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Near-term fetal response to maternal spoken voice

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ABSTRACT

Knowledge about prenatal learning has been largely predicated on the observation that newborns appear to recognize the maternal voice. Few studies have examined the process underlying this phenomenon; that is, whether and how the fetus responds to maternal voice in situ. Fetal heart rate and motor activity were recorded at 36 weeks gestation ($n = 69$) while pregnant women read aloud from a neutral passage. Compared to a baseline period, fetuses responded with a decrease in motor activity in the 10 s following onset of maternal speech and a trend level decelerative heart rate response, consistent with an orienting response. Subsequent analyses revealed that the fetal response was modified by both maternal and fetal factors. Fetuses of women who were previously awake and talking ($n = 40$) showed an orienting response to onset of maternal reading aloud, while fetuses of mothers who had previously been resting and silent ($n = 29$) responded with elevated heart rate and increased movement. The magnitude of the fetal response was further dependent on baseline fetal heart rate variability such that largest response was demonstrated by fetuses with low variability of mothers who were previously resting and silent. Results indicate that fetal responsivity is affected by both maternal and fetal state and have implications for understanding fetal learning of the maternal voice under naturalistic conditions.

1. Introduction

Neonates show preference for their mother's voice just hours after birth (DeCasper & Spence, 1986; Fifer, 1987; Fifer & Moon, 1995; Granier-Deferre, Ribeiro, Jacquet, & Bassereau, 2011; Moon, Cooper, & Fifer, 1993; Moon & Fifer, 2000; Spence & DeCasper, 1987). As evidenced originally by behavior during a non-nutritive sucking discrimination procedure (DeCasper & Fifer, 1980; Fifer, 1989), two day-old infants engage in more frequent sucking bursts to elicit an audio recording of their mother's voice over that of another female (DeCasper & Fifer, 1980; Fifer, 1989). Newborn infants also show a physiological orienting response to the maternal voice, exhibiting heart rate decelerations (Ockleford, Vince, Layton, & Reader, 1988) and fewer movements (Fernald, 1989) while listening to a recording of their mother's voice versus a stranger female voice. Further, they prefer a low-pass filtered version of the maternal voice, designed to mimic prenatal speech sounds, over an unfiltered version (Fifer & Moon, 1995).

Preference for the maternal voice must be preceded by both fetal detection and learning through recurrent exposure. The fetal ear is well-equipped to detect auditory stimuli. Mechanisms of hearing are notably different for the fetus and neonate as

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oxygen diffusion by the placenta results in attenuation of the sensorineural threshold in utero relative to postnatal pulmonary oxygenation (Sohmer & Freeman, 1995), however, cochlear biomechanics are fully matured by near term (Granier-Deferre et al., 2011; Hepper & Shahidullah, 1994; Lecanuet & Schaal, 1996; Moon & Fifer, 2000). The human intrauterine environment provides a rich auditory environment as the fetus is exposed to sounds of the maternal cardiovascular, gastrointestinal, and respiratory systems and those generated by body movements. The maternal voice figures prominently on audio recordings of the uterine environment relative to background sounds. It is far less attenuated than other voices that emanate outside the uterus given that external transmission through the uterine wall is also coupled with internal vibrations of the maternal larynx and diaphragm (Busnel, 1979; Querleu, Renard, Versyp, Paris-Delrue, & Crepin, 1988). Spectral analysis indicates that the maternal voice has well preserved prosodic characteristics in utero (Spence & DeCasper, 1987), imparting information about rhythm and pitch contours (Moon, Lagercrantz, & Kuhl, 2013). Thus, neonatal preference for the maternal voice is attributed to the uniquely multimodal sensory input during maternal speech (Moon & Fifer, 2000) and recurrent prenatal exposure (DeCasper, Lecanuet, Busnel, Granier-Deferre, & Maugeais, 1994; Gerhardt & Abrams, 2000) necessary for postnatal discrimination of the maternal voice versus others.

