An investigation of novel carrying experience on infant rhythm perception

Sinead Rocha, Birkbeck, University of London, London, UK, University of Cambridge, Cambridge, UK*

Victoria Southgate, University of Copenhagen, Copenhagen, Denmark

Denis Mareschal, Birkbeck, University of London, London, UK

Correspondence:

Sinead Rocha

sineadrocha@gmail.com

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Abstract

Prior research suggests infants who are regularly carried in an infant sling are more accurate at moving in time with an auditory rhythm. Moreover, the rate of walking cadence during infant carrying was found to impact infant spontaneous motor tempo. In the current study we ask if part of the advantage of locomotive experience on sensorimotor synchronization results from greater sensorimotor neural activation, utilized to predict the beat, during the perception of rhythmic auditory stimuli. Five-month-old infants were carried at either a Fast or Slow rate. EEG was then used to measure infants' recruitment of a sensorimotor program, indexed by sensorimotor alpha suppression, during the auditory presentation of the Fast and Slow rhythms. Our results suggest that infants do not seem to preferentially exploit a sensorimotor representation when hearing an auditory tempo that matched the rate at which they were carried, compared to when hearing an incongruent tempo.

Introduction

Previous work suggests an advantage for more frequently carried infants in sensorimotor synchronization (SMS; the ability to match movement to auditory rhythms), and that being carried at a novel tempo can change the tempo an infant spontaneously produces during rhythm production (Rocha, 2018). There are two components to successful SMS; (i) accurately predicting when the next beat will occur, and (ii) timing one's movements to coincide with the following beat, which involves initiating movement before the beat is present. The current paper asks if part of the advantage of carried locomotive experience on SMS results from greater sensorimotor neural activation, utilized to *predict* the beat, during the perception of rhythmic auditory stimuli. Such a benefit could be thought of within a general context of default action simulation by the sensorimotor system during event prediction, as proposed by Schubotz (2007), and in line with the Action Simulation for Auditory Prediction (ASAP) hypothesis (Patel, 2014).

Sensorimotor activation can be measured in infants using electroencephalography (EEG). Sensorimotor alpha suppression describes the desynchronization of neuronal activity over the sensorimotor cortex of the brain, in the alpha range (8-13 Hz frequency band in adults), and is distinguishable from the classic (occipital) alpha signal (Pineda, 2005). Desynchronisation reflects the activation of underlying areas. Sensorimotor alpha suppression, measured as the reduction of the alpha power band over central sites, relative to a baseline period, has been recorded during action execution and action observation/prediction (Fox et al., 2016).

The current study aims to test whether infants show increased recruitment of their sensorimotor system when they are presented with sounds that match the tempo of walking they have experienced than when they hear sounds at another tempo. Five-month-old infants were walked in a sling at either a Fast or Slow tempo for 10 minutes. Following this carrying experience, infants were presented with counter-balanced blocks of metronome recordings at both the Fast and Slow tempi. We hypothesized that if infants' rhythmic skill involves the recruitment of a motor program, then we may see evidence that they can recruit a motor program generated during walking experience, recruited during rhythm detection and/or prediction. Specifically, we hypothesized that infant walked at a fast tempo would show greater motor system recruitment, reflected in greater sensorimotor alpha suppression, when listening to fast tempo sound recordings and infants walked at a slow tempo would show greater motor system recruitment when listening to slow tempo sound recordings. If so, this could suggest that a mediating factor in the relationship between carrying experience and rhythm production might be a motor program which infants can later exploit during rhythm perception, and – in the case of sensorimotor synchronization – rhythm production.

Method

Participants

Twenty-six 5-month-old infants (13 female; $M = 159$ days, range = 137 to 179 days) were randomly allocated to the Fast condition, and 26 infants (10 female; $M = 154$ days, range = 136 to 180 days) to the Slow condition in a between-subjects design. All caregivers gave written informed consent concerning the experimental procedure, in accordance with the Declaration of Helsinki. The department ethics committee, Birkbeck, University of London, approved the protocol. Infants received a certificate and a t-shirt as a thank you for participation.

Procedure

Treadmill training. Infants were walked on a Domyos Comfort Run treadmill for 10 minutes at either the Fast (138 BPM, 434 ms between steps) or Slow (98 BPM, 612 ms between steps) pace. Infants were carried by the experimenter in a forward-facing sling and viewed an infant cartoon. The experimenter listened to a metronome recording at the corresponding tempo through a headphone. The carrying session was recorded using a Logitech HD 1080p webcam with a sideview of the treadmill.

