Supplement

S1.1 Purpose: Family income as a moderator

Prior work has suggested relations between contextual factors related to childhood socioeconomic status (SES) and selective attention abilities (Isbell et al., 2017; Lawson et al., 2016; Lipina et al., 2013; Markant et al., 2016). Based on this prior work we conducted exploratory analyses on the interactions between mu rhythm modulation during anticipation of touch, executive function, and family income in our sample of 80 children aged 6-8 years.

S1.2 Methods: Measurement of family income

Caregivers completed the MacArthur Sociodemographic Questionnaire, reporting total annual household income within a prescribed set of 10 categories, ranging from under $5,000 to greater than $125,000 (for exact increments, see Kishiyama et al., 2009). Our sample consisted of families across a wide range of income levels, with 25% of families reporting annual incomes under $20,000. We opted to use total household income in further analyses, as this measure allowed us to create groups of lower and higher income families by median sample income range ($35,000) for ANOVA and to examine incremental effects of family income using regression analyses. Relatively few primary caregivers had completed a 4-year college degree (n = 19) but the majority had graduated high school (n = 72). The mean income-to-needs ratio of our sample was 0.72, with 65% of participating families reporting an income-to-needs ratio below 1. We note that racial identity was distributed fairly evenly across the dichotomized income groups in our sample. Preliminary analyses showed that dummy-coded variables dichotomizing membership in racial and ethnic groupings were not significantly correlated with study variables and thus information on race and ethnicity was not included in further analyses.

S1.3.Results: Income as a moderator of anticipatory mu ERSP

To visualize differences in mu desynchronization by family income, continuous ERSP waveforms at central sites were plotted by median income (Figure S1). For the purpose of interpreting the initial ANOVA, family income was treated as a binary factor ("income group"), with children from families earning less than the sample median of $35,000 characterized as "lower income," and families earning greater than the median characterized as "higher income". examine differences in anticipatory mu ERSP, a mixed effect ANOVA was conducted on mu ERSP with electrode (C3, C4) and cue direction (left, right) as within-subjects factors and income group as a binary between-subjects factor. There were no significant main effects of electrode and cue direction, but there was a significant interaction of these factors, $F\ (1, 78) = 31.430$, $p < .001$, $\eta^2_p = 0.276$. As expected from the results described in the main body of the manuscript, this interaction was driven by the greater mu ERD at the contralateral central site compared to minimal modulation of mu at the ipsilateral site. There were no other significant 2-way interactions. A main effect of income group trended towards significance, $F\ (1, 78) = 3.296$, $p = .073$, $\eta^2_p = 0.041$, and there was a significant 3-way interaction between income group, electrode, and cue direction, $F\ (1, 78) = 4.501$, $p = 0.037$, $\eta^2_p = 0.055$. As shown in Figure S1, pairwise comparisons revealed that the significant interaction was driven by differences in contralateral mu ERSP by income group ($p < .05$) for the right cue at the left central site (C3) as well as for the left cue at the right central site (C4). Contralateral mu desynchronization was enhanced in children from higher-income families compared to children from lower-income families. No significant differences in mu ERSP were found between the income groups at the central electrode sites ipsilateral to the cue direction.

