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Cognitive Demands of Mothers of Young Children in the Presence of Emotional Distraction

Michelle Duersch
Brigham Young University

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Michelle Duersch

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C. Brock Kirwan, Chair
Julianne Holt-Lunstad
Rebecca A. Lundwall

Neuroscience Center

Brigham Young University

ABSTRACT

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Michelle Duersch
Neuroscience Center, BYU
Master of Science

Stress and parenting often go hand in hand, with high physical and emotional demands from children often coupled with pressures and responsibilities adults bear from work, school, and other involvements outside the home. Parents often prioritize their children's needs above their own physical, emotional, and social needs. While current literature addresses stress in mothers, it has yet to understand under what circumstances her children may modify her stress levels and whether her stress response, in turn, affects cognition. This study seeks to investigate the impact of such a taxing environment on mothers' stress and cognition using a challenging mnemonic discrimination paradigm. It was hypothesized that the auditory distraction of a mother's own children during the task would impair her ability to encode and retrieve images and also increase her physiological stress response. Prior research has outlined how irrelevant noise and induced stress modify behavioral outcomes, and how mnemonic discrimination of emotional stimuli differs from that of neutral stimuli. However, to our knowledge, there have been no tests in any group using distracting noise (a type of induced stress) during emotionally valenced mnemonic discrimination tasks. This led to the development of our task in order to better understand stress and distraction coupled with valenced imagery. Encoding was divided into two blocks, with one block occurring during the presentation of white noise and the alternate block occurring during the presentation of noise from children, either live audio feed to a mother's own children (experimental condition) or prerecorded audio of a group of children (control condition). We found that retrieval did decrease as a result of child noise, and that memory performance for neutral stimuli was greater than for negative or positive stimuli. Physiological measurements (electrodermal activity and heart rate) were also obtained to view the stress response, but only electrodermal activity showed significance. A significant relationship was found between electrodermal activity and behavioral scores in the experimental group. Our results also suggest that perceived and induced stress coupled with distraction leads to lower memory performance and increased physiological stress responses.

Keywords: amygdala, child audio, distraction, electrodermal activity, emotion, hippocampus, memory, mothers, MST, stress, valence

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Mothers have been highlighted as a population of interest in numerous studies on stress, mainly pertaining to emotional health, and some on intellectual gains and losses during pregnancy; however, many of these projects focus on what the mother's state means for her baby or her children and not for herself. For studies that do focus on the mother, the majority use questionnaires as the sole means of assessment. Current literature has yet to address what cognitive function coupled with preexisting or induced stressors looks like in parents, particularly in mothers who spend most of their waking hours with their young children. The aim of the present study is to investigate whether mothers of young children experience increased stress responses and cognitive impairments when they face auditory emotional distraction (a stressor) from their children.

For many mothers, bringing their young children into a new public situation can be stressful, or at the very least, emotionally distracting, and hearing noise and activity from children can propagate or simulate this feeling. It is in this induced-stress situation that we assessed whether cognitive impairments were evident by having mothers complete a mnemonic discrimination paradigm as she had either live-audio feed to her children in a nearby room or heard prerecorded audio of another's children. Images displayed on a computer were emotionally valenced, meaning that they were previously categorized (by Leal, Tighe, & Yassa, 2014) as either negative, neutral, or positive, and this represents an effect of emotion during encoding. Encoding was followed by a retrieval block, which completed the data set needed to analyze whether encoding was successful or disruptive. Physiological measurements (electrodermal activity: EDA, and heart rate) were also taken for assessment of the stress response.

Literature Review

A mother's level or perceived level of stress is associated with numerous challenges to both herself and other members of her family. Previous research has demonstrated that a mother's perceived stress can lead to anxiety in children (Platt, Williams, & Ginsburg, 2016), parenting burnout (Meeussen & Van Laar, 2018), reduced default mode connectivity (Zeev-Wolf, Levy, Goldstein, Zagoory-Sharon, & Feldman, 2019) and reduced executive functioning (Cuevas et al., 2014; de Cock et al., 2017) in both mothers and their children, child behavior problems (Tsotsi et al., 2019), a decline in health (Eisenhower, Baker, & Blacher, 2009), and partner relationship instability (Halpern-Meekin & Turney, 2016). Stress in parenting can come in many forms and intensities, with some stressors passing in the short-term, defined as acute stress, and other stressors in the family that do not seem to dissipate with time, leading to chronic stress (Dickerson, & Kemeny, 2004; McEwen, 2004).

