech processing postulated by the perceptuomotor view necessarily belongs to this level, because of the implicit assumption of a differentiated subject-object (articulation-perceptual speech information) relationship. The auditory view may also belong to this level, for incoming information can be processed at a sensory as well as at a perceptual level (i.e. without or with the ability to refer information to the object's properties).

- the *syllable*, which can be understood as an elementary and independent unit (in contrast to phonemes, whose definitions are based on their interrelationships), may be the first speech unit of the perceptual level. Visuo-auditory information may very well specify an articulatory pattern, although the processed unit is not the word but a syllable (see MacKain, who argues that the perceptuomotor view requires a wholistic unit such as the word), but in no way is this specification "direct" in our opinion. An internal representation of the incoming auditory-visual information must be postulated to account for speech perception and speech production. Language pathology shows cases in which neither perception nor

production of speech stimuli (acoustic discrimination versus spontaneous production) are distorted when assessed independently, but are disturbed when they must be integrated.

- then, the *word* is likely to be the unit of speech perception (by around 9-12 months). Meaning conveyed by the speech sound contrasts plays a crucial role in determining specific auditory-visual-articulatory associations.

- finally, the unit at which speech is processed may be *phonemic*. We fully agree with MacKain (1987) that the knowledge infants acquire about phonetic segments results from analysis subsequent to their sensitivity to the whole word. Mounoud (1986) described a similar transition from syllabic to phonemic segmentation in reading.

The various assertions stated above, if valid, make it clear that speech perception processes are not developmentally different from general object perception processes. Moreover, the different theoretical views of speech perception should not be considered as competing alternatives. They are all valid, depending on the developmental step under consideration. The fact that speech perception processes have mainly been studied in adults is probably responsible for this state of "competition" between theories. We think that detailed analysis of the speech stimuli and of the experimental situations should reveal that, in adults too, qualitatively different levels of processing and different units of speech perception can be contemporaneously observed.

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Eimas, P.D. 1975. Auditory and phonetic coding of the cues for speech: Discrimination of the (r-1) distinction by young infants. *Perception & Psychophysics,* 18, 341–347.

Eimas, P.D., Siqueland, E.R., Jusczyk, P., Vigorito, J. 1971. Speech perception in infants. *Science,* 171, 303–306.

Fantz, R. 1966. Pattern discrimination and selective attention as determinants of perceptual development from birth. In A. Kidd and J. Rivoire (Eds.). *Perceptual development in children.* New York: International University Press.

Fantz, R., Fagan, J.F. 1975. Visual attention to size and number of pattern details by term and preterm infants during the first six months. *Child Development,* 16, 3–18.

Fantz, R., Fagan, J.F., Miranda, S.B. 1975. Early visual selectivity. In L.B. Cohen & P. Salapatek (Eds.). *Infant perception: from sensation to cognition.* Vol. 1. N.Y.: Academic Press.

Field, T.M., Woodson, R., Greenberg, R., Cohen, D. 1982. Discrimination and imitation of facial expressions by neonates. *Science,* 218, 179–182.

Fontaine, R. 1982. Conditions d'évocation des conduites imitatives chez l'enfant de 0 à 6 mois. *Unpublished Ph.D. Thesis of The University of Paris.*

Gardner, J., Gardner, H. 1970. A note on selective imitation by a six-week-old infant. *Child Development,* 41, 1209–1211.

Goren, C.C., Sarty, M., Wy, P.Y.K. 1975. Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics,* 56, 544–549.

Guernsey, M. 1928. Eine genetische Studie über Nachahmung. *Zeitschrift für Psychologie,* 107, 105–178.

Hainline, L. 1978. Developmental changes in the scanning of face and non-face patterns by infants. *Journal of Experimental Child Psychology,* 25, 90–115.

Hayes, L.A., Watson, J.S. 1981. Neonatal imitation: fact or artifact? *Developmental Psychology,* 17, 655–660.

Jacobson, S.W. l979. Matching behavior in the young infant. *Child Development,* 50, 425–430.

Karmel, B.Z. 1969. The effect of age, complexity and amount of contour on pattern preferences in human infants. *Journal of Experimental Child Psychology,* 7, 339–354.

Koepke, J.E., Hamm, M., Legerstee, M. 1983. Neonatal imitation: two failures to replicate. *Infant Behavior and Development,* 6, 97-102.

Kugiumutzakis, J. 1985a. Imitation in newborns 10-45 minutes old. *Uppsala Psychological Reports,* 376, 1–16.

Kugiumutzakis, J. 1985b. Development of imitation during the first six months of life. *Uppsala Psychological Reports,* 377, 1–21.