EEG auditory test. Infants were seated on their parent's lap facing a TV screen and two stereo speakers. The auditory stimuli were Fast and Slow blocks presented in a pseudo-randomised order. Each block consisted of four trials. Trials were a metronome recording of 12 beats at 138 BPM or 98 BPM depending on condition, immediately preceded by a jittered 1500 - 3000 ms baseline period of white noise. The trials were matched by number of metronome beats, rather than absolute time, to give infants equal experience of each type of stimuli across the experiment, resulting in trial lengths of 5000 ms in the Fast condition and 7000 ms in the Slow condition.

For each trial the pitch of the metronome alternated between four possible pitches, to maintain infant interest. Infants concurrently saw still colour photographs (houses, infant faces, landscapes) that transitioned via crossfade every two to three seconds. Stimuli were created in Audacity and Apple Final Cut Pro and presented with MATLAB (The MathWorks, Natick, MA) using the Psychophysics Toolbox extension. Infants were exposed to up to 16 blocks (8 Fast, 8 Slow), so that each participant heard a maximum of 64 trials, 32 at the tempo congruent to their treadmill experience, and 32 incongruent. The maximum duration was just over eleven minutes, shortened if the infant fussed.

EEG was recorded using a 128-channel Geodesic Sensor Net (GSN; EGI Inc, Eugene, Oregon), with respect to the vertex electrode, sampled at rate of 250 Hz.

Data Processing

Video coding. To ensure that sensorimotor alpha suppression was related to the auditory perception of the beat rather than execution of movement, video footage was examined and trials where infants made a visible action were excluded from analyses.

EEG cleaning. Data were filtered in NetStation version 4.5.4 (EGI, Inc., Eugene, Oregon), with a 0.3 Hz to 30 Hz bandpass filter. Data were segmented into epochs around the beginning of each event. An extra 400 ms were added prior to the start of the baseline period to be able to remove the distortion created by the wavelet transform performed later. For the five-second-long Fast trials, this resulted in a segment of 6400 ms, (-1400 ms to +5000 ms), and for seven second Slow trials, 8400 ms (-1400 to +7000 ms). Each trial was then visually inspected for artifacts in the EEG signal. If artifacts were apparent in less than 20% channels these bad channels were interpolated, else the trial was discarded. Cleaned data were exported to Matlab for further analysis. Only infants who, following video coding and EEG cleaning, had at least four clean trials per condition were included. This left a final sample of 13 infants in the Fast condition and 12 infants in the Slow condition, an attrition rate in line with the infant EEG literature (e.g. de Klerk et al., 2015).

EEG Time-Frequency Analyses. The following analyses used Matlab toolbox WTools (Parise & Csibra, 2013). Data were imported and re-referenced to the average reference. Morlet wavelets were computed at 1 Hz intervals between 1 and 25 Hz. Average activation for each participant in each condition was computed. The Morlet transform creates distortion, so 400 ms buffers were cut from the trial. A 400 ms long section (-400 to 0 ms) prior to the start of each trial was selected as a baseline period. Activity in the target alpha frequency range for this age of infants (5 – 7 Hz; Southgate & Verneti, 2014), during baseline was subtracted from activity in the 5 - 7 Hz range during the trial. The first 4600 ms of each trial was selected for analyses to allow direct comparison of the two conditions. Analyses used the average activation over 4 left sensorimotor channels, which have previously been identified as reflecting infant sensorimotor alpha suppression during observation/prediction (electrode numbers 30, 36, 37 and 42; Southgate et al., 2009).

Results

We conducted a repeated measures ANOVA with sensorimotor alpha during the Fast Sound trials and Slow Sound trials entered as within-subjects factors, and walking condition (Fast Walked or Slow Walked) entered as a between subjects factor. The predicted result was an interaction, such that infants would show less alpha activity during the congruent trials (Fast Sound if Fast Walked, Slow Sound if Slow Walked) than during the incongruent trials. Figure 1 shows time frequency plots for the selected channels over the baseline and trial period. Responses in each condition are in the hypothesized direction (i.e., suppression in the congruent condition, synchronization in the incongruent condition), see Table 1. However, we do not find a main effect of Sound ($F(1,25) = .183, p = .672, \eta^2 = .007$) or Walking condition ($F(1,25) = .767, p = .390, \eta^2 = .030$). Critically, we do not see a Sound*Walking condition interaction ($F(1,25) = 1.834, p = .188, \eta^2 = .068$).

