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Information Processing Efficiency and Regulation at Five Months

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Abstract

Infants with short look durations are generally thought to have better attentional capabilities due to their efficient information processing. Although effortful attention is considered a key component of developing regulatory abilities, little is known about the relation between speed and efficiency of processing and self-regulation. In this study, 5-month-old infants with shorter look duration had greater EEG power values than infants with longer look during baseline, as well as during a distressing task and a post-distress attentional processing task. These short looking infants also demonstrated higher heart rate, relative to long looking infants, during post-distress information processing. Behaviorally the two groups differed in the amount of distraction during distress. These data provide evidence for an association between the efficiency of information processing and beginning regulatory abilities in early infancy.

Keywords

Information Processing; Attention; Regulation; EEG; Heart Rate

1. Introduction

Look duration is commonly used as an indicator of infant visual attention and cognitive abilities (Colombo, 2004). Infants with shorter looks exhibit an adult-like processing pattern by first attending to the global aspects of stimuli followed by a focus on details (Colombo, Freeseman, Coldren & Frick, 1995). Infants who encode visual stimuli more slowly scan stimulus information less extensively and have more intervals of visual attention to only one aspect of a stimulus (Bronson, 1991). It may be that differences in the speed of encoding are produced by quantitative differences in neural organization, as well as the qualitative use of different strategies of attention processing (Frick & Colombo, 1996). This means that short lookers (SL) may be more receptive to the information available to them and, because SL attend more efficiently, they have the potential for greater learning about the visual environment (Ruff & Rothbart, 1996). Indeed, shorter look duration has been linked to higher IQ (Rose, Slater, & Perry, 1986) and better performance on discrimination and recognition memory tasks (Colombo, Mitchell, Coldren & Freeseman, 1991). Because attentional skills are critical to both cognitive and emotion processing (Jones, Rothbart, & Posner, 2003), it may be that SL are better at self-regulation than LL, in addition to having enhanced cognitive skills. The purpose of this study was to examine the neural and

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behavioral organization of SL and LL infants during attentional processing and during tasks that required regulation of distress.

Colombo and colleagues have provided evidence suggesting that individual differences in look duration are linked to the development of the neural attentional systems (e.g., the orienting network; Posner & Rothbart, 2007) that control the ability to disengage and shift attention elsewhere and/or the ability to effortfully inhibit visual fixation (Colombo, Richman, Shaddy, Greenhoot, & Maikranz, 2001; Frick, Colombo, & Saxon, 1999). Other neural attentional systems, such as the executive network (Posner & Rothbart, 2007) may play a role when the attentional demands are more effortful or when the situation involves an emotional component. Evidence with adults suggests that components of the frontal cortex serve to regulate both cognitive and emotion processing (Bush, Luu, & Posner, 2000). For example, the anterior cingulate has two major subdivisions to process cognitive and emotional information. The cognitive subdivision has interconnections with the prefrontal cortex, parietal cortex, and premotor and supplementary motor areas and is activated by tasks that involve choice selection from conflicting information (Banfield, Wyland, Macrae, Munte, & Heatherton, 2004; Bush et al., 2000). The emotion subdivision has interconnections with the orbitofrontal cortex, amygdala, and hippocampus, among other brain areas. Recent studies with adults point toward some interaction between cognition and emotion areas of the anterior cingulate on emotion-based Stroop-like tasks (Banfield et al., 2004; Bush et al., 2000). For the purposes of our work, there is much speculation suggesting that early regulation capabilities are facilitated by the development of the executive network and resultant improvements in attentional control (Rothbart, Derryberry, & Posner, 1994; Rothbart & Bates, 2006). This regulation – attention conceptual framework is supported by reports in the developmental literature of behavioral changes in attentional control paralleling dramatic increases in behavioral and emotional regulation during infancy (e.g., Jones et al., 2003; Kochanska, Murray & Harlan, 2000).