Physical Stress Responses

An acute or short-lived stressful event can have longer lasting repercussions than the event itself, stemming from two main physiological mechanisms which often act in concert: the sympathoadrenal system—the connection between the sympathetic nervous system and the adrenal medulla which acts quickly in its release of catecholamines (Schwabe, Joëls, Roozendaal, Wolf, & Oitzl, 2012), and the activity of the hypothalamic pituitary adrenal (HPA) axis, which releases the glucocorticoid cortisol (Khalili-Mahani, Dedovic, Engert, Pruessner, M., & Pruessner, J.C., 2010; Gagnon, & Wagner, 2016). The release of catecholamines epinephrine and norepinephrine from the adrenal medulla could lead to headaches, an increase in blood pressure, feelings of anxiety, rapid heart rate (Fisher & Newman, 2013; Taelman, Vandeput, Spaepen, & Van Huffel, 2009), and other negative physiological symptoms (Goldstein, 2003). In response to stressors, cortisol secretion is involved in maintaining homeostasis and preparing a "fight-or-flight" response; however, this healthy short-term cortisol release becomes unhealthy if prolonged (Guilliams & Edwards, 2010). Chronic stress can lead to many unwanted effects such as decreased immune system response, metabolic changes, cardiovascular disease, and mental health struggles (Tsigos, Kyrou, Kassi, & Chrousos, 2016), any of which can contribute to undesirable life-long consequences (Tsigos et al., 2016; Schwabe & Wolf, 2013).

The hippocampus, the brain structure known for its prominent role in learning and memory, is densely packed with glucocorticoid receptors, which demonstrates the close relationship this area has with stress and stress hormones (Schwabe & Wolf, 2013). It is well understood that stressors and stress responses can impact learning, but the affect is not always detrimental. For this reason, we chose to study the impact of stressors in mothers in order to determine potential effects on encoding and retrieval of information. In this experiment, we chose EDA and heart rate as measures to test for the stress response.

EDA and heart rate as stress measures

Physical responses to stress, especially acute stress, can be obtained experimentally with relative ease through EDA in the hand due to its numerous sweat gland receptors (Fernandes, Helawar, Lokesh, Tari, & Shahapurkar, 2014). Acute stress is known to increase EDA, and this measurement in concert with heart rate are reliable reporters of the stress response (Fernandes et al., 2014), although blood pressure and salivary or plasma cortisol are also frequently used as stress response markers (Groer, Jevitt, Sahebzamani, Beckstead, & Keefe, 2013; Guilliams & Edwards, 2010; Hines & Brown, 1936; Vaisvaser et al., 2013). In this study, we obtained EDA and heart rate with BIOPAC's Bionomadix wireless brace.

Stress in Mothers

Stress has been examined in mothers in a variety of ways. Many mother-stress studies lean heavily on self-reports via questionnaires, which ask participants to assess their quality of life, perceived stress levels, behaviors, moods, and parenting styles (Schetter & Tanner, 2012; Norlin & Broberg, 2013). Some of the commonly used stress perception questionnaires are the Parenting Stress Index (Burke, & Abidin, 1980), the Perceived Stress Scale (PSS; Cohen, & Williamson, 1988), the Positive and Negative Affect Scale (Watson, Clark, & Tellegen, 1988), the Edinburgh Postnatal Depression Scale (Cox, Holden, & Sagovsky, 1987), and the State-Trait Anxiety Inventory-Trait Version (Spielberger, 2010). These self-report questionnaires give researchers a glimpse at how a woman perceives her life and her ability to cope with daily pressures; however, what surveys cannot do is to help quantify the physical and mental stress response, and how a child or a new baby may modify the response.

Prenatal maternal stress studies have run the gamut from MRI testing, which purports mid-gestational anxiety can result in children with reduced grey matter (Buss, Davis, Muftler, Head, & Sandman, 2010), to data collection on maternal prenatal stress and smoking, which concludes that these prenatal factors are together associated with later child symptoms of ADHD, notably in boys (Rodriguez & Bohlin, 2005).