JASP (JASP Team 2017; Version 0.8.1.2) was used to calculate the Bayes Factors for the interaction, using the default priors, to test if the lack of a significant interaction is reflective of evidence for the null, or is the result of insufficient power. It is assumed that $BF_{10} < .33$ provide good evidence to support the null, and a $BF_{10} > 3$ good evidence for the hypothesis (Jeffreys, 1939; Lee & Wagenmakers, 2014). A Bayesian repeated measures ANOVA with the same factorial design as above reveals good evidence for the null (Walk*Sound $BF_{10} = .328$).

Despite the clear lack of hypothesized interaction, a more basic criterion that could be applied asks if the decrease in activation seen in congruent conditions truly reflect sensorimotor alpha *suppression*. A one-sample t-test against zero reveals no significant suppression in the Slow Walked infants when

hearing the Slow Sound, in relation to baseline, with anecdotal evidence for the null ($t(12) = -.868$, $p = .402$, $BF_{10} = .601$). The equivalent analyses for all other conditions also show non-significant results ($p > .264$), and also do not clearly support the null (BF_{10} between .446 and 1.027).

Discussion

Our results do not support our hypothesis that infants will show greater sensorimotor alpha suppression when they hear an auditory beat that matches the cadence of walking they were exposed to via a ten-minute carrying session. Traditional inferential statistics showed the hypothesized direction of results, with non-significant p -values. A Bayesian repeated measures ANOVA revealed that for the hypothesized interaction, the data convincingly support the null. It is therefore probable that infant recruitment of their sensorimotor system during the auditory presentation of a beat is not different following exposure to motor activation at the same tempo, at least as is reflected by sensorimotor alpha suppression. However, alternative possibilities are discussed below.

It is possible that ten-minutes of training was insufficient. Further, training undertaken in prior infant sensorimotor alpha suppression studies (de Klerk et al., 2015; Gerson et al., 2015) involved gross motor activities, including self-locomotion. Infants in the current study were carried, and our results may therefore reflect insufficient activation of the motor cortex during training, suggesting less *active* experience, in addition to less experience. Relatedly, though a recent meta-analysis reveals no effect of whether actions were transitive or intransitive on sensorimotor alpha suppression (Fox et al., 2016) too few studies have examined non-goal-oriented actions for this to be included in the meta-analysis. The importance of goal-directedness on the sensorimotor response remains highly debated (e.g. Cook & Bird, 2013), but it is possible that the lack of a clear goal in the auditory stimuli may contribute to our null results. Further, the infants in the current study were five-month-olds, and the youngest study employing this measure to date used six-month-olds (Southgate & Vermetti, 2014). Considering changes in strength of response and somatotopic organization during the first years of life (de Klerk et al., 2015), it is possible that older infants may show a different response to the ones tested here.

The aim of the current study was to explore if infants were recruiting a motor program gained from carrying, when they heard rhythms that matched the rate at which they were carried. Sensorimotor alpha suppression was used as an index of infant sensorimotor engagement during a passive listening task following a period of walking. We did not find evidence of sensorimotor alpha suppression at test. Whilst these null results are indicative of infants not recruiting a motor program for being walked when hearing a corresponding rhythm, further measures are necessary to test if carrying experience has sensorimotor consequences not illuminated by sensorimotor alpha suppression.

204 **Table 1.** Power in the infant sensorimotor alpha band (5 – 7 Hz) over the left sensorimotor channels,
 205 during congruent (Fast Walk Fast Sound, Slow Walk Slow Sound) and incongruent (Fast Walk Slow
 206 Sound, Slow Walk Fast Sound) auditory presentations.
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	Sensorimotor Alpha Power			
	M	SE	95% CI	95% CI
Fast Walk Fast Sound	-.031	.068	-.171	.110
Fast Walk Slow Sound	.078	.158	-.247	.403
Slow Walk Fast Sound	.014	.071	-.132	.160
Slow Walk Slow Sound	-.195	.164	-.532	.142

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 211 **Figure 1.** Time-Frequency heat map plots for the Fast and Slow sound conditions, plotted separately
 212 for the Fast and Slow walking conditions. A (Fast Walk Fast Sound) and D (Slow Walk, Slow
 213 Sound) show congruent conditions, B (Slow Walk Fast Sound) and C (Fast Walk, Slow Sound) show
 214 incongruent conditions. Trial onset is marked with black dashed lines. Analysis period and frequency
 215 band is marked with white dashed lines. The x-axes reflect time in milliseconds. The y-axes reflect
 216 the frequency of oscillations present in the EEG. Lower power is denoted with cooler colours.
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 223

224 **Author Contributions**

225 SR, VS and DM contributed to the conception and design of the study; SR collected and analysed the
 226 data; SR wrote the first draft of the manuscript, VS and DM contributed to all sections of the
 227 manuscript.

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