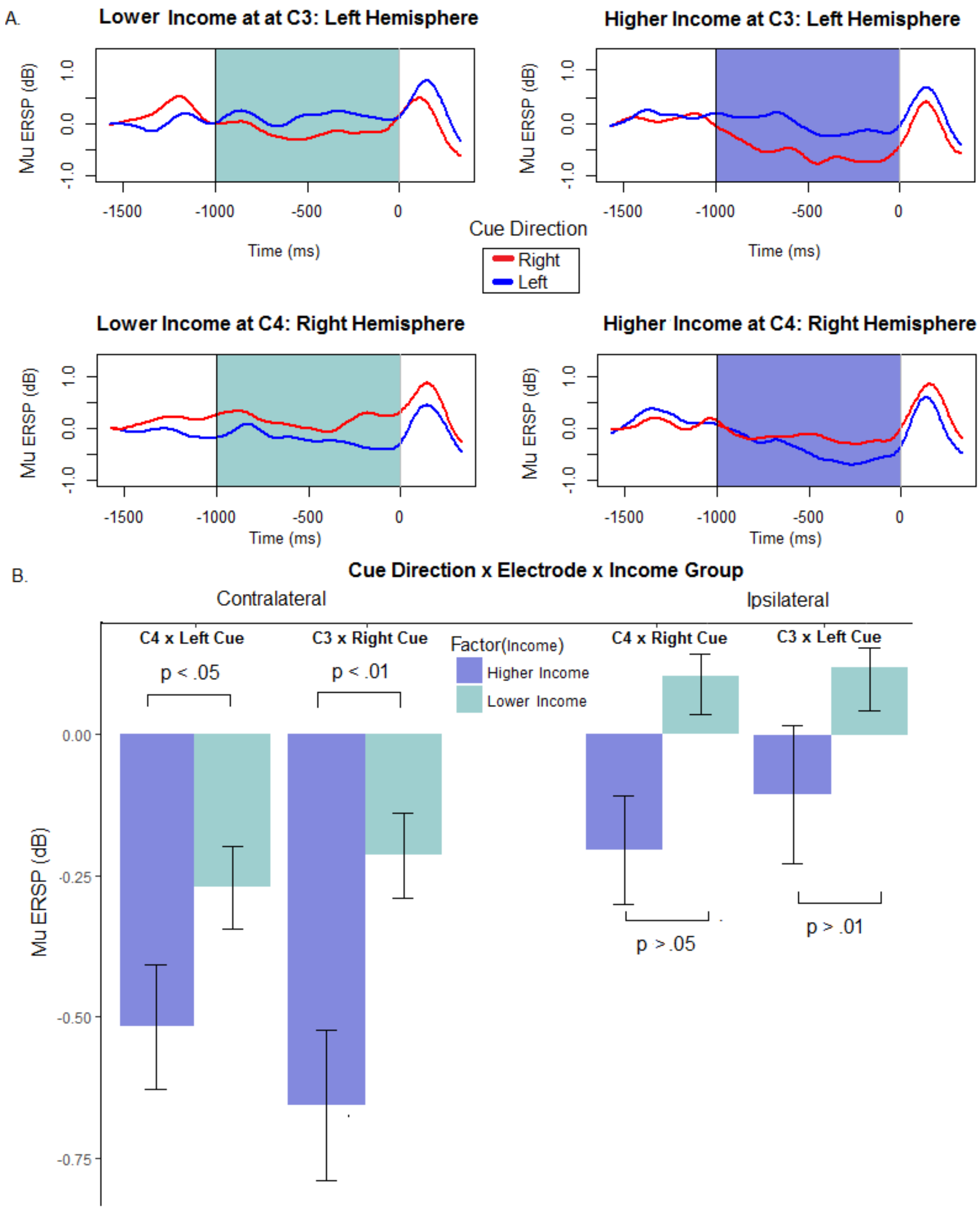

Fig. S1. (A) Continuous mu ERSP waveforms for the high- and low-income groups, shown by electrode (C3/C4) and cue direction. The shaded area from -1000 to 0 ms highlights the anticipatory period of interest. (B) Mean anticipatory ERSP amplitude over the -1000 to 0 ms period plotted by income group, electrode, and cue direction, with the error bars indicating standard error.

1.3.1 Executive function by contralateral mu ERSP and family income

To further examine the relations between executive function, mu desynchronization, and family income, separate multiple regressions were conducted predicting scores on the Flanker, Card Sort, Language and Speed Processing tasks from the interaction between income range (entered as an ordinal variable) and contralateral mu ERSP, controlling for the individual contribution of these variables to EF scores. The variables of Income Range and contralateral mu power were non-significant predictors of EF when entered simultaneously into the regression, indicating that they contribute shared variance to Flanker and Card Sort scores (Table S1). Flanker score was related to the interaction of income range and contralateral mu ERSP, $t(79) = -2.506$, $p = 0.014$, $\eta^2 p = 0.123$. Card sort scores were also related to the interaction of income range and contralateral mu ERSP, $t(79) = -2.135$, $p = 0.036$, $\eta^2 p = 0.092$. Further analyses examined whether Language (receptive vocabulary) and Processing Speed scores were related to contralateral mu ERSP via an interaction with income range; just as no main effects were significant when mu ERSP was examined alone, no interaction effects approached significance for these cognitive task scores.