During the postpartum period, mothers are frequently highlighted in literature with an abundance of studies investigating their physical and mental health, and how a mother's condition may impact her baby. Postpartum studies have analyzed the relationship between mothers' perceived levels of stress and responses to stressors and whether or not they breastfeed or bottle feed their babies (Mezzacappa, & Katlin, 2002; Mezzacappa, Kelsey, & Katkin, 2005; Groer et al., 2013). Here, the evidence suggests that mothers who are breastfeeding experience decreased stress and sympathetic nervous system reactivity and have lower blood pressure and heart rates than mothers who bottle feed, and conclusions have been drawn regarding physical and mental maternal benefits associated with breastfeeding (Groer et al., 2013; Mezzacappa et al., 2005). In another effort to understand how stressors impact mothers and their babies, a stress-play baby interaction task was designed during which oxytocin levels in mothers were measured, and it was determined that oxytocin levels negatively correlate with relationship distress and positively correlate with their ability to bond with their child (Feldman, Gordon, & Zagoory-Sharon, 2011). From this research, we better understand whether perceived stress or stressors may modify her physiological health and/or mother-child interactions.

FMRI coupled with perceived stress questionnaires have been used to examine how a mother's mood during postpartum correlates with brain activity as she rates the emotional valences of a series of pictures of her baby (Barrett et al., 2012) and views pictures of her infant vs. other infants (Swain et al., 2003; Swain et al., 2004). Other FMRI neural correlate investigations weigh responses when parents hear recordings of their infants crying (Swain et al., 2003; Swain et al., 2004; Kim et al., 2011). These studies predict what brain activity may look like in emotion centers, such as the amygdala, based on preexisting stress, depression, and parenting questionnaires.

Due to preexisting stressors, mothers with previous psychological trauma or those bearing the responsibility of caring for children with various diseases and disorders are other groups of interest. Mothers who have a history of interpersonal violence and subsequent post-traumatic stress disorder (IV-PTSD) are more likely to later report subjective stress in their daily lives, and when compared with controls, they show decreased activation in the dorsolateral prefrontal cortex (dlPFC), dorsomedial PFC, and ventromedial PFC when viewing emotionally negative videos of parents and children interacting (Schechter et al., 2015).

Meta-analyses survey parents' self-reported stress due to rearing children with various disorders, including those who care for children with autism spectrum disorder (Hayes & Watson, 2012) and attention-deficit/hyperactivity disorder (ADHD) (Theule, Wiener, Tannock, & Jenkins, 2012). Mothers of children with intellectual disabilities experience higher reported stress than controls, and caregiving stressors correlate with depression levels, which serve as markers of a mother's well-being (Norlin & Broberg, 2013). Although, whether mothers are actually experiencing abnormal physiological or psychological stress responses remains highly subjective, and this perceived stress is difficult to quantify through questionnaires.

When mental mindset and preexisting beliefs are assessed with questionnaire data, it is understood that these factors may play a pivotal role in perceived parenting stress. Parents who have negative beliefs about parenting or relationships are likely to report higher levels of parenting stress (Respler-Herman, Mowder, Yasik, & Shamah, 2012). For instance, mothers more often report subjective stress and fatigue from time spent with their children than fathers (Musick, Meier, & Flood, 2016), and mothers who remain in a good relationship with a child's biological father report significantly less parenting stress than when the relationship is unstable or non-existent (Cooper, McLanahan, Meadows & Brooks-Gunn, 2009). These examinations rely on self-reports, which may not consider chronic stressors unassociated with mothering. Further, these self-reports do not assess live stress-states or what specific mental benefits or detriments may correlate with stressors.