Neurologically, the electroencephalogram (EEG) can be used as an index for brain functioning associated with attention and concomitant regulatory skills (Rueda, Posner, & Rothbart, 2004). EEG power reflects the excitability of groups of neurons and is expressed in terms of picowatt ohms or microvolts squared (Nunez, 1981). Power represents a sustained trend of activity at a specific frequency band and is highly correlated from month to month during infancy (Bell & Fox, 1994). In infant EEG literature, increasing power values across age are considered a marker of brain maturation (for review see Bell & Fox, 1994). Furthermore, greater EEG activity typically is associated with greater cognitive and attentional processing during memory tasks (Bell, 2002; Bell & Wolfe, 2007). If the SL are indeed more neurologically mature (Colombo, 2004) and look duration shows test-retest reliability (Abelkop & Frick, 2003), then it may be significant that attentional advances parallel developing regulatory skills (Jones et al., 2003; Kochanska et al., 2000). This suggests that potential EEG differences between SL and LL may be present during resting baseline EEG recordings, as well as during attentional processing and regulation of distress. Thus, it may be that SL exhibit greater frontal EEG activity than LL infants.

Further evidence for neurological differences between SL and LL can be examined with the electrocardiogram. Lower heart rate (HR) during sustained attention has been associated with greater attention processing (Richards & Casey, 1992). Richards has speculated that the neural control of HR associated with effortful sustained attention originates from a cardio-inhibitory center located in the frontal cortex (Richards & Hunter, 1998). Colombo and colleagues have demonstrated, however, that longer periods of sustained attention (i.e., characterized by lower HR) are associated with longer periods of look duration (Colombo et al., 2001). Since LL encode visual stimuli more slowly and have more intervals of visual attention, they may demonstrate a lower HR than SL. In addition, longer looking infants have shown significantly greater HR changes to stimulus onsets than shorter looking infants, connecting arousal to individual differences in look duration (Maikranz, Colombo, Richman, & Frick, 2000). An increase in HR reactivity at onset of stimulus presentation may be delaying the initiation of visual processing and encoding leading to longer periods of sustained attention and lower HR activity for LL compared to SL infants (Colombo & Mitchell, 2008). This look duration and visual information processing association may have implications for the processing of emotion as well. Laboratory studies have shown positive affect to be correlated with long look durations and slower learning in 5-, 7-, and 9-month old infants, whereas short looks and neutral affect correspond with analytical processing (Rose, Futterweit, & Jankowski, 1999). Self-regulation of affect may be associated with the speed of processing differences implicated in SL and LL infants. Thus, it may be that LL exhibit lower HR than SL during the attention and distress tasks. There is no prior evidence that SL and LL will exhibit HR differences at baseline.

This study focused on associations among infant attention, regulation, and neural organization measured via EEG, HR and behavior. We studied 5-month-old infants because they are considered to still require external assistance with regulation (Kopp, 1982; Kopp & Neufeld, 2003). We hypothesized that SL would have greater frontal EEG power values than LL, not only during baseline, but also during attentional and regulation tasks due to their advanced processing and encoding skills. We also hypothesized that LL would demonstrate a lower HR than SL during attentional and regulation tasks due to their delayed processing and encoding skills. SL infants were hypothesized to demonstrate more regulation behaviors than LL while in distress. We reasoned that individual differences in look duration could be measured physiologically and that it is the infant's neural organization that is associated with self-regulation. Thus, the neurological foundations for early regulatory abilities associated with SL may be evident via EEG and HR prior to behavioral manifestations of self-regulation.

2. Method

Participants of this study are part of an ongoing longitudinal examination of cognition and emotion from infancy through early childhood. This report focuses on the initial visit when the infants were 5 months old. The participants were 106 full-term, healthy infants (50 boys, 56 girls) and their mothers (99 Caucasian, 2 African American, 3 Asian American, 2 Hispanic) recruited from two university towns in the southeastern portion of the United States. Infants were seen no later than three weeks after their 5-month birth date. All infants were born to parents with a high school diploma. College degrees or higher were held by 72% of the mothers and 66% of the fathers. Mothers were 29.63 years of age (range 20–38) and fathers were 32.95-years-old at their infant's birth (range 23–52).