Kuhl, P.K. 1983. Perception of auditory equivalence classes for speech in early infancy. Infant Behavior and Development, 6, 263–285.

Kuhl, P.K., Meltzoff, A.N. 1982. The bimodal perception of speech in infancy. *Science,* 218, 1138–1141.

Kuhl, P.K., Meltzoff, A.N. 1984. The intermodal representation of speech in infants. *Infant Behavior and Development,* 7, 361–381.

Lempers, J.M. 1976. Production of pointing, comprehension of pointing, and understanding of looking behavior in young children. *Unpublished Ph.D. Thesis of the University of Minnesota.*

Lewis, M., Wolan-Sullivan, M. 1985. Imitation in the first six months of life. *Merrill Palmer Quarterly,* 31, 315–333.

Liberman, A.M., Studdert-Kennedy, M. 1977. Phonetic Perception. In R. Held, H. Leibowitz & H.L. Teuber (Eds.). *Handbook of sensory physiology. Vol. 8.* Heilderberg: Springer-Verlag.

Lyakh, G.S. 1968a. Articulatory and auditory mimicry in the first months of life (in Russian). *Zhurnal Vysshey Nervnoy Deyatel'nosti imeni I.P. Pavlova,* 18, 831–835.

Lyakh, G.S. 1968b. Characteristics of conditioned connections in mimo-articulatory and auditory components of speech stimuli in the first year of life (in Russian). *Zurnal Vysshey Nervnoy Deyatel'nosti imeni I.P. Pavlova,* 18, 1069–1071.

MacDonald, J., McGurk, H. 1978. Visual preferences of speech perception processes. *Perception & Psychophysics,* 6, 230–245.

McGurk, H., Lewis, M. 1974. Space perception in early infancy: perception within a common auditory–visual space? *Science,* 186, 649–650.

McGurk, H., MacDonald, J. 1976. Hearing lips and seeing voices. *Nature,* 264, 746–748.

McGurk, H., Turnure, C., Creighton, S.J. 1977. Auditory-visual coordination in neonates. *Child Development,* 48, 138–143.

MacKain, K.S. 1987. Filling the gap between speech and language. In M.D. Smith, J.L. Locke (Eds.). *The emergent lexicon: the child's acquisition of a linguistic vocabulary.* N.Y.: Academic Press.

MacKain, K.S., Studdert-Kennedy. M., Spieker, S., Stern, D.S. 1983. Infant intermodal speech perception is a left-hemisphere function. *Science,* 219, 1347–1349.

McKenzie, B., Over, R. 1983. Young infants fail to imitate facial and manual gestures. *Infant Behavior and Development,* 6, 85–89.

Maratos, 0. 1973. The origin and the development of imitation during the first six months of life. *Unpublished Doctoral Dissertation of the University of Geneva.*

Maratos, 0. 1982. Trends in the development of imitation in infancy. In T.G. Bever (Ed.). *Regressions in Mental Development: Basic phenomena and theories.* Hillsdale: Lawrence Erlbaum.

Marq, E., Freeman, D.N., Peltzman, P., Goldstein, P.J. 1976. Visual acuity development in human infants: evoked potentials measurements. *Investigative Ophthalmology in Visual Sciences,* 15, 150–153.

Massaro, D.W. 1984. Children's perception of visual and auditory speech. *Child Development,* 55, 1777–1788.

Massaro, D.W., Cohen, M.M. 1983. Evaluation and integration of visual and auditory information in speech perception. *Journal of Experimental Psychology: Human perception and performance,* 9, 753–771.

Maurer, D., Salapatek, P. 1976. Developmental changes in the scanning of faces by young infants. *Child Development,* 47, 523–527.

Meltzoff, A.N., Moore, K.M. 1977. Imitation of facial and manual gestures by human neonates. *Science,* 198, 75–78.

Meltzoff, A.N., Moore, K.M. 1982. The origins of imitation in infancy: paradigm, phenomena, and theories. In L.P. Lipsitt & C.K.Rovee-Collier (Eds.). *Advances in Infancy research.* Norwood: Ablex, 263–299.

Milewski, A. 1976. Infants' discrimination of internal and external pat-tern elements. *Journal of Experimental Child Psychology,* 22, 229–246.

Mounoud, P. 1979. Développement cognitif: construction de structures nouvelles ou construction d'organisations internes. *Bulletin de Psychologie,* 36, 107–118.

Mounoud, P. 1983. L'évolution des conduites de préhension comme illustration d'un modèle de développement. In S. de Schonen (Ed.). *Le développement dans la première année de la vie.* Paris: PUF.

