**SUPPORTS SENSORY MODULATION FOR ATTAINING AND MAINTAINING A REGULATED STATE**

This section will include summaries of articles on arousal and the neurobiology of arousal…suggesting that optimal arousal level is important for learning to occur.

**2019**

**Lim, H. A. & Park, H. (2018). The effect of music on arousal,**

 **enjoyment, and cognitive performance. *Psychology of Music,***

***47*(4), 539-550. doi:10.1177/0305735618766707.**

The present study examined the relationship between arousal and cognitive performance after musical experience via different music activities. Participants performed four musical tasks as music activities – listening, singing, rhythm tapping, and keyboard playing – in addition to a non-musical task. In order to examine music-induced arousal, the arousal level of each participant was measured before and after the musical task. Participants’ recall of lyrics was measured, along with the ratings on the task difficulty and enjoyment of the musical task. While arousal changed after active musical tasks, the arousal change did not contribute to recall. Instead, an indirect relationship between arousal and recall was found: arousal change after a musical task was related to enjoyment of the task and enjoyment mediated the relationship between arousal and recall by predicting recall. These results do not support the direct effect of music on recall. Instead, the present findings suggest that enjoyment of musical experience plays a critical role in the relationship between music-induced arousal and memory.

**Hyde, J., &amp; Garcia-Rill, E. (2019). Autism and arousal. *Arousal in***

 ***Neurological and Psychiatric Diseases*, *6,* 83-114.**

**doi:10.1016/b978-0-12-817992-5.00006-4.**

Autism spectrum disorder (ASD) is a neurological condition with no known cause or cure and generates lifelong effects. Autism is a highly heterogeneous condition with a spectrum of phenotypes including poor social skills, disrupted communication skills, and aberrant behavior. Current Center for Disease Control data suggest that 1 out of 59 children are diagnosed with ASD with a lifetime cost of nearly $2.4 million dollars per family. This chapter discusses earlier and recent findings on the neurobiological basis of ASD, clinical presentation, and treatment with particular emphasis on sensory gating and arousal. Addressing the dysregulation of vigilance in this disorder may be a key to successful treatment.

**Hoogerheide, V., Renkl, A., Fiorella, L., Paas, F., & Gog, T. V. (2019).**

 **Enhancing example-based learning: Teaching on video increases**

 **arousal and improves problem-solving performance. *Journal of***

***Educational Psychology, 111*(1), 45-56.**

**doi:10.1037/edu0000272.**

Recent findings show that after studying a text, teaching the learned content on video to a fictitious peer student improves learning more than restudying the content. This benefit may be in part due to increased arousal associated with the teaching activity. The present experiment investigated whether teaching on video is also effective for acquiring problem-solving skills from worked examples, and explored the role of cognitive load, worry, and arousal. Participants (N = 61 university students) first studied two worked examples on electrical circuits troubleshooting and completed a practice problem. Then they either taught the content of a worked example of the practice problem on video (teaching condition) or studied that worked example (control condition) for the same amount of time. Self-reported cognitive load was measured after each task and self-reported worry after the final task. Effects on arousal were explored via the Empatica wristband measuring electrodermal activity (EDA; i.e., galvanic skin response). Teaching the content of the worked example on video was not associated with more worry, but did result in higher perceived cognitive load, more arousal, and better performance on isomorphic and transfer problems on the posttest. Although this finding has to be interpreted with caution, teaching also seemed to moderate the effect of prior knowledge on transfer that was present in the study condition. This suggests that teaching is particularly effective for students who initially have low prior knowledge.

**Rietz, E. D., James, S., Banaschewski, T., Brandeis, D., Asherson, P.,**

 **& Kuntsi, J. (2019). Autonomic arousal profiles in adolescents**

**and young adults with ADHD as a function of recording context.**

***Psychiatry Research, 275,* 212-220.**

**doi:10.1016/j.psychres.2019.03.039.**

A recent study (James et al. 2016) found that attention-deficit/hyperactivity disorder (ADHD) was associated with hypo-arousal, indexed by low electrodermal activity, during a low-demand reaction-time task, which normalized in a fast-incentive condition. We now investigate if (1) autonomic arousal in individuals with ADHD changes over a long testing session and (2) across time, to clarify if arousal profiles are context-dependent. We also examine (3) how autonomic arousal relates to each ADHD symptom domain, and specificity of arousal profiles to ADHD, by controlling for oppositional defiant/conduct disorder (ODD/CD) symptoms. Skin conductance level and non-specific fluctuations were measured during four successive resting-state and cognitive conditions (Resting-state time 1, Continuous Performance Task, Fast Task: Baseline and Fast-Incentive conditions, Resting-state time 2) from 71 adolescents/young adults with ADHD and 140 controls. Lower arousal was observed in individuals with ADHD only during a slow, low-demanding task, and more fluctuating arousal was observed towards the end of assessment. Both inattentive and hyperactive-impulsive symptoms were associated with arousal levels and fluctuations, independently from ODD/CD. Overall, we extend previous findings showing that under-arousal, but also fluctuating arousal, are context-specific rather than stable impairments in ADHD.