2.1 Procedures

The infant sat on mother's lap and was distracted with toys in order for the research assistants to place the electrodes on the scalp and chest for electrophysiology recordings. Electrodes remained on the infant's scalp and chest during the entire procedure. The session was videotaped for coding purposes. One minute of baseline physiology was recorded and then the infant participated in memory tasks that are not part of this report. Associated with this report are the attention and regulation tasks that occurred after the memory tasks.

First, the infant was presented with a glove puppet and look duration assessed. Next the infant was placed in either a Sassy Seat or on a research assistant's lap at mother's discretion based on the infant's stability at sitting alone. During the toy removal task, mother and infant played with a busy box infant toy for 45 seconds and then mother removed the toy from her infant's reach while refraining from interaction. Infant regulatory behaviors were measured during toy removal. For infants who were not distressed to the point of hard crying during toy removal, mother was asked to restrain her infant's movement during an arm restraint task. Regulation behaviors were measured during this task as well. If an infant protested by crying continuously for more than 10 seconds during either task, the task was stopped. Finally, a 45-second Sesame Street video clip was used as a physiological measure of self-regulation after distress.

2.1.1 EEG recordings—Upon arrival to the research laboratory, the EEG electrodes were placed on the infant's head and one minute of baseline physiology was recorded while the infant sat on mother's lap and watched a research assistant manipulate a toy containing brightly colored balls on top of the testing table 1.1 m in front of the infant. This procedure quieted the infant and yielded minimal eye movements and gross motor movements which allowed the infant to tolerate the EEG cap (Bell, 2001, 2002). EEG also was recorded during the attention and regulation tasks detailed below. Mothers were instructed not to talk or interact with their infant during the tasks.

EEG was recorded using a stretch cap (Electro-Cap, Inc.) with electrodes in the traditional 10/20 pattern (Jasper, 1958), with Cz as the recording reference. After the cap was placed on the head, the recommended procedures regarding EEG data collecting with infants was followed (Pivik et al., 1993). Specifically, a small amount of abrasive gel was placed into each recording site and the scalp gently rubbed. Next, conductive gel was placed in each site and the scalp gently rubbed. Electrode impedances were measured and accepted if they were below 10K Ohms. The electrical activity from each lead was amplified using separate SA Instrumentation Bioamps and bandpassed from 1 to 100 Hz. Activity for each lead was displayed on the computer monitor. The EEG signal was digitized on-line at 512 samples per second for each channel so that the data would not be affected by aliasing. The acquisition software utilized was Snapshot-Snapstream (HEM Data Corp.) and the raw data was stored for later analyses.

EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). Data was re-referenced via software to an average reference configuration. The electrode montage used in the present study was extensive enough to justify the use of an average reference (Marshall, Bar-Haim, & Fox, 2002). The re-referenced were artifact scored for eye movements and gross motor artifact and these artifacts scored epochs were eliminated from all subsequent analyses. Three infants had too much gross motor artifact in the EEG recording throughout every task and seven other infants became too fussy to do the pre-distress task where look duration was assessed. Thus, 96 infants contributed EEG data to this study.

The data were analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1-second width and 50% overlap. Power was computed for the 6 to 9 Hz frequency band as this is the dominant frequency for infants (Bell & Fox, 1992; Marshall et al., 2002) and has been the focus of much infant research (e.g., Bell, 2002; Orekhova, Stroganova, & Posikera, 2001). EEG power is expressed as mean square microvolts and the data transformed using the natural log (ln) to normalize the distribution.

2.1.2 ECG Recording—Heart rate was measured from two neonatal disposable electrodes using modified lead II (right collarbone and lower left rib; Stern, Ray, & Quigley, 2001), grounded at the scalp near electrode cite Fz. The modified lead II is less sensitive to the gross motor movements than the standard leads, which are placed on the limbs. The heart rate signal was digitized at 512 samples per second and the resulting data file of inter-beat intervals, determined from the R waves, was stored for later analyses. The heart data were examined and analyzed using software developed by James Long Company and computed for each task.