Motherhood and Cognition

Cognition during pregnancy and postpartum has been a debate for several decades, with the callous designation "baby brain" becoming linked to studies which give evidence of decreased cognitive capabilities in women during these periods (Hurt, 2011). Processing speed and neuropsychological tests were used to determine women's cognitive capabilities in one study which demonstrated that pregnant and postpartum mothers had significantly poorer encoding and memory than healthy controls, and during postpartum, women took a noticeable dip in testing speed (de Groot, Vuurman, Hornstra, & Jolles, 2006). Opposing this research is a body of evidence from the largest study on cognition and motherhood: an eight-year longitudinal study following women before, during, and after pregnancy (Christensen, Leach, & Mackinnon, 2010). Christensen and colleagues (2010) gathered participant data with tests of cognitive speed, working memory, and immediate and delayed recall, demonstrating that pregnant women and new mothers did not perform at a lower rate than controls. Only in late pregnancy was an effect seen when women performed at a lower speed (Christensen et al., 2010). Aside from studies on cognition during pregnancy and early postpartum, the academic and scientific interest in motherhood and cognition wanes, and studies are virtually non-existent.

Induced Stressors and Cognition Studies

Cognition performance studies with PTSD groups often scrutinize stress and learning by inducing a stress response in their participants, and in some cases the stress mimics real-life physiological and cognitive responses. Post-9/11 veterans with PTSD were recruited for a working memory task which interspersed emotionally distracting combat images with task images (Morey et al., 2009) and a heightened distractibility (decreased dlPFC activity) in the PTSD group was significant, regardless of image content. Liberzon and colleagues (1999) presented combat sounds to PTSD war veterans and used single-photon emission computerized tomography (SPECT) to visualize changes in blood flow, namely a marked activation in the amygdala and nucleus accumbens within the PTSD group. Behavioral and imaging studies of clinically stressed groups help determine the extent of cognitive impairments and factors that may exacerbate symptoms in an effort to promote disorder management.

Other studies induce stress responses in participants with tasks, such as the Stroop Color-Word Test (Stroop, 1935; Teixeira et al., 2015), or post-encoding with a social evaluation test: the Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993; Cunningham, Leal, Yassa, Payne, 2018) or even by cortisol administration, which served to enhance memory (Buchanan & Lovallo, 2001).

Emotional distraction tasks are another form of stress induction which may consist of stimuli with varying emotional valences (negative, neutral, and positive). The results in many of these studies point to a trend toward higher retrieval rate of negative emotional content when compared with neutral or positive (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Dolcos et al., 2013; Leal et al., 2014; Cunningham et al., 2018) and experimental groups exposed to stress near encoding can demonstrate additionally enhanced memory for negative images (Cunningham et al., 2018; Schwabe & Wolf, 2013).

Induced stress can alternatively play a detrimental role in subsequent retrieval of previously presented words and pictures, likely because the physiological stress response is in competition with encoding or the consolidation of new information (Schwabe & Wolf, 2013; Gagnon, & Wagner, 2016; Shields, Sazma, McCullough, & Yonelinas, 2017). One such example is with participants who attempted to memorize a series of words during a cold pressor test (Hines & Brown, 1936): they remembered significantly fewer words than the control group upon testing (Schwabe & Wolf, 2010) which shows that stressors presented during encoding can have an adverse impact on memory for retrieval. Diversifying the evidence of stress effects on memory, Balderston and colleagues (2017) demonstrated decreased mnemonic discrimination of indoor and outdoor images when testing took place during a threat of shock condition, and an enhancement when encoding occurred during threat of shock with testing in a safe, no-shock condition. Yet similar studies demonstrate that anxiety or induced anxiety can lead to generalization when stimuli is valenced and an inability to successfully pattern separate (McMakin, Kimbler, Tustison, Pettit, & Mattfeld, 2020; Starita, Kroes, Davachi, Phelps, & Dunsmoor, 2019). Clearly, task design including the timing of stress induction, a subject's psychological and physiological history and susceptibility, and the type of stressors have varying behavioral outcomes pertaining to memory.

Stress and Memory

Pattern separation is the mechanism whereby two similar memory representations can be distinguished from one another (Kirwan & Stark, 2007). In order for memory to be successfully encoded, memory representations which are similar need to be established as distinct to avoid catastrophic interference (Yassa & Stark, 2011). It is commonly accepted that this process of reducing overlap in representations of memory depends on pattern separation occurring in the hippocampus (HPC), specifically within the CA3 and dentate gyrus subregions (Bakker, Kirwan, Miller, & Stark, 2008; Duncan, Ketz, Inati, & Davachi, 2012; Kumaran & Maguire, 2007) and the surrounding medial temporal lobe (MTL) structures (Squire, Stark, & Clark, 2004).