**Hoyer, R., Elshafei, H., Hemmerlin, J., Bouet, R., & Bidet-Caulet, A.**

 **(2019). Why are children so distractible? Development of**

**attentional capacities and phasic arousal from childhood to**

**adulthood. doi:10.1101/747527.**

Distractibility is the propensity to behaviorally react to irrelevant information in a world flooded with sensory stimulation. Children are more distractible the younger they are. The precise contribution of attentional and motor components to distractibility and their developmental trajectories have not been characterized yet. We used a new behavioral paradigm to identify the developmental dynamics of components contributing to distractibility in a large cohort of participants (N=352; age range: 6-25). We assessed the specific developmental trajectories of voluntary attention and distraction, as well as impulsivity and motor control. Our results reveal that each of these components present distinct maturational timelines. These findings show that in young children, increased distractibility is mostly the result of reduced sustained attention capacities and enhanced distraction, while in teenagers, it is the result of decreased motor control and increased impulsivity.

**Nakagawa, A., & Sukigara, M. (2019). Early development of**

 **attentional disengagement and phasic alertness. *Infant Behavior***

 ***and Development, 55*, 38-45. doi:10.1016/j.infbeh.2019.02.004.**

Attention development is a critical foundation for cognitive abilities. This study examines the relationship between phasic aspects of alertness and disengagement in infants, using the overlap paradigm. Research shows that visual disengagement in overlap condition is modulated by auditory cues in 6-year-olds. Our participants were aged 6 months (N = 20), 12 months (N = 27), and 24 months (N = 14). Phasic alertness during overlap and no-overlap tasks was manipulated using a spatially nondirective warning signal shortly before onset of the peripheral target. Responses in overlap condition were slower and fewer than in no-overlap condition. The signal showed a tendency to reduce latencies in both overlap and no-overlap conditions. While our hypothesis that the warning signal might be more effective in younger infants was not supported, we confirmed the association reported in previous studies between temperamental soothability and disengagement latencies in infancy.

**Tam, S. K., Bannerman, D. M., & Peirson, S. N. (2020). Mechanisms**

 **mediating the effects of light on sleep and alertness: Current**

**challenges. *Current Opinion in Physiology, 15*, 152-158.**

**doi:10.1016/j.cophys.2020.01.005.**

Light is an important environmental cue that exerts a direct and potent effect on vigilance states. In humans, light exposure increases subjective alertness and activates brain regions that are involved in promoting wakefulness. The spectral characteristics of these alerting effects of light are consistent with a role of melanopsin-expressing photosensitive retinal ganglion cells (pRGCs) in mediating non-visual responses to light. In photophobic nocturnal rodents, light exposure can be anxiogenic and increase alertness in some studies, but in other studies it clearly induces sleep and reduces body temperature, heart rate, and locomotor activity. In this review, we propose several factors that may influence whether light has an alerting or sleep-promoting effect in mice. These include preceding sleep history, preceding light history, as well as the behavioural context in which light stimuli are delivered.

**Barber, A. D., John, M., Derosse, P., Birnbaum, M. L., Lencz, T., &**

 **Malhotra, A. K. (2020). Parasympathetic arousal-related**

**cortical activity is associated with attention during cognitive task**

**performance. *NeuroImage, 208,* 1-12.**

**doi:10.1016/j.neuroimage.2019.116469.**

Parasympathetic arousal is associated with states of heightened attention and well-being. Arousal may affect widespread cortical and subcortical systems across the brain, however, little is known about its influence on cognitive task processing and performance. In the current study, healthy adult participants (n ​= ​20) underwent multi-band echo-planar imaging (TR ​= ​0.72 ​s) with simultaneous pulse oximetry recordings during performance of the Multi Source Interference Task (MSIT), the Oddball Task (OBT), and during rest. Processing speed on both tasks was robustly related to heart rate (HR). Participants with slower HR responded faster on both the MSIT (33% variance explained) and the OBT (25% variance explained). Within all participants, trial-to-trial fluctuations in processing speed were robustly related to the heartbeat-stimulus interval, a metric that is dependent both on the concurrent HR and the stimulus timing with respect to the heartbeat. Models examining the cardiac-BOLD response revealed that a distributed set of regions showed arousal-related activity that was distinct for different task conditions. Across these cortical regions, activity increased with slower HR. Arousal-related activity was distinct from task-evoked activity and it was robust to the inclusion of additional physiological nuisance regressors into the models. For the MSIT, such arousal-related activity occurred across visual and dorsal attention network regions. For the OBT, this activity occurred within fronto-parietal regions. For rest, arousal-related activity also occurred, but was confined to visual regions. The pulvinar nucleus of the thalamus showed arousal-related activity during all three task conditions. Widespread cortical activity, associated with increased parasympathetic arousal, may be propagated by thalamic circuits and contributes to improved attention. This activity is distinct from task-evoked activity, but affects cognitive performance and therefore should be incorporated into neurobiological models of cognition and clinical disorders.

**2018**

**Pallini, S., Vecchio, G. M., Baiocco, R., Schneider, B. H., & Laghi,**

 **F. (2018). Student–teacher relationships and attention problems**

**in school-aged children: The mediating role of emotion**

**regulation. School Mental Health, 11(2), 309-320.**

**doi:10.1007/s12310-018-9286-z.**

The aim of this study was to explore the relationship between the quality of student–teacher relationship and attention problems, taking into account two different attention problems (Attention Dysregulation and Attentive Detachment), and the mediating role of Emotion Regulation. Through a multi-informant methodology, teachers rated 161 school-aged children (87 boys and 74 girls) using the Emotion Regulation Checklist, Teacher’s Report Form, and Student–Teacher Relationship Scale, and observers rated the same children on attentive behavior in class using the Child’ s Attention Scale. Results demonstrated the influence of the student–teacher relationship on attentional behavior, via the mediating role of Emotion Regulation. On dealing with children’s attention problems, it will be useful to strive for improving student–teacher relationships that in turn could foster their emotion and attention regulation.