2.1.3 Pre-Distress Attention Processing Task—Infants were presented with a glove puppet until they accrued four looks, each separated by a 3-second look away from the puppet (Diamond, Prevor, Callender & Druin., 1997). Research on visual paired comparison has shown the importance of infant controlled procedures (Diamond, 1990; Rose et al., 1982). If the stimulus is presented for a standard amount of time, that time may be too short or too long for some children to become properly familiarized. This task allows the stimulus to be available until each child reached their familiarized criterion. Behavioral coding of look duration was accomplished off-line using the Visual Coding System developed by James Long Company.

2.1.4 Distress Regulation Tasks—Using procedures used by Stifter (Stifter & Braungart, 1995; Stifter & Spinrad, 2002) and Calkins (Calkins, Dedmon, Gill, Lomax,, & Johnson, 2002), the mother and infant played with a busy box toy containing moving parts for 45 seconds. Mothers then were cued to remove the toy and hold it out of reach while maintaining a neutral facial expression and not interacting with their infant. The toy was held this way for 2 minutes or terminated after 10 seconds of hard crying. The regulation construct cannot be reliably studied unless infants have a need for self-regulation. At this point, mothers were cued to return the toy. If the infant did not stop crying after the toy was returned, the arm restraint task was eliminated and the experimenter immediately presented the short video clip associated with the post-distress processing task. Two cameras were used to record the procedure; one focused on the infant and the other on the mother-infant dyad.

The arm restraint procedure (Calkins et al., 2002; Stifter & Braungart, 1995; Stifter & Spinrad, 2002) was used to assess negative reactivity only if the toy removal did not elicit the need to self-regulate. The arm restraint task reliably produces short-term distress in infants and is prominently used in the developmental literature for this purpose (Calkins et al., 2002). Mothers were asked to face their infants and instructed to gently hold their infant's arms down at the infant's sides so that their arm movements would be restricted. Mothers were also instructed to maintain a neutral facial expression and use no vocalizations with their infant for a duration of 2 minutes, or after 10 seconds of hard crying. As with the toy removal task, two cameras were used to record the procedure; one focused on the infant and the other on the mother-infant dyad. The camera on the dyad captured the mother’s profile; thus we were unable to code whether or not the mother was looking at her infant.

2.1.5 Post-Distress Attention Processing Task—After the distress tasks and prior to maternal comforting, the infant was shown a 45-second video consisting of a musical segment from Sesame Street. This task was conceptualized as a behavioral and physiological measure of attentional processing. Behavioral coding of look duration was accomplished off-line using the Visual Coding System developed by James Long Company.

2.1.6 Behavioral Measures—Regulatory behaviors were coded using the Self-Regulation coding scheme (Calkins et al., 2002). The following behaviors were scored in 10-second epochs during each distress task. Self comforting included thumb sucking, hair-twirling, or other automanipulative behavior. Mother orienting included looking to mother, talking to or playing with mother, or touching/pulling on mother. Distraction was coded when the infant was attending to or manipulating an object other than the task object and does not include automanipulative behavior. Orienting to task object involved looking at, touching, or manipulating task object. Finally, scanning was coded when the infant was visually exploring the environment, with orienting duration on any object less than two seconds. The proportion of task epochs during which these five regulatory behaviors were exhibited are shown in Table 1.

Reliability coding was accomplished on 20 percent of the sample. The average adjusted kappas between each pair of coders were examined and determined to be acceptable: self comforting (.73), mother orienting (.77), distraction (.92), orienting to task object (.75) and scanning (.85).

3. Results

Median peak look to the glove puppet stimulus during the pre-distress attention processing task was used to classify infants as short lookers (SL) or long lookers (LL) (Maikranza et al., 2000). In several studies with 4-month-olds, the median peak look to a 2-dimensional photograph of a female face was between 10 and 15 seconds (Colombo et al., 1991). In our study the stimulus was a 3-dimensional puppet and median peak was 12.88 seconds. Thus, infants whose peak look was 12.88 seconds or above were classified as LL, whereas those whose peak look fell below 12.88 seconds were classified as SL.