Mounoud, P. 1984. A point of view on ontogeny. *Human development,* 27, 329–334.

Mounoud, P. 1986. Similarities between developmental sequences at different age periods. In I. Lewin (Ed.). *Stage and Structure.* Norwood: Ablex, 40-58.

Mounoud, P., Vinter, A. 1981. Representation and sensori-motor development. In G. Butterworth (Ed.), *Infancy and Epistimology.* Brighton: Harvester Press, 200–235.

Muir, D., Clifton, R.K. 1985. Infants' orientation to the location of sound sources. In G. Gottlieb & N.A. Krasnegor (Eds.). *Measurement of audition and vision in the first year of postnatal life.* Norwood: Ablex, 171–194.

Muir, D., Abraham, W., Forbes, B., Harris, L. 1979. The ontogenesis of an auditory localization response from birth to four months of age. *Canadian Journal of Psychology,* 33, 320–333.

Papousek, H., Papousek, M. 1979. Early ontogeny of human social interaction: its biological roots and social dimensions. In P. von Cranach, K. Foppa, W. Loprnies, D. Plooj (Eds.). *Human Ethology.* Cambridge: Cambridge University Press.

Papousek, H., Papousek, M. 1982. Vocal imitation in mother-infant dialogue. *Paper presented at the International Conference of infant studies,* Austin.

Pechman, T., Deutsch, W. 1982. The development of verbal and non-verbal devices for reference. *Journal of Experimental Child Psychology,* 34, 330–341.

Piaget, J. 1945. *La formation du symbole chez l'enfant.* Neûchatel et Paris: Delachaux et Niestlé.

Razran, G. 1971. *Mind in evolution, an East-West synthesis of learned behavior and cognition.* Boston: Houghton-Mifflin.

Salapatek, P. 1975. Pattern perception in early infancy. In L.Cohen & P. Salapatek (Eds.). *Infant perception.* N.Y.: Academic Press.

Scaife, M., Bruner, J. 1975. The capacity of joint visual attention in the infant. *Nature,* 253, 265–266.

Spelke, E.S. 1976. Infants' intermodal perception of events. *Cognitive Psychology,* 8, 553–560.

Spelke, E.S. 1985. Preferential looking methods as tools for the study of cognition in infancy. In G. Gottlieb & N.A. Krasnegor (Eds.). *Measurement of audition and vision in the first year of postnatal life.* Norwood: Ablex, 31–52.

Spelke, E.S., Cortelyou, A. 1981. Perceptual aspects of social knowing: looking and listening in infancy. In M.E. Lamb & L.R. Sherrod (Eds.). *Infant social cognition.* Hillsdale, N.J.: Erlbaum.

Spelke, E.S., Owsley, C.J. 1979. Intermodal exploration and perceptual knowledge in infancy. *Infant Behavior and Development, 2,* 13–28.

Stevens, K.N. 1975. The potential role of property detectors in the perception of consonants. In G. Fant & M.A.Tatham (Eds.). *Auditory analysis and perception of speech.* N.Y.: Academic Press.

Studdert-Kennedy M. 1983. On learning to speak. *Human Neurobiology, 2,* 191–195.

Studdert-Kennedy, M. 1986. Sources of variability in early speech development. In J.S. Perkell & D.H. Klatt (Eds.). *Invariance and variability of speech processes.* Hillsdale, N.J.: Erlbaum.

Straight, H.S. 1980. Auditory versus articulatory phonological processes and their development in children. In G.H. Yani-Komshian, J. F. Kavanagh & C.A. Ferguson (Eds.). *Child Phonology. Vol. 1.* N.Y.: Academic Press, 43–71.

Summerfield, 0. 1979. Use of visual information for phonetic perception. *Phonetica, 36,* 314–331.

Thelen, E., Fisher, D.M. 1982. Newborn stepping: an explanation for a "disappearing" reflex. *Developmental Psychology, 18,* 760–775.

Trevarthen, C. 1974. The psychobiology of speech development. In E.H. Lenneberg (Ed.). *Language and Brain: Developmental aspects.* Boston: Neurosciences Research Program.

Trevarthen, C. 1979. Communication and cooperation in early infancy: a description of primary intersubjectivity. In M. Bullowa (Ed.). *Before Speech: the beginning of interpersonal communication.* Cambridge: Cambridge University Press, 321–347.

Trevarthen, C. 1980. The foundations of intersubjectivity: Development of interpersonal and cooperative understanding in infants. In D. R. Olson (Ed.). *The social foundation of language and thought.* N.Y.: Norton.