**Zhang, D., Johnstone, S. J., Roodenrys, S., Luo, X., Li, H., Wang, E., . . . Sun, L. (2018). The role of resting-state EEG localized activation and central nervous system arousal in executive function performance in children with Attention-Deficit/Hyperactivity Disorder. *Clinical Neurophysiology,129*(6), 1192-1200. doi:10.1016/j.clinph.2018.03.009**

**Objective:** This study explored the relationships between resting-state electroencephalogram (RS-EEG) localized activation and two important types of executive functions (EF) to extend the prognostic utilization of RS-EEG in children with Attention-Deficit/Hyperactivity Disorder (AD/HD). Also, the role of central nervous system (CNS) arousal in the relationships was examined.

**Methods*:*** children with AD/HD participated in the study. RS-EEG localized activation was derived from spectral power differences between EEG in eyes-closed and eyes-open conditions. CNS arousal was measured based on alpha band power. Common and everyday EF scores were obtained as EF outcomes.

**Results*:*** Frontal delta activation predicted common EF ability and posterior alpha activation predicted everyday EF. A serial mediation analysis found that lower CNS baseline arousal was related to greater arousal and delta activation in series, which in turn related to worse common EF. A follow-up study found that baseline arousal was related to larger interference cost.

**Conclusions*:***RS-EEG is indicative of individual differences in two important types of EF in children with AD/HD. Lower CNS arousal may be a driving force for the poorer common EF performance.

**Significance:**The current study supports prognostic utilization of RS-EEG and AD/HD models that take resting brain activity into consideration in children with AD/HD

**Kuan, G., Morris, T., Kueh, Y. C., & Terry, P. C. (2018). Effects of relaxing and arousing music during imagery training on dart-throwing performance, physiological arousal indices, and competitive state anxiety. *Frontiers in Psychology,9*. doi:10.3389/fpsyg.2018.00014**

Music that is carefully selected to match the requirements of activities and the characteristics of individuals has been shown to produce significant impacts on performance enhancement ([Priest et al., 2004](https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00014/full#B32)). There is also evidence that music can enhance imagery ([Grocke and Wigram, 2007](https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00014/full%22%20%5Cl%20%22B9)), although few studies have investigated the effects of music on imagery in the context of sport skills. In the present study, the effects of relaxing and arousing music during imagery on dart-throwing performance, physiological arousal indices, and competitive state anxiety, were investigated among 63 novice dart throwers. Participants had moderate-to-high imagery ability and were randomly assigned to unfamiliar relaxing music (URM), unfamiliar arousing music (UAM), or no music (NM) groups. Performance was assessed by 40 dart throws at a concentric circles dartboard before and after 12 imagery sessions over 4 weeks. Measures of galvanic skin response (GSR), peripheral temperature (PT), and heart rate (HR) were taken during imagery sessions 1 and 12, and the Competitive State Anxiety Inventory-2 Revised (CSAI-2R) was administered prior to the pre- and post-intervention performance task. Dart-throwing gain scores were significantly higher for URM than for UAM and NM, with no significant difference between UAM and NM (URM = 37.24 ± 5.66, UAM = 17.57 ± 5.30, and NM = 13.19 ± 6.14, *F*2,62 = 5.03, *p* = 0.01, η2 = 0.14). GSR, PT, and HR reflected lower arousal for URM than for UAM or NM. Significant decreases in somatic anxiety were evident for URM and UAM but not NM. Significant decreases in cognitive anxiety were evident for URM and NM but not UAM. Significant increases in self-confidence were evident for URM but not UAM or NM. Performance improved in all three conditions but URM was associated with the largest performance gain, the lowest physiological indices of arousal, and the most positive CSAI-2R profiles. Listening to relaxing music during imagery may have benefits for performance in other fine motor skills.

**Jawinski, P., Kirsten, H., Sander, C., Spada, J., Ulke, C., Huang, J.,... Hegerl, U. (2018). Human brain arousal in the resting state: A genome-wide association study. *Molecular Psychiatry*. doi:10.1038/s41380-018-0052-2**

Arousal affects cognition, emotion, and behavior and has been implicated in the etiology of psychiatric disorders. Although environmental conditions substantially contribute to the level of arousal, stable interindividual characteristics are well-established and a genetic basis has been suggested. Here we investigated the molecular genetics of brain arousal in the resting state by conducting a genome-wide association study (GWAS). We selected N = 1877 participants from the population-based LIFE-Adult cohort. Participants underwent a 20-min eyes-closed resting state EEG, which was analyzed using the computerized VIGALL 2.1 (Vigilance Algorithm Leipzig). At the SNP-level, GWAS analyses revealed no genome-wide significant locus (p < 5E-8), although seven loci were suggestive (p < 1E-6). The strongest hit was an expression quantitative trait locus (eQTL) of TMEM159 (lead-SNP: rs79472635, p = 5.49E-8). Importantly, at the gene-level, GWAS analyses revealed significant evidence for TMEM159 (p = 0.013, Bonferroni-corrected). By mapping our SNPs to the GWAS results from the Psychiatric Genomics Consortium, we found that all corresponding markers of TMEM159 showed nominally significant associations with Major Depressive Disorder (MDD; 0.006 ≤ p ≤ 0.011). More specifically, variants associated with high arousal levels have previously been linked to an increased risk for MDD. In line with this, the MetaXcan database suggests increased expression levels of TMEM159 in MDD, as well as Autism Spectrum Disorder, and Alzheimer's Disease. Furthermore, our pathway analyses provided evidence for a role of sodium/calcium exchangers in resting state arousal. In conclusion, the present GWAS identifies TMEM159 as a novel candidate gene which may modulate the risk for psychiatric disorders through arousal mechanisms. Our results also encourage the elaboration of the previously reported interrelations between ion-channel modulators, sleep-wake behavior, and psychiatric disorders.