3.1 Baseline EEG Activity

To test for look duration group differences in baseline EEG, a MANOVA with region (frontal pole (Fp1, Fp2); medial frontal (F3, F4); lateral frontal (F7, F8); central (C3,C4); anterior temporal (T3, T4); posterior temporal (T7,T8); parietal (P3, P4); and occipital (O1, O2)) and hemisphere (left, right) as the within-subjects factors and performance group (SL, LL) as the between-subjects factor was used. The dependent variable was baseline EEG ln power values at 6 to 9 Hz. Effects and interactions with group were the focus of the analyses.

There was a main effect for group ($F(1,93) = 3.93$, $p=.05$, $\eta^2 =.04$), with SL exhibiting greater EEG power values than LL during baseline. A one-way ANOVA was performed to distinguish which individual EEG electrodes contributed to the group main effect during baseline (Table 2). Results indicated SL had greater EEG power values than LL at frontal scalp sites (Fp1, Fp2, F7), as well as other locations (C3, T6).

3.2 Task-Related EEG Activity

EEG data were collected during several different types of tasks thought to require information processing demands potentially associated with regulation. MANCOVA was used to ensure that any group effects or interactions found in the task-related EEG were due to the processing requirements of the specific task being performed and not influenced by group differences in baseline EEG power values. The task EEG analyses mirrored the baseline EEG analysis. The within-subjects independent variables were region and hemisphere and the between-subjects factor was look duration group (SL and LL). The covariates were the baseline EEG power values for each electrode site. The effects and interactions involving look duration group were further examined with one-way ANCOVAs of the 16 electrode sites to pinpoint the scalp locations with group differences in task-related EEG power. A Bonferroni procedure was adopted to limit the familywise Type I error rate in the follow-up ANCOVAs. The adjusted p value was $\leq .003$ (.05/16 = .0003125).

For the pre-distress attention processing task, there was no main effect, as well as no interactions involving group (all p's > .19).

For the toy removal distress regulation task, there was a group by region interaction ($F(1,75) = 51.00$, $p=.04$, $\eta^2 =.23$). As shown in Table 3, the p-values failed to reach the adjusted significance level of .003 for the follow-up ANCOVA analyses.

For the arm restraint distress regulation task, there was a group by hemisphere interaction ($F(1,58) = 4.33$, $p=.04$, $\eta^2 =.10$). The arm restraint procedure was used only if the toy removal did not elicit the need to self-regulate. Fifty-eight had artifact-free EEG data during the arm restraint task of whom 28 were SL and 30 LL. As shown in Table 3, ANCOVA analyses demonstrated that the SL had greater EEG power values than the LL at the left hemisphere frontal (F4, F8) and parietal (P4) sites.

During the post-distress attention processing task, there was a main effect of group ($F(1,82) = 6.25$, $p=.02$, $\eta^2 =.09$). As shown in Table 3, ANCOVA analyses demonstrated that the SL had greater EEG power values than the LL at frontal (F7, F8) as well as other (C4, T6) scalp locations.

3.3 HR Activity

To test for further physiological differences between the look duration groups, a one-way ANOVA was performed on the baseline and task-related HR values. The group means during baseline and each task, as well as the *F*-statistics, are shown in Table 4. There were no group differences in baseline heart rate. Likewise, there were no group differences in HR during the pre-distress attention processing task, toy removal, and arm restraint tasks. There were group differences, however, in HR during the post-distress attention processing task, with LL having lower HR than SL.

3.4 Regulation Behaviors

One-way ANOVA was used to examine if SL and LL demonstrate different regulation behaviors while in distress. The behavioral means are shown in Table 4. SL demonstrated more distraction than LL during toy removal. There were no other group differences in regulation behaviors during the distress tasks.

3.5 Post Distress Attention

For the post-distress attention processing task, there were no differences in look duration between SL (M =58.9, SD =26.12) and LL (M = 65.57, SD = 24.41; $F(1,92) = 1.63$, $p=.21$). 4.

