Infancy Studies Come of Age:

Jacques Mehler's Influence on the Importance of Perinatal Experience

for Early Language Learning

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Abstract

In this paper, we pay homage to Jacques Mehler's empirical and theoretical contributions to the field of infancy studies. We focus on studies of the ability of the human fetus and newborn to attend to, learn from, and remember aspects of the environment, in particular the linguistic environment, as a part of an essential dynamic system of early influence. We provide a selective review of Mehler's and others' studies that examined the perinatal period and helped to clarify the earliest skills and predilections that infants bring to the task of language learning. We then highlight findings on newborns' perceptual skills and biases that motivated a shift in researchers' focus to fetal learning to better understand the role of the maternal voice in guiding newborns' speech perception. Finally, we point to the inspiration drawn from these perinatal approaches to more full-scale empirical treatments of how prenatal experience and behavior have come to be recognized as essential underpinnings to the earliest mental architectures of human cognition.

Introduction

Jacques Mehler published his first paper in 1963 (Mehler, 1963). His earliest published work examined sentence processing in adults using free recall (Mehler, 1963; Mehler & Carey, 1967), eye tracking (Mehler, Bever, & Carey, 1967), and reaction time judgments of sentence veracity (Carey, Mehler, & Bever, 1970; Mehler & Carey, 1968). His first work with children soon followed, focusing on young children's ability to use logical operations to compute quantities in simple number conservation tasks. Mehler and Bever (1967) reported in *Science* that 2-year-olds seemed to conserve quantity in arrays of pellets more reliably than did 3-year-olds, with performance subsequently improving again by age 4. With arrays of candies, however, children at the intermediate age were better at conserving. These results were taken as evidence for an innate capacity to conserve, with the failure to conserve at age 3 described as temporary and due to an overreliance on perceptual strategies to determine quantity. This led to an exchange with Piaget (also in *Science*) in which the merits of nativist vs. empiricist views of cognitive development were debated (Bever, Mehler, & Epstein, 1968; Mehler & Bever, 1967; Piaget, 1968).

This interesting discussion is an early elucidation of the "competence-performance" distinction that has animated much cognitive development research, including studies of infant cognition. That is, under given task contexts, failures to perform are often taken as evidence for immaturity and/or lack of reasoning or skill. But changing task demands or increasing motivation can often lead to important insights into what young infants and children know and understand about the world around them. Jacques Mehler often argued passionately for the nature of the human infant that he saw as innately endowed, particularly with respect to language learning. Ironically, his dedication to finding experimental means to probe the mind of the young infant and fetus led to some of the most important developmental discoveries of our time in terms of what is now called “transnatal continuity theory” (Hopkins & Johnson, 2005). Mehler was not a proponent of transnatal continuity theory, yet the work he and others performed in exploring the capacities of the newborn infant for processing language encouraged others to examine ties to fetal experience. In other words, the insights gleaned from Mehler’s work on newborns opened the door to a progressive view of late-term prenatal experiences forging a path toward newborn infants’ perceptual and cognitive organization that remains in place today.

For example, influential studies by Mehler and his students examined infants’ responses to voices, in particular their preferences for specific individuals (Mehler, Bertoncini, Barriere, & Jassik-Gerschenfeld, 1978), syllables (Bertoncini & Mehler, 1981; Mehler, 1981), and phonemes (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987). Mehler’s interest in perinatal speech perception was an abiding feature of his work, extending more recently into investigations of newborns’ and young infants’ discrimination of abstract rules (Gervain, Macagno, Cogoi, Peña, & Mehler, 2008; Kovács & Mehler, 2009), statistical, positional, and prosodic patterns (Fló et al., 2018; Hochmann, Langus, & Mehler, 2016), and consonant and vowel sounds (Hochmann, Benavides-Varela, Fló, Nespor, & Mehler, 2018) in continuous speech.

Emerging within the time of the “poverty of the stimulus” argument (Chomsky, 1965, 1980), Mehler encouraged and enabled himself and others to ask questions about early experiences and how they could bias young infants’ speech perception toward the native language, examining language rhythm, voice recognition, vowel perception, prosody, neurophysiological priming, and hemispheric specialization. Although Mehler remained an ardent defender of innate cognitive abilities that guide infants’ behavior (e.g., Marno et al., 2015), his work consistently opened the door to new avenues of inquiry about how early perceptual/cognitive functioning can shape and mold trajectories of learning from the earliest days of postnatal development extending through adulthood, in particular how it shapes language acquisition and speech perception (e.g., Cutler, Mehler, Norris, & Segui, 1983; Peña, Pittaluga, & Mehler, 2010; Sebastián-Gallés, Dupoux, Segui, & Mehler, 1992). As a result, infancy research came into its own as a period of high importance for the study of structural/functional, bidirectional relations between what infants experience and what they learn—that is, how specific kinds of experiences sculpt developing children's physical and mental architectures. Without these bold approaches, there might have been no infancy research as we know it today. In addition, Mehler consistently exhibited an incredible respect for infants as sentient, aware, active participants in their own development—a cutting-edge view of basic human worth and value.