Two types of studies have evaluated the fetal response to the maternal voice as a basis for understanding prenatal learning. The first, more common, approach uses a recording of the maternal voice presented as an auditory stimulus via speakers placed near the maternal abdomen. Results are mixed. Two studies report an increase in fetal heart rate in response to the maternal voice relative to a stranger female voice (Kisilevsky et al., 2009; Kisilevsky et al., 2003), while two others show a significant decrease in fetal heart rate, consistent with the observed neonatal orienting response to the maternal voice (Fifer & Moon, 1994; Lecanuet, Manera, & Jacquet, 2002). One study found that fetuses did not discriminate between their mother's and a stranger's voice played to them via audio recording (Hepper, Scott, & Shahidullah, 1993).

Presentation of the maternal voice from an external source does not capture the true nature of sound transmission to the fetus because it omits the acoustical complexity of the internally transmitted signal. Study of the spoken maternal voice in situ is uncommon, but is most germane to the underlying processes inherent to fetal detection of and attention to the maternal voice in the natural uterine environment. To our knowledge, there is only a single published study that relied on the maternal spoken voice to determine a fetal response. Hepper et al. (1993) evaluated ultrasound observed fetal motor activity in response to the maternal spoken voice in comparison to a presentation of a pre-recording of the maternal voice in a small sample ($n = 10$) of fetuses. Findings suggested 36 week old fetuses were capable of discrimination, as evidenced by a reduction in motor activity unique to onset of the maternal spoken voice (Hepper et al., 1993). Two other preliminary reports from conference proceedings document opposing fetal heart rate responses to the maternal spoken voice. One report found that fetuses exhibiting low heart rate variability and motor activity showed a heart rate decrease from baseline 5 s post onset of maternal spoken voice (Masakowski & Fifer, 1992), while the second reported a fetal heart rate acceleration (Lecanuet et al., 2002).

To this end, other work has confirmed that the fetal response to speech and other sound stimuli varies by fetal state and/or the degree of fetal heart rate variability prior to stimulus application (Groome, Bentz, Mooney, Singh, & Collins, 1994; Groome et al., 1999; Lecanuet, 1989; Lecanuet, Granier-Deferre, Cohen, LeHouezec, & Busnel, 1986; Lecanuet, Granier-Deferre, Jacquet, & Busnel, 1992; Zimmer et al., 1993). Specifically, fetuses stimulated when heart rate variability is low are more responsive relative to those stimulated when heart rate variability is higher. Although responsiveness depends, in part, on sound characteristics, they are more likely to startle in response to high intensity sounds (Groome et al., 1994) as well as show a decelerative orienting response when presented with low intensity sounds (Zimmer et al., 1993).

Thus, while it is clear that the maternal spoken voice should be detectable to the fetus little information is available on either whether or how the fetus responds to the spoken voice in situ. The goal of the current study is to describe the near-term fetal response, measured by changes in fetal heart rate and motor activity, to onset of spoken maternal voice while reading a neutral passage. This method provides a naturalistic context to maternal speech production and potential fetal response. Based on limited existing results that suggest that the maternal spoken voice evokes an 'orienting' movement response in the near term fetus (Hepper et al., 1993) we predict the fetal response will be consistent with mild orienting. Given that the fetal response to a presentation of the audiotaped maternal voice unfolds over tens of seconds (DeCasper et al., 1994), we expect the fetal response to have a relatively short latency, occurring within 30 s of stimulus onset from when the mother begins to read aloud. Potential moderating influences of maternal and fetal parameters that might affect either the nature of the stimulus presented to the fetus (i.e., maternal state) or the propensity of the fetus to detect the stimulus (i.e., fetal heart rate variability level) were also evaluated.

2. Methods

2.1. Participants

Eligibility was restricted to normotensive, non-smoking women carrying a singleton fetus with uncomplicated pregnancies at the time of enrollment. Accurate dating of the pregnancy based on last menstrual period and early confirmation by ultrasound was required. Seventy-four women participated in maternal–fetal monitoring at 36 weeks gestation ($M = 36.4$ weeks GA, SD = 0.3). On average, participants were well educated (M years of education = 17.5 years, SD = 1.8) and mature (M age = 32.4, SD = 4.5). The sample was 70% non-Hispanic white, 12% African American, and 18% Hispanic or Asian American. The majority of women were married (97%) and working outside the home at the time of data collection (91%). Most (64%)