Table S1. *Executive function scores by income range and contralateral ('CL') Mu ERSP*

Outcome		**B**	**SE**	**β**	**T**	**P**		η^{2p}
Flanker	(Intercept)	48.972	1.458		33.593	< .001	*	
0	Contralateral Mu	-2.345	1.515	-0.178	-1.549	0.126		0.051
	Income Range	0.360	0.415	0.100	0.867	0.389		
1	CL Mu x Income Range	-1.180	0.471	-0.483	-2.506	0.014	*	0.123
Card Sort	(Intercept)	39.096	9.276		4.215	< .001	*	
0	Contralateral Mu	-2.258	1.547	-0.165	-1.460	0.148		0.045
	Income Range	0.670	0.429	0.177	1.563	0.122		
1	CL Mu x Income Range	-0.781	0.366	-0.305	-2.135	0.036	*	0.092

* p < .05

The interaction between income and contralateral mu ERSP was significantly related to EF, as visualized by dichotomized income group (Figure S2). Follow-up regressions within income groups revealed that the relation between contralateral mu ERSP and Flanker scores was significant for children from higher-income families, t (1, 42) = -2.170, p = 0.036, but was not significant for children from lower-income families, t (1, 36) = -1.073, p = 0.290. Similarly, follow-up regressions indicated that the relation between contralateral mu ERSP and Card Sort scores was significant for children from higher-income families, t (1, 42) = -2.136, p = 0.039, but not for children from lower-income families t (1, 36) = -2.136, p = 0.149.

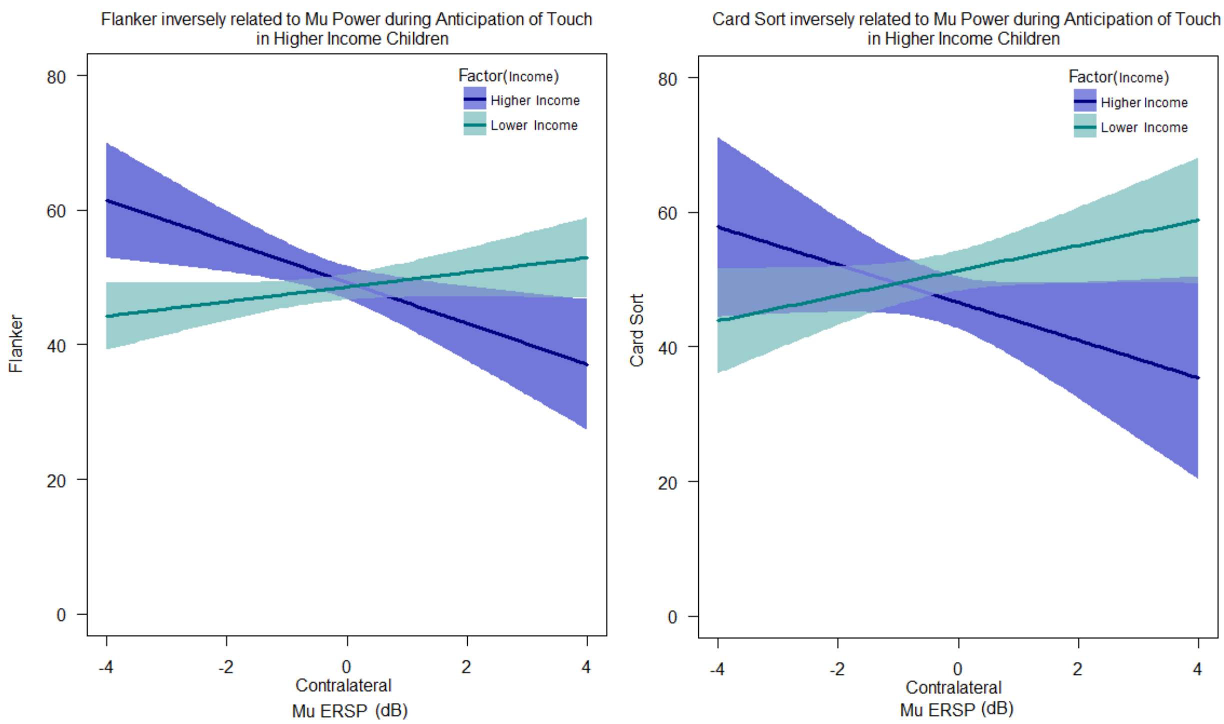

Fig. S2. Plots showing the relation between children's executive function task scores (Flanker and Card Sort) and contralateral mu ERSP at central sites during anticipation of tactile stimulation, split by higher and lower income group.