**2017**

**Prince, E. B., Kim, E. S., Wall, C. A., Gisin, E., Goodwin, M. S., Simmons, E. S., ... & Shic, F. (2017). The relationship between autism symptoms and arousal level in toddlers with autism spectrum disorder, as measured by electrodermal activity. *Autism*, *21*(4), 504-508.**

Electrodermal activity was examined as a measure of physiological arousal within a naturalistic play context in 2-year-old toddlers (*N* = 27) with and without autism spectrum disorder. Toddlers with autism spectrum disorder were found to have greater increases in skin conductance level than their typical peers in response to administered play activities. In the autism spectrum disorder group, a positive relationship was observed between restrictive and repetitive behaviors and skin conductance level increases in response to mechanical toys, whereas the opposite pattern was observed for passive toys. This preliminary study is the first to examine electrodermal activity levels in toddlers with autism spectrum disorder during play-based, naturalistic settings, and it highlights the potential for electrodermal activity as a measure of individual variability within autism spectrum disorder and early development.

**2016**

**Flom, M., Cohen, M., & Saudino, K. J. (2016). Tipping points? Curvilinear associations between activity level and mental development** in toddlers. *Journal of Child Psychology and Psychiatry*.

The Theory of Optimal Stimulation (Zentall & Zentall, *Psychological Bulletin*, 94, 1983, 446) posits that the relation between activity level (AL) and cognitive performance follows an inverted U shape where midrange AL predicts better cognitive performance than AL at the extremes.

**Methods:** We explored this by fitting linear and quadratic models predicting mental development from AL assessed via multiple methods (parent ratings, observations, and actigraphs) and across multiple situations (laboratory play, laboratory test, home) in over 600 twins (2- and 3-year olds).

**Results**: Only observed AL in the laboratory was curvilinearly related to mental development scores. Results replicated across situations, age, and twin samples, providing strong support for the optimal stimulation model for this measure of AL in early childhood.

### **Conclusions:** Different measures of AL provide different information. Observations of AL which include both qualitative and quantitative aspects of AL within structured situations are able to capture beneficial aspects of normative AL as well as detriments of both low and high AL.

**Barbaro, K. D., Clackson, K., & Wass, S. V. (2016). Infant attention is dynamically modulated with changing arousal levels. *Child Development,88*(2), 629-639. doi:10.1111/cdev.12689**

Traditional accounts of developing attention and cognition emphasize static individual differences in information encoding; however, work from Aston-Jones et al. suggests that looking behavior may be dynamically influenced by autonomic arousal. To test this model, a 20-min testing battery constituting mixed photos and cartoon clips was shown to 53 typical 12-month-olds. Look duration was recorded to index attention, and continuous changes in arousal were tracked by measuring heart rate, electrodermal activity, and movement levels. Across three analyses, we found that continuous changes in arousal tracked simultaneous changes in attention measures, as predicted by the Aston-Jones model. It was also found that changes in arousal tended to precede (occur before) subsequent changes in attention. Implications of these findings are discussed.

**Obradović, J. (2016). Physiological responsivity and executive functioning: Implications for adaptation and resilience in early childhood. *Child Development Perspectives*, *10*(1), 65-70.**

Knowledge of how physiological responsivity and executive functioning relate to adaptation and resilience in early childhood has improved dramatically over the last decade, yet most studies focus on only one of these processes. By highlighting new findings and ongoing research, in this article, I advocate for investigating the dynamic interplay among physiological arousal, executive functions, and contextual experiences. New analytic approaches advance the conceptualization and measurement of physiological response as a process that comprises both reactivity and recovery. I also offer strategies for capturing complexities in contextual influences through examination of stimulating experiences, unique proximal and distal pathways, nonlinear effects, and longitudinal cascade models. This work can improve our understanding of how young children cope with stressors, engage with challenges, and achieve the optimal arousal and well-regulated behavior that supports development and learning.

**Hegerl, U., Sander, C., & Hensch, T. (2016). Arousal regulation in affective disorders. In T. Frodl (Ed.), *Systems Neuroscience in Depression* (pp. 341-370). Elsevier San Diego.**

In this chapter a new concept will be introduced that links affective disorders and other psychiatric conditions to a disturbed regulation of brain arousal. After a short overview on terminological difficulties, theoretical models, and common means of assessments an electroencephalography (EEG)-based assessment approach, the Vigilance Algorithm Leipzig will be described, facilitating research on brain arousal regulation. Afterward, the arousal model of affective disorders will be described with respect to depression, mania, and attention deficit/hyperactivity disorder (ADHD).

