Journal of Experimental Child Psychology 152 (2016) 106–122

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Variation in infant EEG power across social and nonsocial contexts

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ARTICLE INFO

Article history:
Received 14 July 2015
Revised 21 March 2016

Keywords:
Infant
EEG
EEG power
Social engagement
Joint attention
Social brain

ABSTRACT

To understand the infant social brain, it is critical to observe functional neural activation *during* social interaction. Yet many infant electroencephalography (EEG) studies on socioemotional development have recorded neural activity only during a baseline state. This study investigated how infant EEG power (4–6 Hz and 6–9 Hz) varies across social and nonsocial contexts. EEG was recorded in 12-month-olds across controlled conditions to disentangle the neural bases of social interactions. Four conditions—nonsocial, joint attention, language-only, and social engagement—were designed to tease apart how different environmental inputs relate to infant EEG power. We analyzed EEG power in frontal, central, temporal, and parietal regions. During the joint attention condition compared with the other conditions, 4–6 Hz frontal, central, and parietal power was lowest, indexing greater neural activation. There was lower 4–6 Hz and 6–9 Hz power in the temporal region in both the joint attention and social engagement conditions compared with the nonsocial condition. In 6–9 Hz, the pattern was consistent with 4–6 Hz findings for the frontal region such that 6–9 Hz frontal power was lower, indexing greater neural activation, in the joint attention condition compared with the nonsocial condition. There were no differences between conditions in central and parietal regions in 6–9 Hz. Findings highlight the methodological importance of recording functional brain activity in multiple controlled contexts to explicate the neural bases of the infant social brain.

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http://dx.doi.org/10.1016/j.jecp.2016.04.007
0022-0965/

Introduction

Social interactions are essential for infant development such that infants who experience social deprivation show neural, social, and emotional deficits (Marshall, Reeb, Fox, Nelson, & Zeanah, 2008; Tarullo, Garvin, & Gunnar, 2011). However, the neural underpinnings of social engagement during infancy are not well understood. Although baseline measures of neural activity have been widely used with infants, less research has explored functional neural activity *while* infants are engaged in social interactions. To better understand the development of what has been termed the *social brain* (Adolphs, 2003; Grossmann, 2015), it is important to measure functional neural activity as infants socially interact. By understanding how patterns of neural activation differ across various social and nonsocial contexts, we can begin to disentangle the neural bases of social interaction, with implications for understanding the physiological processes underlying social development.

Infant EEG and recording context

Electroencephalography (EEG) has been widely used to measure infant brain activity. Electrodes are placed on the scalp to assess electrical activity released from neuronal communication, mostly in the cerebral cortex. EEG power measures voltage at an electrode site and is a continuous EEG measure as it assesses global neural activity across a period of time (Molfese, Molfese, & Kelly, 2001). EEG is noninvasive and allows for robust movement, an advantage in research with infants. Furthermore, the use of high-density EEG allows for greater spatial resolution. EEG can be compared across brain hemispheres (called *asymmetry*), brain regions, and conditions.

Dominant frequency bands in infant EEG research are 4–6 Hz and 6–9 Hz (Calkins, Fox, & Marshall, 1996; Marshall, Bar-Haim, & Fox, 2002). They reflect slow wave brain activity, so lower power in these frequency bands is thought to index greater neural activation (Allen, Coan, & Nazarian, 2004; Davidson, 1988).

Baseline EEG

Disentangling the neural bases of social interaction is a crucial step toward understanding the neural circuitry underlying the social brain. However, in infant research, continuous EEG measures are commonly recorded during a baseline or resting state rather than during social learning or social engagement. Operationalization of baseline varies across studies, but the common goal is that infants maintain a state of quiet visual attention to ensure usable EEG data. In some cases, EEG is recorded as infants watch an experimenter spin a Bingo wheel (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Mundy, Card, & Fox, 2000; Nichols, Martin, & Fox, 2005), watch an experimenter blow bubbles (Mize & Jones, 2012), watch an experimenter shake a rattle (Field, Fox, Pickens, & Nawrocki, 1995; Jones, Field, Fox, Lundy, & Davalos, 1997), or watch a video clip (Tomalski et al., 2013). These baseline conditions do not clearly differentiate between social and nonsocial input because infants may attend to the experimenter or the object.

Recording EEG in controlled social and nonsocial contexts would enable researchers to assess how aspects of social interaction differentially relate to neural activation. Social interaction involves various components such as engaging in joint attention, hearing language, and face-to-face interaction. Joint attention includes coordinating attention with a social partner to an object or event and is an essential form of social learning (Mundy & Acra, 2006). Responding to another individual's bids for joint attention has been related to language ability (Morales et al., 2000) and emotion and attention regulatory behaviors (Morales, Mundy, Crowson, Neal, & Delgado, 2005). Furthermore, face-to-face social interaction is associated with experiencing positive affect and decreased distress and negative affect (Abe & Izard, 1999). Despite the importance of social interaction, to our knowledge no study has systematically compared EEG recorded across all of these different social contexts. By comparing infant EEG power in a nonsocial condition with various social conditions such as engaging in joint attention, hearing language, and face-to-face interaction, we can begin to elucidate the neural bases of social engagement during infancy.