Discussion

This study investigated individual differences in look duration and associations with attentional systems and regulation in infancy. Although SL are generally thought to have better cognitive capabilities due to their efficient information processing, little is known about the relation between speed of processing and self-regulation in non-cognitive domains. Accordingly, look duration was investigated both behaviorally and electrophysiologically to see its association with regulation during distress.

Differences in EEG were evident between SL and LL during baseline. SL had greater EEG power than LL across multiple EEG scalp locations. However, after accounting for baseline EEG power, there were no group EEG differences evident during a pre-distress task attentional task. During the distress of the arm restraint task and immediately afterwards during a post-distress attentional task, SL exhibited greater EEG power values relative to the LL above and beyond the group difference seen during resting baseline. This pattern of increases in EEG power values during a task has also been reported for various cognitive processes during infancy, including working memory (Bell, 2001, 2002), recall memory (Morasch & Bell, 2009), and controlled attention (Orekhova et al., 2001). When brain electrical activity is recorded during task performance, the better performing infants exhibit frontal brain electrical activity values that increase from baseline to task, whereas the infants with poorer performance have values that are comparable from baseline to task. This is interpreted as the electrophysiology associated with effortful cognitive processing. The same interpretation may be used here. When the SL infants were faced with duress, they used their efficient information processing skills and their effortful control of attention to regulate. This processing was manifested in the EEG differences between the SL and LL groups during arm restraint.

An interesting pattern emerged in the HR differences between the groups during the post-distress attentional task. There were no differences in looking behavior during the post-distress task and yet LL had lower HR than SL. Differences had been expected during the distress tasks, but not during post-distress. Although we focused on associations between HR and attentional processing, it may be that the group differences in HR during post-distress were due to arousal during the distress tasks. However, our EEG and behavioral regulation findings suggest that the SL infants were employing regulatory strategies during distress and thus should not have been more aroused. These group differences in post-distress HR deserve further investigation.

Behavioral differences between SL and LL were not as strong as the electrophysiological differences. The one behavior that the groups did differ on was critical, however. During toy removal, SL had higher levels of distraction, meaning that they were able to periodically disengage from the task object (i.e., the toy which had been pulled out of reach). LL had lower levels of distraction and thus were not able to refocus to other aspects of the situation to better help with regulation. Being distractible means that SL were able to disengage their attention more efficiently and were more receptive to the information available around them.

According to McCall (1994), disengaging fixation and inhibiting uninformative stimuli quickly and efficiently involves the capacity to direct attention to other aspects of the environment which may be more informative. LL may not have developed this ability yet as they are still relying on only the local information with prolonged fixations on the source of frustration during distress. Ruff and Rothbart (1996) consider attention part of the larger construct of self-regulation, with individual differences in attention impacting the degree of success in the development of regulatory abilities. The inherent behavioral, but especially physiological bias SL have at 5 months of age may have impacted the foundations of developing such skills. These results lend further evidence to quantitative and qualitative differences in how SL and LL process visual information, as well as provide impetus for future investigations of individual differences in look duration as a correlate of self-regulatory behaviors.

4.1 Caveats and Future Studies

This study is not without its limitations, the most important being that the camera on the dyad only captured the mother’s profile. Thus, we were unable to code whether or not the mother was looking at her infant. The rich history of the still-face procedure has provided invaluable information regarding infants’ strong negative reaction to maternal neutral nonresponsive eye contact (e.g., Adamson & Frick, 2003). Because we did not capture maternal gaze, we cannot account for individual differences in distress due to maternal behavior.

Future studies should also investigate the relation between look duration and regulation at different points of development, as attentional systems associated with frontal functioning have an extensive developmental process. For instance, at around 10 months of age substantial advancements in attention control (Ruff & Rothbart, 1996), cognitive control (Diamond et al, 1997), and regulation of emotions (Calkins et al., 2002; Kopp & Neufeld, 2003) have been reported. It would be informative to examine how associations between information processing and self-regulation change with development throughout infancy and early childhood (Bell & Deater-Deckard, 2007).