**Huiberts, L. M., Smolders, K. C., & de Kort, Y. A. (2016). Non-image forming effects of illuminance level: Exploring parallel effects on physiological arousal and task performance. *Physiology & behavior*, *164*, 129-139.**

This study investigated diurnal non-image forming (NIF) effects of illuminance level on physiological arousal in parallel to NIF effects on vigilance and working memory performance. We employed a counterbalanced within-subjects design in which thirty-nine participants (mean age = 21.2; *SD* = 2.1; 11 male) completed three 90-min sessions (165 vs. 600 lx vs. 1700 lx at eye level) either in the morning (*N* = 18) or afternoon (*N* = 21). During each session, participants completed four measurement blocks (incl. one baseline block) each consisting of a 10-min Psychomotor Vigilance Task (PVT) and a Backwards Digit-Span Task (BDST) including easy trials (4–6 digits) and difficult trials (7–8 digits). Heart rate (HR), skin conductance level (SCL) and systolic blood pressure (SBP) were measured continuously.

The results revealed significant improvements in performance on the BDST difficult trials under 1700 lx vs. 165 lx (*p* = 0.01), while illuminance level did not affect performance on the PVT and BDST easy trials. Illuminance level impacted HR and SCL, but not SBP. In the afternoon sessions, HR was significantly higher under 1700 lx vs. 165 lx during PVT performance (*p* = 0.05), while during BDST performance, HR was only slightly higher under 600 vs. 165 lx (*p* = 0.06). SCL was significantly higher under 1700 lx vs. 165 lx during performance on BDST easy trials (*p* = 0.02) and showed similar, but nonsignificant trends during the PVT and BDST difficult trials. Although both physiology and performance were affected by illuminance level, no consistent pattern emerged with respect to parallel changes in physiology and performance. Rather, physiology and performance seemed to be affected independently, via unique pathways.

**2015**

**Chen, F. R., Raine, A., Glenn, A. L., & Granger, D. A. (2015). Hypothalamic pituitary adrenal activity and autonomic nervous system arousal predict developmental trajectories of children's’ comorbid behavior problems. *Developmental Psychobiology,58*(3), 393-405. doi:10.1002/dev.21379**

The combined effects of hypothalamic-pituitary-adrenal (HPA) axis activity and autonomic nervous system (ANS) arousal were examined on developmental trajectories of children's comorbid internalizing and externalizing problems. Participants were 394 urban dwelling, primarily African American, youth (50% male, age 11–12 years). Parent-reported child behavior problems were obtained initially, 3, 6, and 12 months later. Saliva samples (collected at the initial assessment) were assayed for cortisol (HPA) and alpha-amylase (ANS). Cross-domain latent class growth analysis identified a stable comorbid trajectory and four other distinct short-term developmental trajectories of internalizing and externalizing behavior problems. ANS arousal was negatively associated with the probability of stable comorbidity, but only among youth who also had *high* levels of HPA axis activity. Findings underscore the predictive value of the interaction of HPA axis activity and ANS arousal in differentiating children with stable comorbidity and have important implications for etiological theories and treatment outcome research. © *2015 Wiley Periodicals, Inc*. Dev Psychobiol 58: 393–405, 2016.

**Chen, F. R., Raine, A., Rudo-Hutt, A. S., Glenn, A. L., Soyfer, L., & Granger, D. A. (2015). Harsh discipline and behavior problems: The moderating effects of cortisol and alpha-amylase. *Biological psychology*, *104*, 19-27.**

Numerous studies link harsh discipline to adjustment problems in youth, yet not all individuals exposed to harsh discipline develop behavior problems. Contemporary theory suggests that this relationship could be moderated by individual differences in environmentally sensitive biological systems. This study investigated whether the interaction between [hypothalamic](http://topics.sciencedirect.com/topics/page/Hypothalamus)-[pituitary](http://topics.sciencedirect.com/topics/page/Pituitary_gland)-adrenal (HPA) activity and [autonomic nervous system](http://topics.sciencedirect.com/topics/page/Autonomic_nervous_system) ([ANS](http://topics.sciencedirect.com/topics/page/Autonomic_nervous_system)) arousal moderated the link between harsh discipline and behavior problems. Three saliva samples were collected on a single day from 425 inner city youth (50% male, age 11–12 years, 80% African American) and were later assayed for [cortisol](http://topics.sciencedirect.com/topics/page/Cortisol) (HPA) and alpha-[amylase](http://topics.sciencedirect.com/topics/page/Amylase) (ANS). Problem behavior was assessed by self- and parent-report using the Child Behavior Checklist. Youth also reported the level of harsh discipline that they experienced. Harsh discipline was positively associated with externalizing and internalizing problems only when there were asymmetrical profiles of HPA activity and ANS arousal. This pattern was evident for boys but not girls. Findings are discussed in relation to prevailing theories suggesting that biological susceptibility translates adversity into risk for behavior problems.

**Reynolds, S., Lane, S. J., & Mullen, B. (2015). Effects of deep pressure stimulation on physiological arousal. *American Journal of Occupational Therapy*, *69*(3), 6903350010p1-6903350010p5.**

Deep pressure stimulation has been used in therapeutic practice because of the assumption that it changes physiological arousal. The purpose of this study was to test the effects of deep pressure stimulation, applied with a Vayu Vest (Therapeutic Systems), on both autonomic arousal and performance in a normative adult sample. A repeated-measures, repeated-baseline design was used with participants completing a performance test before and after deep pressure application. A convenience sample of 50 adults participated in the study. Results showed that wearing the Vayu Vest for even short periods of time reduced sympathetic arousal and non-stimulus-driven electrical occurrences. Concomitant increases in parasympathetic arousal were found. Performance improvements were noted after wearing the Vayu Vest, potentially because of changes in arousal. We conclude that deep pressure stimulation is capable of eliciting changes in autonomic arousal and may be a useful modality in diagnostic groups seen by occupational therapy practitioners.