S1.4 Discussion

The current findings support theorizing that selective attention is an early indicator of executive function skills (Garon et al., 2008), with the caveat that individual differences related to family income may moderate this relation. Exploratory analyses revealed that though anticipatory desynchronization of the sensorimotor mu rhythm was associated with children's executive function skills, family income moderated the observed relations. The finding of enhanced preparatory EEG activity in children from higher-income families supports the notion that the early environment may shape neural activation related to attentional focusing, prediction, and goal-directed action (Hackman and Farah, 2009; Posner et al., 2012; Raver et al., 2012). Further, the magnitude of mu suppression in higher-income children was comparable to the extent of mu modulation observed in adults during a similar paradigm (Shen et al., 2017). In contrast, children from lower-income households exhibited a less pronounced reduction in mu rhythm amplitude prior to the delivery of the tactile stimulus; we speculate the smaller variation in anticipatory mu modulation within the lower-income sample limited our power to identify a significant association of family income with executive function skills.

These findings are in line with prior work that finds a more 'mature' response in children of more highly educated parents during auditory selective attention (D'Angiulli et al., 2008; Hair et al., 2015; Isbell et al., 2016; Stevens et al., 2009), such that children with more educated caregivers exhibited ERP responses that differentiated distractors from target stimuli, similar to the differences evident in adults and older children (Hampton Wray et al., 2017; Stevens et al., 2009). Other studies of selective attention report that ERP amplitudes and theta rhythm modulation evoked by distracting, uncued auditory stimuli distinguished between children from high and low income families (D'Angiulli et al., 2008). Similar to our results, prior evidence found that SES differences in EEG indices of selective attention were not accompanied by group differences in stimulus detection (D'Angiulli et al., 2008; Kishiyama et al., 2009; Raizada, 2010). However, direct comparisons with the existing literature linking neural measures and SES are limited by our use of a unidimensional income measure (Lipina, 2017) and unique focus on activity during anticipation of the target tactile stimulus.

The literature on SES disparities in developmental cognitive neuroscience is largely focused on physiological activity related to higher-order outcomes such as executive function (Raver et al., 2012), language (Pace et al., 2017; Raizada et al., 2008) and self-regulation (Sturge-Apple et al., 2016; Watts et al., 2018). One speculation drawn from the current results is that common variance across these diverse domains of cognition may be the ability to focus attention on sensations and predict upcoming stimuli relevant to task demands.

S2.1 Purpose: Alpha modulation in response to visual cue

The specificity of the relations between EF and mu rhythm modulation during the anticipatory period at central sites is addressed here by applying ANOVA and correlational analyses to alpha modulation during visual cue response period at posterior sites over the occipital cortex.

S2.2 Methods: EEG processing of visual response alpha modulation

For statistical analyses, a key variable was mean alpha (8-13 Hz) ERSP for the period from visual cue onset at -1500 ms to -1000 ms prior to tactile stimulation, with this time window selected to capture changes in ERSP over posterior occipital (O1/O2) sites in response to the visual cue evident from -1500 to -1000 ms.

S2.3.1 Results: Visual response alpha ERSP

After inspection of the time frequency plots and alpha waveforms at posterior sites O1 and O2 (Figure S3), repeated-measures ANOVA was conducted comparing mean 8-13 Hz ERSP in the -1500 to -1000 ms window by electrode (O1/O2) and cue direction (left/right). No significant main effects were observed. As expected, there was a significant interaction between cue direction and electrode, F (1, 79) = 9.477, p = .003, η^2_p = 0.107. As suggested by the ERSP waveforms (Figure 3), this significant interaction was driven by greater mu desynchronization at the left posterior contralateral (O2) site than at the other sites. Following a cue to expect stimulation of the left hand, mu ERSP was significantly more positive at O2 (M = 0.010, SD = 1.175) than at O1 (M = -0.175, SD = 1.194, t (79) = 2.491, p = .015). In contrast, following a cue to expect stimulation to the right hand, mu ERSP was not significantly more positive at O1 (M = 0.054 SD = 1.113) than at O2 (M = -0.042, SD = 1.026, t (79) = 1.433, p = .115).