A mnemonic discrimination task, such as with this experiment, is thought to depend on hippocampal-dependent pattern separation processes (Bakker et al., 2008). Another necessary component of a memory task of this nature is the ability one has to pattern complete, or correctly classify an image as "old" that has previously been seen. Pattern completion is also a hippocampal-dependent process and is known to occur largely in the CA1 subregion (Bakker et al., 2008).

In this task, there was an initial encoding phase followed by a retrieval phase with presentation of images which were either old, new, or similar. The ability of a subject to later successfully identify images as new (not previously presented), similar (high and low similarity), or old (previously presented) was assessed (Kirwan & Stark, 2007), particularly, whether a participant's preexisting or induced stressors during the task modified image encoding and retrieval.

The physiological consequences stemming from stressors act in a time-dependent manner, sometimes enhancing memory encoding and retrieval and other times impairing these cognitive functions (Schwabe et al., 2012; Smith & Thomas, 2018). One model of stress and learning research proposes that stress can act to enhance memory when it is in-context with the learning material or when it occurs close in time to encoding or retrieving information, but often acts as a distractor to memory retention when out-of-context or is distantly separated in time from the learning event (Schwabe et al., 2012; Schwabe & Wolf, 2013).

Alternate models of stress research indicate that the amygdala (AMY), HPC and associated MTL areas are strong players for enhancing or otherwise modulating the processing and encoding of emotional content (Dolcos, LaBar, & Cabeza, 2004; McEwen, Nasca, & Gray, 2016; McGaugh, 2004; McGaugh, Cahill, & Roozendaal, 1996). It is well established that both induced stressors and preexisting stress responses can increase the connectivity within AMY-HPC encoding-retrieval centers in the brain (Shin & Liberzon, 2010; Vaisvaser et al., 2013) which can improve memory while connectivity is still enhanced. Whereas increased AMY-HPC activation in concert with reduced dlPFC activation can be an indicator that an individual is more likely to have an impaired memory effect during a study-test design, such as Dolcos and colleagues' 2013 study. Here, the use of emotionally distracting images produced initial cognitive impairments, yet emotionally distracting images were enhanced and later remembered better than neutral images (Dolcos et al., 2013). Another example is with post-combat PTSD individuals recruited for a cognitive study-test design interspersed with combat image distractors (Morey et al., 2009). Here greater activation in the AMY and significantly depressed dlPFC activity resulted in overall lower working memory scores for PTSD participants compared with controls (Morey et al., 2009). These studies demonstrate that AMY-HPC activity alone does not predict strength of encoding or retrieval.

Increased AMY-HPC connectivity may also suggest that emotion (a potential stressor) has the power to enhance memory for emotional content (Dolcos et al., 2004; McEwen et al., 2016; McGaugh, 2004; McGaugh et al., 1996). This emotion can take the form of previous psychological or physiological conditions, such as acute or chronic stressors (Hayashi, Mizuno-Matsumoto, Okamoto, Kato, & Murata, 2012; McEwen et al., 2016), depression (Leal et al., 2014), anxiety (Bernstein, Kleiman, & McNally, 2019), and PTSD (Morey et al., 2009). Alternatively, stress responses and heightened emotion can arise in a subject as an induced element pre- (Wolf, 2012; Wirkner, Weymar, Löw, & Hamm, 2013), post- (Cunningham et al., 2018), or mid-encoding and testing (Balderston et al., 2017).

In Cunningham and colleagues' study which induced stress post-encoding (2018), both cortisol levels and self-report questionnaires testified of a marked increase in responses to and feelings of stress after TSST procedures. It was concluded that stress induction during the early post-encoding period was a key modulator in the brain's ability to enhance storage of information with emotional content, as seen from the experimental group's strengthened mnemonic discrimination of negative slides when compared with controls (Cunningham et al., 2018). Post-encoding stress induction has also been shown to significantly strengthen familiarity during a task consisting of emotionally valenced images (McCullough & Yonelinas, 2013; Yonelinas, Parks, Koen, Jorgenson, & Mendoza, 2011). As mentioned previously, some researchers creatively employ the use of both induced stressors and groups of participants with preexisting stress conditions to determine whether such conditions can predict task outcomes.