**2014**

**Chen FR., Raine A., Soyfer L., & Granger D. (2014). Interaction of adrenocortical activity and autonomic arousal on children’s externalizing and internalizing behavior problems. *Journal of Abnormal Child Psychology,* *43*(1), 189-202. doi:10.1007/s10802-014-9900-y**

The psychobiology of stress involves two major components, the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (ANS). Research has revealed the association between behavior problems and the psychobiology of stress, yet findings are inconsistent and few studies have addressed the moderate correlations between behavior problems. This study examines the individual and interactive effects of HPA and ANS on child behavior problems while taking into account the comorbidity of externalizing and internalizing problems. Four saliva samples were collected from each participant in a community sample (*N* = 429; aged 11–12 years; 50.49 % male), which were assayed for cortisol (HPA) and alpha-amylase, sAA (ANS). Children’s behavior problems were assessed using parent-report and self-report versions of thecChild Behavior Checklist. Latent variables were constructed to represent trait-like individual differences in cortisol and sAA. Low levels of HPA axis activity were associated with higher levels of both externalizing and internalizing problems, but only among children with low ANS arousal. The association between externalizing and internalizing problems diminished to non-significant after taking into account the influence of HPA axis activity and ANS arousal, which suggests that the psychobiology of stress explains a fair proportion of comorbidity of behavior problems. The findings support that interaction between HPA axis and ANS functioning has potential to clarify prior mixed findings and advance our understanding of the child behavior problems.

**Neuenschwander R., Roebers CM., & Blair C. (2014). Being optimally aroused matters: Effects of a weak stress manipulation on children’s executive functions are moderated by temperament and age. *Journal of Educational and Developmental Psychology, 4*(1), 194. doi:10.5539/jedp.v4n1p194**

We tested a core assumption of the bidirectional model of executive function (EF) (Blair & Ursache, 2011) indicating that EF is dependent on arousal. From a bottom-up perspective the performance on EF tasks is assumed to be curvilinearly related to arousal, with very high or low levels of arousal impairing EF. *N* = 107 4- and 6-year-olds’ performance on EF tasks was explored as a function of a weak stress manipulation aiming to raise children’s emotional arousal. EF (Stroop, Flanker, Go/no-go, and Backwards Color Recall) was assessed and stress was induced in half of the children by imposing a mild social-evaluative threat. Furthermore, children’s temperament was assessed as a potential moderator. We found that stress effects on children’s EF performance were moderated by age and temperament: 4-year-olds with high Inhibitory Control and high Attentional Focusing were negatively affected by the stressor. However, it is unclear whether these effects were mediated by self-reported arousal. Our findings disconfirmed the hypotheses that adverse effects of the stressor are particularly high in children high on emotional reactivity aspects of temperament and low on self-regulatory aspects of temperament. Further, 6-year-olds did not show any stress effects. Results will be discussed within the framework of the Yerkes-Dodson law and with regard to stress manipulations in children.

**Peifer, C., Schulz, A., Schachinger, H., Baumann, N., & Antoni, C. H. (2013). The relation of flow-experience and physiological arousal under stress: Can u shape it? PsycEXTRA Dataset. doi:10.1037/e574802013-204**

In this study, we investigate the relationship between stress and flow-experience with the help of psychophysiological arousal indicators. Whereas recent studies suggest a positive relation between flow and physiological arousal, so far nothing is known on the relation between flow and high arousal in response to a salient stressor. We here suggest that the relation of flow with sympathetic arousal and hypothalamic–pituitary–adrenal (HPA) axis activation follows an inverted u-curve rather than a linear function: moderate physiological arousal should facilitate flow-experience, whereas excessive physiological arousal should hinder flow. In order to experimentally stimulate high physiological arousal, we exposed 22 healthy male participants to a modified version of the Trier Social Stress Test. Then, participants had to perform a complex computer task for 60 minutes and to rate their flow-experience on the Flow Short-Scale directly after task completion. During the experiment, cortisol samples were taken every 15 minutes, and heart rate variability measures were assessed by continuous electrocardiography. We found an inverted u-shaped relationship of flow-experience with indices of sympathetic arousal and cortisol, whereas parasympathetic indices of heart rate control during stress were linearly and positively correlated with flow-experience. Our results suggest that moderate sympathetic arousal and HPA-axis activation and possibly a co-activation of both branches of the autonomic nervous system characterize task-related flow-experience.

**2011**

**Gower, A. L., & Crick, N. R. (2011). Baseline autonomic nervous system arousal and physical and relational aggression in preschool: The moderating role of effortful control. *International Journal of Psychophysiology,81*(3), 142-151. doi:10.1016/j.ijpsycho.2011.06.001**

The current study investigates whether established associations between physical aggression and low autonomic nervous system arousal, as indexed by heart rate and blood pressure, also apply to the study of the development of relational aggression. Baseline heart rate and blood pressure were collected in two samples of preschoolers, and teachers reported on classroom physical and relational aggression. In Study 1, lower systolic and diastolic blood pressure were related to increased engagement in relational aggression among older preschoolers. In Study 2, lower heart rate and blood pressure predicted increased engagement in classroom physical and relational aggression concurrently and across a preschool year in some cases. Low baseline arousal–aggression associations were strongest for children with poorer self-regulation abilities, whereas high self-regulation appeared to protect children with low heart rate and blood pressure from engagement in aggressive classroom behavior. These findings suggest the utility of examining baseline physiological measures in the study of relational aggression as well as physical aggression. Implications for interventions targeted to physical and relational aggression in early childhood are discussed.