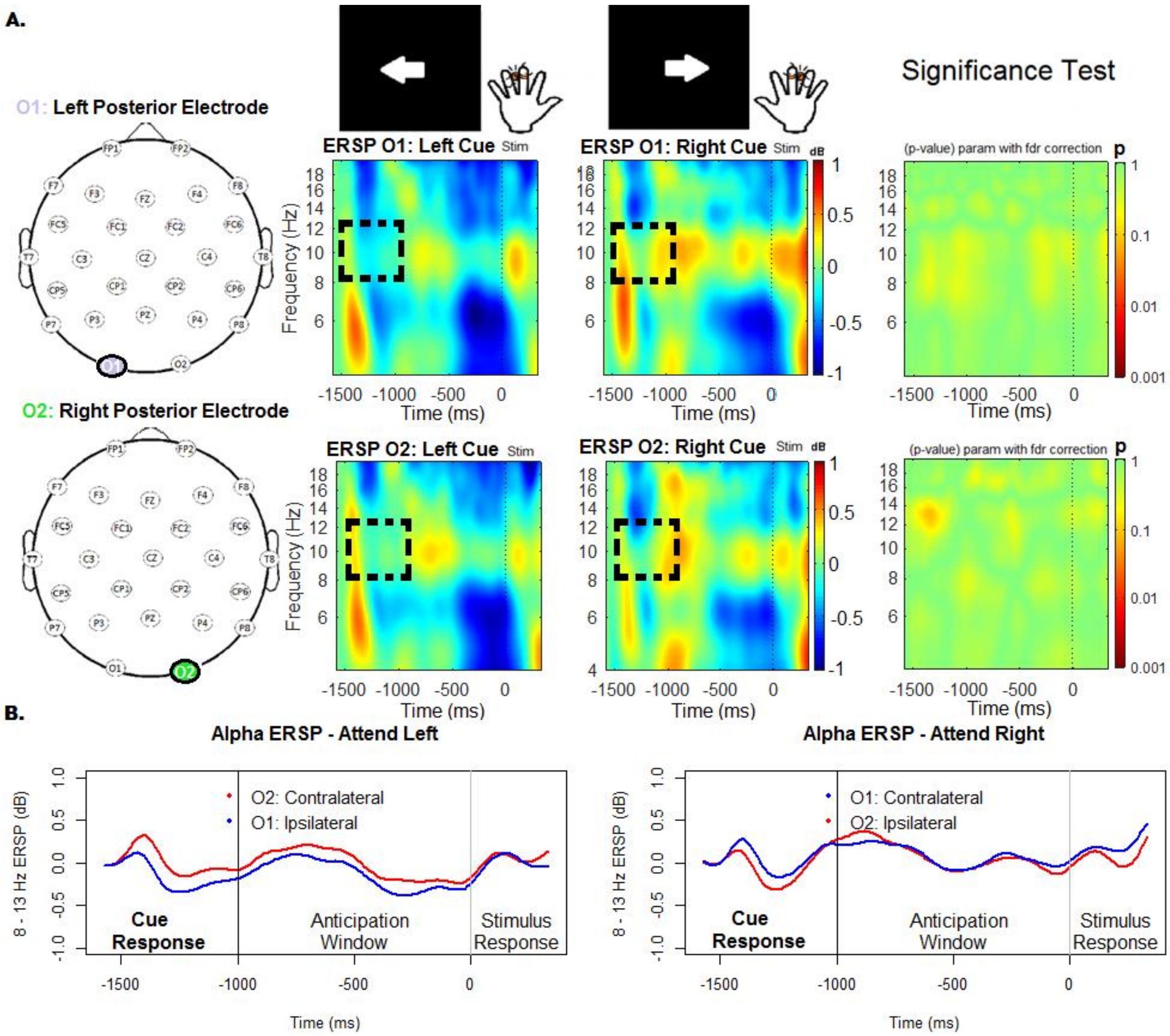

Fig. S3. (A) Time-frequency plots showing ERSP (event-related spectral perturbation) at left and right posterior (occipital) sites (O1/O2) across a frequency range of 5 – 20 Hz for the time period from 1500 ms before the tactile stimulus is presented to the 300 ms following. The dashed boxes highlight alpha activity (8 – 13 Hz) evoked by the visual cue. Stimulus response is the period after delivery of the tactile stimulus (0 ms – 300 ms). The significance test panels show statistical comparisons of ERSP within each electrode site in response to left vs. right cue directions.
(B) The waveforms visualize the alpha-range (8-13 Hz) ERSP at O1 and O2 in response to the right or left visual cue.

S2.3.2 Visual response alpha ERSP in relation to key variables

Despite the absence of a clear, significant lateralized pattern of posterior alpha ERSP, we proceeded to collapse mean alpha at ipsilateral and contralateral sites, to parallel previous analyses. We then correlated these means with key cognitive and demographic variables. There are significant associations observed between occipital alpha and post-stimulus mu ERSP in both hemispheres, though curiously anticipatory mu was not associated with the preceding occipital alpha, advancing our understanding of the temporal and spatial specificity of anticipatory bodily attention. We followed up the association observed between age and visual response alpha with a regression, which revealed a marginally significant relationship driven by the posterior electrode sites ipsilateral to the visual cue, $t(79) = -2.080$, $\beta = -0.231$, $p = 0.051$, while the contralateral sites remained non-significant, $t(79) = 0.519$, $\beta = 0.058$, $p = 0.606$.

Table S2. *Correlation of visual response alpha ERSP with key study variables.*

	Contralateral Occipital Alpha ERSP	Ipsilateral Occipital Alpha ERSP
Ipsilateral Occipital Alpha ERSP	0.874 ***	—
Contralateral Anticipatory Mu ERSP	0.064	0.085
Ipsilateral Anticipatory Mu ERSP	0.098	0.021
Contralateral Post-Stimulus Mu ERSP	0.437 ***	0.378 ***
Ipsilateral Post-Stimulus Mu ERSP	0.366 ***	0.343 **
Language	-0.090	-0.041