Distraction and Attention

Among mothers, there are several oversimplified stereotypes on how they react to child noise. One is that they have been around child noise for so long, that they no longer feel that it is distracting or stressful. In another camp, regardless of experience parenting, mothers still feel highly distracted and emotionally tied to noise from her children. And certainly, there are any number of variations between these two extremes. With distractions from children, we hypothesized that attentional mechanisms would function according to serial bottlenecks and bottom-up processing, which would disallow high retrieval on the task during noise from children when compared with no noise.

While it is possible to cognitively process more than one task at the same time, such as verbally answering elementary school math questions while washing the dishes, there is a diminishing point when information can no longer be processed in parallel, and some details will be lost in one task in order to select desired or salient information outside the target task (Anderson, 2015, p. 53).

There is a general consensus that sensory cues play a major role in selection, and that distractor information involuntarily captures attention via bottom-up processing (Johnston & Dark, 1986). Because bottom-up messages have the power to win our attention even when we are focused, we know that serial bottlenecks allow this filtered information the opportunity to override attended tasks (Anderson, 2015; Cherry, 1953; Wang et al., 2012). And so, it is our hypothesis that some cognitive resources will be involuntarily allocated to attending noise from children, and we will see this affect in diminished behavioral scores.

Distracting Sounds and Cognitive Function

Researchers have long explored whether or not irrelevant noise, which may induce the orienting response—a form of a bottom-up capture of attention, tends to habituate or resists habituation and continues to impair test stimuli recall (Tateuchi, Itoh, & Nakada, 2012; Sokolov, 1990). Although this task was not designed to test for habituation, the consensus is that irrelevant noise with repeated elements may habituate, but unrepeated noise patterns, as with the child noise in this task, will stably maintain distraction over time (Jones, Macken, & Mosdell, 2011). Yet individual differences and the task design are also varying elements to assess with regard to habituation (Beaman, 2005).

In a participant population with preexisting severe anxiety, one study with an induced psychological stressor (TSST; pre-induced) showed a decrease in the ability to mnemonically discriminate, while a second study with a physical stressor (aversive sounds played at random intervals during testing) showed no such group decline when compared with controls (Bernstein et al., 2019). However, this was to be expected given that the severe anxiety group was sensitive to social stressors and not merely to distracting noises. In an FMRI study with a different high stress population, processing emotional sounds and images impaired their working memory and control of attention (Hayashi et al., 2012). Aversive city noises has been another means of introducing distraction, and this was presented to self-reported introverts and extroverts where both groups performed more poorly on tests of word recall and mental arithmetic than when they heard music or no noise, although noise was more detrimental to introverts than extroverts (Dobbs, Furnham, & McClelland, 2011; Furnham & Strbac, 2002). A review of research on distraction noises and cognition makes it clear that the type of noise, decibel level, personality characteristics, and psychiatric disorders all contribute to varying behavioral outcomes.

While recent literature identifies stressors, perceived stress, and stress responses in mothers through physiological data-gathering, self-report questionnaires, behavioral testing, and FMRI, current literature has not yet addressed whether stressors within a sample of mothers impact their ability to encode and later recall information. Although we cannot easily examine the negative compound effect due to prolonged stress responses that may take a toll on the lives of mothers and their families, we can test their memory by simulating a live stressor through a public outing of mothers with their children.

In the current experiment, participants encoded a series of images with positive, neutral, or negative valence during both auditory distraction (audio from children) and a control, white-noise condition. Mothers in the task were pretested with questionnaires to allow for later statistical analysis of whether a participant's perceived level of stress or depression could predict task outcomes. Physiological measurements (EDA and heart rate) were also taken for further assessment and verification of the stress response.