**Kreibig, S. D., Wilhelm, F. H., Roth, W. T., & Gross, J. J. (2011). Affective modulation of the acoustic startle: Does sadness engage the defensive system? *Biological Psychology,87*(1), 161-163. doi:10.1016/j.biopsycho.2011.02.008**

It has been suggested that high arousal negative affective states, but not low arousal negative affective states, potentiate the startle response. Because sadness has generally been studied as a low arousal emotion, it remains unclear whether high arousal sadness would produce startle potentiation to a similar degree as high arousal fear. To address this issue, 32 participants viewed two sets of 10-min film clips selected to induce two affective states of high subjective arousal (fear, sadness) and a neutral state of low subjective arousal, while the eyeblink startle response associated with brief noise bursts was assessed using orbicularis oculi EMG. Larger blink magnitude was found for fearful than for sad or neutral clips. Implications for conceptualizing sadness are discussed.

**Bortoletto, M., Lemonis, M. J., & Cunnington, R. (2011). The role of arousal in the preparation for voluntary movement. *Biological Psychology,87*(3), 372-378. doi:10.1016/j.biopsycho.2011.04.008**

Planning and readiness for action are associated with pre-movement brain activity reflected in the readiness potential (RP). Previous research suggests that RP is affected by higher-order cognitive functions. The present study investigated the relationship between arousal and RP. Twenty participants performed a RP paradigm in which they executed self-paced movements approximately every 4–5 s. Participants’ arousal level was directly manipulated through interaction with the experimenter during the rest breaks preceding the movement task. Skin conductance level (SCL) differed between arousal conditions, indicating that the arousal manipulation was effective. RP was significantly higher under the low arousal than the high arousal condition. This arousal effect also changed depending on whether RP was measured at overall high or low levels of arousal. Our data indicate that arousal does not directly activate structures underlying action preparation. We suggest that the arousal effect may be mediated by the attentional resources allocated to the movement.

**Zheng, Y., Xu, J., Jia, H., Tan, F., Chang, Y., Zhou, L., . . . Qu, B. (2011). Electrophysiological correlates of emotional processing in sensation seeking. *Biological Psychology,88*(1), 41-50. doi:10.1016/j.biopsycho.2011.06.006**

Previous studies have consistently reported a relationship between sensation seeking and emotional reactivity. However, little is known about the neural correlates and the time course of emotional processing in sensation seeking. The present study addressed these issues by recording event-related potentials (ERPs) during an emotional oddball task. Valence effect was significant at N2, P3 and LPP whereas arousal effect was significant at P3 and LPP. More importantly, low sensation seekers (LSSs) exhibited an increased emotional N2 whereas high sensation seekers (HSSs) showed an enhanced emotional P3. Furthermore, the arousal effect was similar across the two groups, but the valence effect at N2 stage was significant in LSSs instead of HSSs. These findings suggest that LSSs tend to show a more active general alerting system toward emotional stimuli, particularly for negative stimuli, whereas HSSs tend to display a stronger preference for intense stimulation irrespective of the emotional valence.

**Lawson, A. L., Gauer, S., & Hurst, R. (2012). Sensation seeking, recognition memory, and autonomic arousal. *Journal of Research in Personality,46*(1), 19-25. doi:10.1016/j.jrp.2011.10.005**

Substantial evidence shows that sensation seeking impacts memory;

however, research has not examined how sensation seeking impacts automatic familiarity and conscious-controlled recollection memory systems. The present study (*N* = 80) examined high and low sensation seekers’ familiarity and recollection of high and low arousal images with negative valence using behavioral and skin conductance measures. Low sensation seekers had more accurate familiarity judgments to high than low arousal images, reflecting a heightened aversive motivational system. High sensation seekers showed an opposite pattern with memory enhancement for low arousal images, regardless of old–new status. The lack of any sensation seeking effects in relation to recollection judgments suggests that this personality trait is more influential on automatic than conscious controlled memory systems.

**Barnard, K. E., Broman-Fulks, J. J., Michael, K. D., Webb, R. M., & Zawilinski, L. L. (2011). The effects of physiological arousal on cognitive and psychomotor performance among individuals with high and low anxiety sensitivity. *Anxiety, Stress & Coping,24*(2), 201-216. doi:10.1080/10615806.2010.494328**

Information-processing models of anxiety posit that anxiety pathology is associated with processing biases that consume cognitive resources and may detract from one's ability to process environmental stimuli. Previous research has consistently indicated that high anxiety has a negative impact on cognitive and psychomotor performance. Anxiety sensitivity, or the fear of anxiety and anxiety-related arousal sensations, is an anxiety vulnerability factor that has been shown to play a role in the development and maintenance of panic attacks and panic disorder. However, relatively little is known regarding the potential impact of anxiety sensitivity on performance. In the present study, 105 college students who scored either high (≥24) or low (≤14) on the Anxiety Sensitivity Index were randomly assigned to complete a series of arousal-induction tasks or no activity, followed immediately by three cognitive and psychomotor performance tasks: digit span – backward, math fluency, and grooved pegboard. Results indicated that participants with high anxiety sensitivity performed comparably to individuals with low anxiety sensitivity on each task, regardless of arousal level.