4.2 Conclusion

The findings from this study provide evidence of an association between look duration and regulation in infancy. Look duration, associated with efficiency of information process, was linked to electrophysiological (EEG, HR) and behavioral regulation techniques. These findings suggest that physiological aspects of regulation during distress and immediately afterwards may be evident in some infants prior to the behavioral manifestations of self-regulatory behaviors.

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Table 1

Summery Scores for Emotion Regulation Variables

	Mean	**SE**	**Range**
Toy Removal (N = 92)			
Self-Comforting	.21	.03	0 – 1
Mother Orienting	.33	.03	0 – .92
Distraction	.37	.03	0 – 1
Orienting to Task	.65	.03	0–1
Scanning	.49	.03	0 – 1
	Mean	SE	Range
Arm Restraint (N = 73)			
Self-Comforting	.06	.02	0– 1
Mother Orienting	.37	.04	0 – 1
Distraction	.37	.04	0 – 1
Scanning	.50	.04	0 – 1

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Table 2

Baseline EEG Differences between SL and LL at Specific Scalp Locations

Electrodes	SL Mean (SD)	LL Mean (SD)	F-statistic	*p*-value	η^2
df 1, 95					
Fp1	2.16(.56)	1.80(.58)	9.46	**.003**	.09
Fp2	2.12(.57)	1.84(.71)	4.47	**.04**	.05
F3	2.06(.50)	1.85(.60)	3.23	.08	.03
F4	2.14(.44)	1.97(.65)	2.26	.14	.02
F7	2.33(.45)	2.08(.53)	6.50	**.01**	.07
F8	2.28(.49)	2.07(.60)	3.45	.07	.04
C3	2.53(.70)	2.21(.70)	4.91	**.03**	.05
C4	2.48(.54)	2.24(.70)	3.33	.07	.04
T3	2.46(.53)	2.22(.71)	3.41	.07	.04
T4	2.43(.47)	2.28(.65)	1.68	.20	.02
T5	2.68(.45)	2.50(.71)	2.10	.15	.02
T6	2.80(.43)	2.54(.67)	5.23	**.02**	.05
P3	2.50(.67)	2.32(.60)	1.90	.17	.02
P4	2.59(.50)	2.46(.68)	1.06	.31	.01
O1	2.88(.58)	2.73(.73)	1.23	.27	.01
O2	2.86(.44)	2.79(.65)	.38	.54	.004

Table 3

Task-related EEG Differences between SL and LL at Specific Scalp Locations Controlling for Baseline EEG

	Electrodes	SL Mean (SD)	LL Mean (SD)	F-statistic	*p*-value	η^2
df 1, 76			Toy Removal			
	Fp1	2.42(.67)	2.33(.79)	.96	.33	.01
	Fp2	2.35(.67)	2.27(1.00)	.78	.38	.01
	F3	2.32(.47)	2.04(.54)	1.17	.28	.02
	F4	2.45(.54)	2.10(.53)	2.51	.12	.03
	F7	2.73(.76)	2.44(.48)	.91	.34	.01
	F8	2.56(.54)	2.30(.45)	.56	.46	.008
	C3	2.69(.66)	2.35(.59)	1.64	.20	.02
	C4	2.71(.59)	2.37(.56)	3.64	.06	.05
	T3	2.91(.88)	2.57(.65)	.13	.72	.002
	T4	2.95(.86)	2.70(.62)	.27	.61	.004
	T5	3.06(.67)	3.08(1.06)	.60	.44	.008
	T6	3.18(.62)	2.81(.53)	1.09	.25	.02
	P3	2.85(.99)	2.55(.53)	.49	.49	.007
	P4	2.79(.79)	2.67(.61)	.05	.83	.001
	O1	3.38(.60)	3.14(.61)	1.21	.28	.02
	O2	3.29(.51)	3.08(.58)	1.03	.31	.01
df 1, 58			Arm Restraint			
	Fp1	2.79(1.06)	2.10(1.07)	2.77	.10	.05
	Fp2	2.59(.79)	2.07(.93)	.98	.33	.02
	F3	2.38(.64)	1.95(.47)	6.69	.01	.11
	F4	2.58(.55)	1.87(.61)	16.73	**<.001**	.23
	F7	2.67(.59)	2.32(.60)	.87	.35	.02
	F8	2.82(.68)	2.11(.59)	14.49	**<.001**	.21
	C3	2.68(.86)	2.26(.53)	.92	.34	.02
	C4	2.69(.76)	2.21(.65)	2.95	.09	.05
	T3	2.99(.71)	2.52(.67)	2.45	.12	.04
	T4	2.91(.60)	2.52(.70)	1.18	.28	.02