Hypotheses

We first asked if there would be a significant effect of distraction vs. no distraction yielding lower behavioral scores in both groups for stimuli encoded during auditory distraction. We hypothesized that the experimental group would have overall poorer encoding of information (as reflected by lower lure discrimination and target recognition scores) because of the probability that stress responses from live audio feed to their own children would substantially distract from encoding. Considering the literature previously presented, our second hypothesis was that lure discrimination would vary depending on the emotional valence of the image (negative, neutral, positive), namely that negatively valenced images would be encoded and retrieved by both groups at higher rates than positive or neutral images. We hypothesized that this valenced effect would be seen most prominently in the group who were exposed to live audio of their own children during stimulus encoding (Dolcos et al., 2013; Leal et al., 2014; Cunningham et al., 2018). Our third hypothesis was that participants who had moderate to high self-reported preexisting stress and depression scores would achieve noticeably lower lure discrimination and target recognition scores than those without high stress and moderate depression. Finally, fourth, we anticipated that stress responses would manifest themselves by elevated EDA and heart rate during the distracted block, likely with higher readings in those with raised depression and stress scores.

Materials and Methods

Participants

Mothers of young children were recruited from the Utah Valley region with flyers and emails through Brigham Young University's Child and Family Studies Laboratory, as well as through local social media mother groups. Recruitment announcements called for mothers to participate in a learning, memory, and stress study for $40 compensation. This study included 59 participants (mean age ± SD, 34 ± 5, range = 23-47). Participants were randomly assigned to the experimental or control group (see below). No significant differences were found between groups on any demographic measures (See Table 1).

Inclusion and exclusion criteria

Each potential participant was required to have guardianship of two or more children ages 8 months to 12 years. Mothers were informed in the recruitment and follow-up communications that they would need to bring at least two of their children ages 8 months to 12 years to the task session to be safely supervised in a nearby room by a designated and trained BYU student. Women who were pregnant or mothers with children under 8-months-old were excluded from participation. In agreement with BYU's Institutional Review Board (IRB), potential participants who scored above clinical cut offs for depression (BDI-II >29) were excluded from further participation (a total of two) and were given health and counselling information. Two participants were removed due to computer error, and one was removed due to inconsistent behavioral responses due to misunderstanding the task, resulting in a final n=56.

Procedure

After an initial email or phone call to explain the study and to confirm inclusion and exclusion criteria, participants who wished to continue with the study were emailed detailed

Table 1 Participant Demographic and Characteristics. Experimental and control groups did not differ significantly on any measure.

Measure	*n* (%)	
Group	Experimental (n=30)	Control (n=26)
Number of children		
2	9 (30)	8 (30.77)
3	8 (26.67)	8 (30.77)
4	6 (20)	3 (11.54)
5	4 (13.33)	5 (19.23)
6	1 (3.33)	1 (3.85)
7	2 (6.67)	1 (3.85)
Race		
White	28 (93.33)	19 (73.08)
Asian	1 (3.33)	4 (15.38)
Hispanic	0 (0)	3 (11.54)
Mixed race	1 (3.33)	0 (0)
Education		
High school diploma/GED	1 (3.33)	0 (0)
Some college	6 (20)	5 (19.23)
College degree	19 (63.33)	12 (46.15)
Graduate degree	4 (13.33)	9 (34.62)
Work Status		
No job outside of parenting	10 (33.33)	8 (30.77)
Part-time (<20 hrs/wk) from home	8 (26.67)	6 (23.08)
Part-time (<20 hrs/wk) away	5 (16.67)	8 (30.77)
Full-time (>20 hrs/wk) from home	4 (13.33)	1 (3.85)
Full-time (>20 hrs/wk) away	3 (10)	3 (11.54)

information and electronic questionnaires. Participants completed questionnaires prior to the day of their testing session. The questionnaires included the Perceived Stress Scale (PSS; Cohen, & Williamson, 1988), which gauges perceived life stress with questions regarding a subject's feelings and reactions to events within the past month. On the 10-item PSS, a score of 0-13 is considered low stress, 14-26 moderate stress, and 27-40 high stress. Participants also completed the Beck Depression Inventory-II (BDI-II), a measurement of severity of depression (Beck, Steer, & Brown, 1996). A score on the BDI-II of 0-14 indicates minimal range, 14-19 mild depression, 20-28 moderate depression, and a score of 29-63 indicates severe depression. Due to the nature of the study and the significance it places on learning about stress and mental health, all participants were given information on BYU's Comprehensive Clinic, as well as other stress and mental health online resources for themselves or family members upon completion of the study.