In this paper, we pay homage to the portion of Mehler's empirical work on the ability of the human fetus and newborn to attend to, learn from, and remember aspects of language emanating from the mother herself as a part of an essential dynamic system of early influence. We start with a selective look at Mehler's inspiration to examine the perinatal period as one that would help clarify the earliest skills and predilections which infants (as humans) bring to the task of language learning. We highlight how the emerging findings on newborns' perceptual skills and biases inspired many to shift focus to the late fetal period as a bridge to understanding how aspects of uterine conduction of the maternal voice could contribute to certain newborn proclivities. Finally, we point to the inspiration drawn from these perinatal approaches to more full-scale empirical treatments of how prenatal experience (and in some cases, behavior) have come to be recognized as essential, dynamic underpinnings to the earliest mental architectures of human cognitive development.

Early Postnatal Contributions to Infant Cognitive Organization

Mehler and colleagues (1978) published one of the first reports of very young infants' recognition of their own mothers' voices (see also Mills & Melhuish, 1974). Mehler et al. found that the infants in their study only showed voice recognition when the mother was speaking in typical infant-directed fashion; when she read from a book in a monotone, no recognition was evident. A few years later, DeCasper and Fifer (1981) published their ground-breaking study on the ability of 2-day-old human infants to differentially adjust their sucking in order to "produce" the voices of their own mothers. Mehler interpreted this early bias toward the maternal voice as a "…mechanism which allows the infant to lock into the linguistically relevant aspects of its acoustical environment" (Mehler et al., 1978, p. 492), and noted also that intonation and other prosodic aspects of speech may play a prominent role in shaping early language perception.

Mehler and his colleagues next launched an extended series of studies on newborns' discrimination of languages based on prosodic patterns, intonation, and rhythm, generally finding that from even the first postnatal days, infants are sensitive to these features of speech. For example, 4-day-old French newborns discriminated French from Russian, but not English from Italian (Mehler et al., 1988). Later studies found significant language discrimination in French newborns listening to Japanese and English (Nazzi et al., 1998), even when low-pass filtered to remove all phonetic-level information, as well as English from Italian (Mehler & Christophe, 1995). English and Spanish newborns showed preferences for their native language over the other (Moon, Panneton-Cooper, & Fifer, 1993), and showed preferences for typical infant-directed speech (e.g., exaggerated in prosody, intonation and rhythm) compared to adult-directed speech within their native language (Cooper & Aslin, 1990). Moreover, when given a choice between hearing monosyllabic nonsense words (e.g., “lif”) and their acoustic analog sine-waves (non-speech), newborns preferred the speech-like sounds (Vouloumanos & Werker, 2007). This result is important because the synthetic versions of the natural speech preserved their prosodic and rhythmic properties, so in this case, it was the “speech-like” quality of the sounds that evoked differential attention.

Collectively, these studies suggest that newborns have an early focus on the prosodic, rhythmic, and intonational aspects of human language and use this information to guide their attention, but that they are also perceptually attuned to sounds that are speech-like. That is, for the most part, newborns exhibit a robust preference for human speech. This early bias toward human speech generally and native language specifically inspired two new lines of research: (1) while attending to speech, do newborns have access to smaller units of the signal? and (2) does this early attention to speech align with brain-specific patterns seen in much older children and adults?

With regard to basic native phonotactics, newborns can discriminate acoustic cues that are correlated with changes in word boundaries (Christophe et al., 1994) and also discriminate at the level of syllables (Bertoncini & Mehler, 1981). French newborns discriminated bi- from tri-syllabic words in French (Bijeljac-Babic et al., 1993) and also in Japanese (Bertoncini et al., 1995). At a finer level of segmentation, French newborns also discriminated synthetic CV tokens in Dutch from those in Japanese, but only when they were played forward (and not backward, which disrupts prosodic flow; Ramus et al., 2000). Moreover, newborns discriminated very brief (< 50 ms) portions of CVs on the basis of changes in place of articulation of the consonant and vowel quality (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987). This was important in that it showed newborns are ready to process speech in ways that signal segmental differences (see also Bertoncini et al., 1988).