Speed	-0.121	-0.167
Flanker	-0.168	-0.189
Card Sort	-0.153	-0.165
Age	0.042	-0.227 *
Gender	0.070	0.148
Family Income	-0.000	0.130

S2.4 Discussion: Visual response alpha ERSP during somatosensory selective attention protocol

Follow-up analyses conducted on the changes in alpha-range ERSP at posterior electrode sites overlying the occipital cortex in response to the visual cue (a directional arrow, relevant to the spatial location of the subsequent tactile stimulation) in 6-8 year old children. The goal was to identify if alpha-range oscillatory activity evoked by the visual cue was related to key study variables, specifically the cognitive skills measured by the NIH Cognitive Toolbox. No association between alpha ERSP and cognitive skills was found, in contrast to the significant relations found between anticipatory contralateral mu ERD and executive function. However, alpha ERSP evoked by the visual cue at ipsilateral and contralateral posterior sites was associated with the mu ERSP evoked by the target tactile stimulus. Further, ipsilateral alpha ERSP was associated with children's age, such that older children exhibited less alpha modulation in the ipsilateral posterior electrode site. These findings are consistent with the interpretation of ipsilateral alpha-range responses to a stimulus serving as an indicator of gated sensory processing, speculated to inhibit the allocation of attention to a visual stimulus presented at the uncued spatial location. Our results are also consistent with behavioral accounts of protracted development of distractor inhibition (Plebanek and Sloutsky, 2017; Ristic and Kingstone, 2009) and prior cross-sectional investigations of oscillatory activity during visual selective attention (Murphy, Moholm, and Foxe, 2016). Further longitudinal investigation of the electrophysiological correlates of attention inhibition and deployment to visual stimuli (and stimuli presented in other modalities) which are relevant or irrelevant to spatial cues can directly address questions on the development of attention allocation separately from attention inhibition.

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