**Prior to 2011**

**Veitch, J. A. (2001). Lighting Quality Contributions from Biopsychological Processes. *Journal of the Illuminating Engineering Society,30*(1), 3-16. doi:10.1080/00994480.2001.10748329**

Internal processes, both biological and psychological, are thought to mediate the relationships between luminous conditions and such behavioral outcomes as task performance, mood, social behavior, aesthetic judgements and satisfaction. This review paper summarizes the state of knowledge concerning mediating bio-psychological processes: visibility, photobiology, and stress and arousal. Visibility is well-understood and obviously relevant to lighting practice. Photobiology, however, is a new entrant to the realm of lighting research; its findings could have important implications for recommended illuminance levels if these were based on more than visibility. Stress and arousal, interrelated concepts, are popular notions, but close examination reveals only weak support for these mechanisms as explanations of lighting effects on behavior. The improved organization of research and increased predictive power that would result from clear exposition of theoretical mechanisms in lighting research holds promise for progress in linking research and application.

**Cosand, L. D., Cavanagh, T. M., Brown, A. A., Courtney, C. G., Rissling, A. J., Schell, A. M., & Dawson, M. E. (2008). Arousal, working memory, and conscious awareness in contingency learning. Consciousness and Cognition,17(4), 1105-1113. doi:10.1016/j.concog.2008.04.007**

There are wide individual differences in the ability to detect a stimulus contingency embedded in a complex paradigm. The present study used a cognitive masking paradigm to better understand individual differences related to contingency learning. Participants were assessed on measures of electrodermal arousal and on working memory capacity before engaging in the contingency learning task. Contingency awareness was assessed both by trial-by-trial verbal reports obtained during the task and by a short post-task recognition questionnaire. Participants who became aware had fewer non-specific skin conductance responses and tended to score higher on a digit span assessment. Skin conductance level was not significantly lower in the aware group than in the unaware group. These findings are consistent with studies showing that lower arousal and greater cognitive processing capacity facilitate conscious perception of a greater breadth of information within a scene or a task.

**Lee, T.R., Davis. J.M., Vye, N., & Bransford, J.D. (2008). Do higher levels of arousal predict better learning? An investigation of learning and physiological responses. *International Conference on Learning Sciences*, 72-74.**

The ability to connect new information to relevant, previously acquired knowledge can facilitate comprehension and memory. This study shows that the addition of person knowledge, or knowledge organized around familiar people, in the design of learning materials has the potential to improve learning while decreasing the amount of effort and attention exerted by the learner; this is measured through skin conductance levels as a physiological correlate of attention. Findings provide explanatory evidence for why people-focused methodologies, such as video cases or written case studies, contribute to longer-term benefits and improved learning.

**Dillon, D. G., & Labar, K. S. (2005). Startle modulation during conscious emotion regulation is arousal-dependent. *Behavioral Neuroscience,119*(4), 1118-1124. doi:10.1037/0735-7044.119.4.1118**

Conscious regulation of negative emotion has been shown to affect human eyeblink startle responses, but whether these results depend on modulation of arousal- or valence-based processes is unknown. The authors presented participants with negative, neutral, and positive pictures and directed them to enhance, maintain, and suppress emotional responses. On emotional picture trials, startle responses decreased as a function of cue in the following order: enhance > maintain > suppress. Analysis of negative and positive picture trials separately revealed similar patterns of startle modulation by emotion regulation. There were no effects of emotion regulation on neutral trials. Results indicate that arousal, not valence, may be critical to startle modulation via conscious emotion regulation.

**Kamijo, K., Nishihira, Y., Hatta, A., Kaneda, T., Kida, T., Higashiura, T., & Kuroiwa, K. (2004). Changes in arousal level by differential exercise intensity. *Clinical Neurophysiology,115*(12), 2693-2698. doi:10.1016/j.clinph.2004.06.016**

**Objective*:*** The purpose of the present study was to investigate the influence of exercise intensity on arousal level.

**Methods*:***Twelve subjects (22–33 years) performed a S1–S2 reaction time task consisting of warning stimulus (S1) and imperative stimulus (S2) in a control condition, and again after low, medium, and high intensity pedaling exercises. During this task, contingent negative variation (CNV) and spontaneous electroencephalogram before S1 were measured as indicators for arousal level.

**Results*:*** CNV amplitude after high intensity pedaling exercise was significantly smaller than after medium pedaling exercise. Compared to the control condition, relative power value of *α* waves increased after the high intensity exercise.

**Conclusions:** These results suggested that arousal level was reduced after high intensity exercise and reached a state near optimal level after medium intensity exercise. The findings also suggested that changes in CNV amplitude by differences in exercise intensity followed an inverted-U shaped dose response curve.

**Significance:** The present study supported the view that CNV amplitude and arousal level followed an inverted-U relationship. It is concluded that differences in exercise intensity influenced arousal level.

**Pliner, P., & Loewen, R. (2002). The effects of manipulated arousal on children’s willingness to taste novel foods. *Physiology & Behavior,76*(4-5), 551-558. doi:10.1016/s0031-9384(02)00782-5**

We examined the effects of manipulated arousal on willingness to taste moderately novel and extremely novel foods in children ranging from 7 to 12 years of age. Children were assigned at random to one of three arousal conditions (low, moderate, and high). Twice during the 30-min manipulation period, the children rated their willingness to taste the foods, with the understanding that these ratings would be used to determine which foods they would taste later in the session. Results of an Age x Gender x Arousal condition analysis on willingness to try the novel foods revealed a significant effect of arousal condition; willingness increased with decreasing arousal. Separate analyses for the moderately and extremely novel foods yielded significant condition and age effects for the former and no significant effects for the latter. The results were discussed in the context of optimal level of arousal theories.