In terms of the neural architecture that undergirds language processing, an impressive number of studies have shown similar patterns of brain responses in newborns listening to speech as found in older children and adults. For example, more left hemisphere activation in newborns has been found for continuous forward speech compared to backward speech (Peña et al., 2003; Sato et al., 2010) and to infants' native vs. non-native language (Dehaene-Lambertz et al., 2002). Newborns also show increased cortical activity to a mis-matched phoneme in a string of familiar phonemes, even when the speaker is randomly changing (Dehaene & Peña, 2001). By presenting information to newborns via the left or right ear, Mehler and Bertoncini (1984) and DeCasper and Prescott (2009) showed that, by birth, the infant brain has developed the same sort of lateralization of function seen in the adult brain in which rapid temporal change is preferentially processed by the left auditory cortex and slower, long interval, change is processed by the right auditory cortex (Poeppel, 2003). In a similar vein, Gervain et al. (2008) found that newborns showed enhanced left cortical activation to syllables that were sequenced together and highly repetitive in their form (e.g., "mubaba" and "penana") compared to random control sequences (e.g., "penaku"). Newborns seem not only able to extract small, meaningful units in the speech stream (e.g., syllables) but also perceive how those units are configured over time.

Thus, this work indicates that adult-like processing patterns are present in newborns and opens the possibility that experiences *in utero* may shape structural properties of the brain (e.g., synaptic density and pruning, white matter volume) and functional properties of behavior prior to birth. It is important to acknowledge that although hemispheric differences in activity to language may be present at birth, the degree of lateralization in newborns is considerably less than that in older children and adults (Holland et al., 2001). Moreover, the availability of heard speech to the late-term fetus is attenuated in many ways (e.g., low-pass filtering), such that it remains unclear how prenatal experience can shape language-relevant processing in newborns (Dehaene-Lambertz, Hertz-Pannier, & Dubois, 2006). Nonetheless, taking all the information gleaned from these studies on newborns' language processing, it was logical to create empirical ways to investigate structural and functional properties of the uterine environment as essential for shaping early language experience. Mehler, his students, and his colleagues were among several important collections of researchers who set out to understand how prenatal experience with language shapes the course of early learning.

Prenatal Contributions to Early Cognitive Organization

As indicated above, the growth in recognition that newborns attend to, process, discriminate, prefer, and remember language-specific information available to them led in turn to specific interest in the fetal period. Initially for many (including Mehler), the assumption was that abilities revealed in newborns constituted innate foundations of later development. Alongside nativists, those interested in exploring direct relationships between experiences and emerging cognition pushed forward with fascinating studies of newborns' perception of language that could be tied to fetal learning. Several key findings in the 1980s had a wide impact and opened up a field of study involving fetal experiences across an array of species, and how such experiences may impact later learning. For example, studies showing that fetuses who were exposed to language through their mothers' reading (DeCasper & Spence; 1986) or singing aloud (Panneton, 1985) at the end of their pregnancies could recognize these sounds (or melodies) as newborns. DeCasper and Spence (1986) demonstrated that prenatal exposure to maternal speech influenced preference for speech sounds following birth. In short, this work demonstrated that the fetus could process auditory information and that resulting learning could be revealed in the neonatal period. This led to the possibility that at least some abilities detected at birth had developed *in utero* as a result of perceptual experience. This view was reinforced by the finding that only sounds likely to be heard *in utero*, such as intrauterine heartbeat (DeCasper & Sigafoos, 1983) and maternal speech (DeCasper & Fifer, 1980), acted as effective reinforcers of newborn behavior. Sounds such as male voices (DeCasper & Prescott, 1984) and whispered maternal speech (Spence & Freeman, 1996) were ineffective, however, and it was assumed that this was because they were sounds unlikely to have been experienced in utero. Much of this work has focused on demonstrating effects of fetal experience on newborn behaviors, but it is now clear that fetal exposure (in this case, to a specific piano melody) can lead to retention up to at least one month after birth (Granier-Deferre, Bassereau, Ribeiro, Jacquet, & DeCasper, 2011).

Another stream of research focused on directly examining fetal responsiveness to properties of language during the last trimester of pregnancy. For example, Lecanuet et al. (2000) found that 36- to 39-week-old fetuses reacted to the onset of a low-pitched musical note and then again to a change to a second note with cardiac decelerations (i.e., attention orienting). The notes were presented via a loudspeaker near the mother's abdomen. In a similar vein, DeCasper et al. (1994) asked the mothers of 33- to 37-week-old fetuses to recite aloud a short nursery rhyme every day. At 37-weeks, the authors recorded cardiac changes in the fetuses when the familiar rhyme was presented vs. a novel rhyme (also read by the mother). Cardiac decelerations were only seen to the familiar rhyme.