Trevarthen, C. 1982. Basic patterns of psychogenetic change in infancy. In T.G. Bever (Ed.). *Regressions in mental development: basic phenomena and theories.* Hillsdale, N.J.: Erlbaum, 7–46.

Uzgiris, I.C., Hunt, J. 1975. *Assessment in infancy.* Urbana, Ill: University of Illinois Press.

Vinter, A. 1985. *L'imitation chez le nouveau-né.* Paris and Neuchatel: Delachaux and Niestlé.

Vinter, A. 1986a. The role of movement in eliciting early imitations. *Child Development, 57,* 66–71.

Vinter, A. 1986b. A developmental perspective on behavioral determinants. *Acta Psychologica,* 63, 337–363.

Vinter, A. 1987. Les fonctions de représentation et de communication dans les conduites sensori-motrices. In J. Piaget, P. Mounoud & J.P. Bronckart (Eds.). *La Psychologie.* Encyclopédie La Pléiade, Paris: Gallimard.

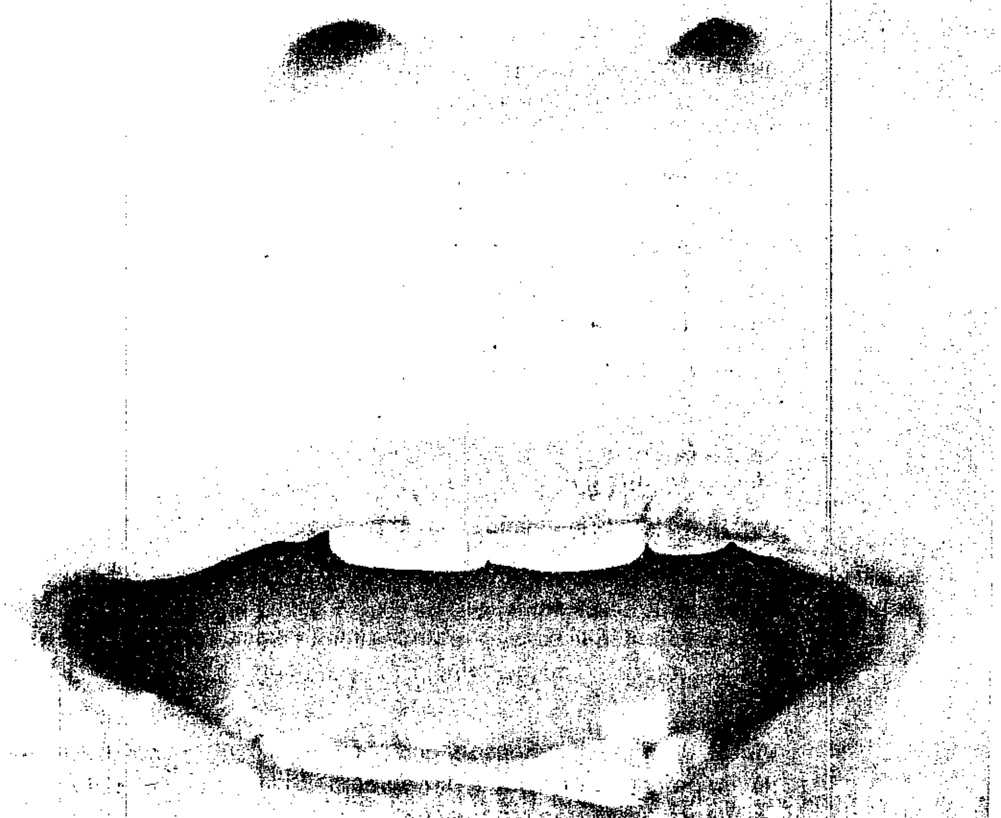
Vinter, A. in press *a.* Sensory and perceptual control of action in early development. In W. Prinz & 0. Neuman, (Eds.). *Perception and Action relationships: Current approaches.*

Vinter, A., Lanares, J., & Mounoud, P. 1986. Development of face perception. *Reports of the Perception and Action Research Group of The Bielefeld University.* # 114.

Vinter, A., de Nobili, G.L., Pelligrinetti, G., & Cioni, G. 1986. Auditory–visual coordination: does it imply an external world for the newborn? *Cahiers de Psychologie Cognitive,* 4, 309–322.

Walker, A.S. 1982. Intermodal perception of expressive behaviors by human infants. *Journal of Experimental Child Psychology,* 33, 516–535.

Zazzo, R. 1957. Le problème de l'imitation précoce chez le nouveau-né. *Enfance,* 10, 135–142.



Reading the Speech of Digital Lips

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