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	Electrodes	SL Mean (SD)	LL Mean (SD)	F-statistic	*p*-value	η^2
	T5	2.97(.59)	2.88(.65)	.06	.81	.001
	T6	3.26(.56)	2.69(.52)	4.40	.04	.07
	P3	2.80 (.90)	2.37(.80)	2.96	.09	.05
	P4	2.95(.73)	2.51(.53)	9.40	**.003**	.14
	O1	3.42(.73)	2.94(.66)	7.24	.009	.12
	O2	3.37(.62)	2.89(.82)	4.99	.03	.08
df 1, 82			Post-Distress			
	Fp1	2.60(.96)	2.12(1.04)	.15	.70	.00
	Fp2	2.27(.57)	1.95(.89)	1.04	.31	.01
	F3	2.20(.44)	1.79(.54)	8.23	.005	.09
	F4	2.36(.50)	1.94(.69)	5.04	.03	.06
	F7	2.66(.65)	1.05(.54)	11.12	**.001**	.12
	F8	2.45(.47)	2.00(.47)	9.75	**.003**	.11
	C3	2.62(.60)	2.14(.61)	5.89	.02	.07
	C4	2.69(.65)	2.14(.53)	10.64	**.002**	.12
	T3	2.66(.79)	2.12(.56	6.21	.02	.07
	T4	2.68(.56)	2.23(.66)	5.14	.03	.06
	T5	2.90(.77)	2.63(.81)	1.04	.31	.01
	T6	3.20(.60)	2.56(.52)	12.08	**.001**	.13
	P3	2.68(.75)	2.14(.46)	8.90	.004	.10
	P4	2.78(.76)	2.29(.50)	3.89	.05	.05
	O1	3.09(.66)	2.86(.57)	1.89	.17	.02
	O2	3.13(.58)	2.88(.54)	3.68	.06	.05

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Table 4

Baseline and Task-related HR Differences between SL and LL

	SL Mean(SD)	LL Mean (SD)	F-statistic	*p*-value	η^2
df 1, 87		Baseline			
	137.86(23.76)	137.31(9.36)	.02	.88	.00
df 1, 84		Pre-Distress			
	142.00(11.00)	138.53(8.21)	2.75	.10	.03
df 1, 69		Toy Removal			
	148.91(10.40)	149.52(9.68)	.07	.80	.001
df 1, 55		Arm Restraint			
	155.53 (11.61)	153.50 (16.14)	.27	.61	.005
df 1, 76		Post-Distress			
	151 .54(15.55)	144.56(12.63)	4.66	**.03**	.06

Table 5

SL and LL Differences in Behavior Regulation during Distress Tasks

Toy Removal	**SL Mean(SD)**	**LL Mean(SD)**	**F-statistic**	***p*-value**	**η^2**
df 1, 90					
Self Comforting	.20(.26)	.21(.44)	.02	.90	.00
Mother Orienting	.28(.24)	.37(.26)	2.38	.13	.03
Distraction	.43(.31)	.31(.28)	4.51	**.04**	.05
Orienting to Task Object	.66(.33)	.64(.34)	.01	.93	.00
Scanning	.48(.28)	.49(.28)	.04	.84	.00
Arm Restraint	SL Mean(SE)	LL Mean(SE)	F-statistic	*p*-value	η^2
df 1, 68					
Self Comforting	.05(.12)	.06(.20)	.07	.80	.00
Mother Orienting	.30(.30)	.42(.34)	2.24	.14	.03
Distraction	.43(.32)	.33(.38)	1.00	.32	.02
Scanning	.57(.37)	.44(.35)	2.00	.16	.03