Other work on prenatal development has focused on the relations between the senses. It was conventionally assumed that any integration between the senses found at birth was an unlearned property of the infant perceptual system and that any such integration could not have happened as a result of development, or in particular as a result of experience. A recent example that might have received this interpretation is the finding that newborns exhibit a very broadly tuned ability to recognize the intersensory match between faces and voices that extends beyond their own species (Lewkowicz, Leo, & Simion, 2010). It is possible that newborns' ability to perceive such congruence relies on the undifferentiated nature of early multisensory processing (Gibson, 1966; Lewkowicz & Lickliter, 1994). That is, it is possible that the intersensory match found between faces and voices is based on recognition of the common temporal patterns and synchrony between auditory and visual information, properties that an undifferentiated perceptual system might detect readily.

There is fascinating evidence from avian species that sensory information received by the fetus can have an effect on perception in different modalities after hatching (Lickliter & Bahrick, 2000). Regarding effects of prenatal input, one might assume that more is better. To the contrary, Sleigh and Lickliter (1996) demonstrated that prenatal exposure of bobwhite quail embryos to their own contentment sounds led to advanced development of intersensory capacity after hatching, whereas exposure to distress calls had the opposite effect. Additionally, providing quail embryos with visual experience by removing part of the egg shell had a detrimental effect on auditory learning after hatching (Lickliter & Hellewell, 1992). Although this research relies on avian models, it is clear that there is a complex developmental interplay across the perinatal period. Lickliter and Lewkowicz (1995) suggested that there is an optimal level of prenatal stimulation for perinatal development across many species, and that departure from that level of stimulation in either direction is liable to be detrimental (see also Gottlieb, 1971; Turkewitz & Kenny, 1982).

With respect to human development, recent research with human fetuses indicates firstly that the uterine environment receives more visual illumination than was formerly assumed.

Secondly, it is possible to present patterned visual stimuli to the fetus and to demonstrate responses to these stimuli. For example, Reid, Dunn, Young, Amu, Donovan, and Reissland (2017) presented facial configurations of lights versus inverted facial configurations to third trimester fetuses, and found that they exhibited more head turns towards the face configuration than towards the inverted configuration. Establishing visual processing in the human fetus is a ground-breaking result, and further work from the same lab has succeeded in measuring fetal eye movements, and through this measure has provided evidence for active visual attention (Donovan, Dunn, Penman, Young, & Reid, 2020). It seems likely that the fetal environment provides some visual differentiation in the mother's dorsal-ventral plane, which may provide important visuo-spatial information prior to birth. Thus, we are really just at the starting point of investigating the functional state of the visual system prior to birth. Effects of visual stimulation prior to birth on auditory processing in general, and speech processing more specifically, are uncharted domains for future researchers.

Concluding Remarks

As the reader will see from the other contributions in this volume, Jacques Mehler contributed to a wide variety of psychological and linguistic issues throughout his long and illustrious career. Here, we have pointed the reader to his profound effect on the earliest stages of human development, and the power of available perinatal experiences to shape and sculpt aspects of young infants' minds. This work was couched within the domain of early language processing, but the impact that it has had on the field extends beyond speech perception. One of the important discoveries of this work is the degree to which prenatal experience influences development. As such, this work has done a great deal to establish the view that newborn abilities are at least partially influenced by developmental processes *in utero* for which appropriate sensory experience is vital. This includes both auditory and visual information that help to shape the newborn's behavioral and perceptual organization. The theoretical view emerging is different in important ways but also complementary to the nativist view Mehler set out with.

We are left with a picture of the newborn as a sentient being who seems ready and willing to participate in the construction of a linguistic environment (DeCasper & Spence, 1991; Lecanuet, Granier-Deferre, & DeCasper, 2005; Moon & Fifer, 2000). Clearly, not all aspects of newborns' abilities with regard to language learning are due directly to specific prenatal experience (May et al., 2011) as there is room in our understanding of early development for both biologically-biased perception and behavior as well as rapid postnatal learning. Nonetheless, the collective works of Mehler, DeCasper, Bertoncini, Lecanuet, Granier-Deferre, Lickliter, and others (along with many students and colleagues) allowed infancy studies to come of age. Jacques Mehler will forever be known for his endless curiosity and creative empiricism when it came to exploring the foundations of cognitive structure and function in human development. Importantly, he coupled his curiosity/creativity with endless mentorship, guidance, and support of his students, such that he left the pursuit of human infant research in the hands of excellent scientists.

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