Upon arrival at the testing facility, the participant escorted her children to the playroom near her test room and got them settled for a few minutes with the researcher. In the presence of the researchers, mothers assured that her children were willing to be watched by the supervisor during her test. If the mother was assigned to the experimental group, the supervisor began preparing the children for five brief play-acting "episodes" explained in more detail below (see Appendix).

A second researcher escorted participants to the testing room where participants completed a consent to study form, followed by a demographics survey which asked about age, the ages and genders of her children (including those not present), race, level of education, and work status. The researcher then fitted participants with BIOPAC's Bionomadix wireless brace with two EDA electrodes placed on the ring and middle fingers of the left hand and one pulse transducer placed on the index finger of the left hand (BIOPAC PPGED-R; interfaced with MP150 platform). The researcher explained:

> This is a wireless device that will take your skin conductance throughout the study. Skin conductance measures slight changes in the properties of your skin that can happen from feelings, what you see, what you hear, exercise, and other physical or mental changes. Don't be alarmed, we cannot know what you are thinking or feeling from this. This device I will put on your index finger will measure your pulse. I'm going to place a sticky

electrode on your middle and ring fingers and the pulse one on your index. Once the study begins, I'll have you lay your hand in your lap, on the bean bag, or in some other way that keeps it from moving, because moving will change the measurements.

The researcher then performed a premeasurement calibration on BIOPAC's Acqknowledge software 4.0 (BIOPAC 150) with a Macbook Pro on a desk near the participant. Participants were able to see their measurement changes during the calibration and the researcher further explained the measurements and answered any questions. Once calibration was complete, the laptop was turned away from participants for the remainder of the study so they were not distracted by their readings. EDA and heart rate were then obtained continuously during each study block and the test.

Mnemonic Discrimination Task

During the study phase, participants sat at a computer and viewed images of people, places, and objects. Images for the study and test phases were generously provided by Leal and colleagues (2014). Participants were asked to rate the emotional valence for each image, pressing one of three buttons to indicate her response. Each image fell into one of three categories: negative, neutral, and positive. Prior to the task, each subject was trained on the key assignments: 1 assigned to negative, 2 to neutral, and 3 to positive. An index card remained on the computer to remind participants what each of the keys represented. Images for this experiment were previously rated by an independent sample for emotional valence and arousal (see Leal et al., 2014 for independent sample rating details). The study phase contained a total of 200 images and lasted 16.7 min and was divided into two 5.83-minute blocks with a 5-min break between blocks. Negative, neutral, and positive images were evenly distributed within each block. For each trial, the image was presented for 2500 ms followed by a fixation cross for 1000 ms. All images were

600 pixels in width and images and fixation cross were centered on the screen with a black background.

Participants were randomly preassigned to either the experimental or control condition before arrival at the testing facility. Both groups performed encoding under distracted and then white-noise conditions (order counterbalanced across participants). For the experimental group, the distraction condition was a live audio of the participant's children in the adjacent room. Audio was presented via Skype call with the audio played via computer speakers. For the control group, the distraction condition was prerecorded audio of a different group of children engaged in similar activities in the same playroom space with the same designated supervisor. The prerecorded audio was also presented via computer speakers. White noise was presented via a Lectrofan white noise machine.

Audio levels were set at 63 dB for both the distraction and white noise conditions based upon trial and error during the pilot condition which determined what felt comfortable for a participant to hear. The chosen decibel level also took into account research that indicates sound levels < 70dB are considered safe (Kardous, Themann, Morata, & Lotz, 2016). Decibel levels were calibrated beforehand with a Check Mae SPL Meter (CM-130; Galaxy Audio) to be certain the volume was consistent between subjects. This was done by holding the sound meter at average head height by the computer chair to gauge the level of white noise, originating on the top of a nearby filing cabinet. The same placement was maintained to calibrate an average of 63dB of loud speaking and child noise to the testing computer, and Macbook Pro near the participant computer which was the output for the control distraction audio. These calibrations were preset before data collection and were maintained at the same level for all participants.

A 5-minute break followed the study phase. During this break, participants were free to stand, move, or talk as they pleased in an effort to return physiological measures to baseline. We learned from pilot testing that five minutes was a long enough period to return EDA and heart rate to baseline, but we understand that there were possibly longer lasting genomic glucocorticoid activities (Schwabe et al., 2012; Schwabe & Wolf, 2013) that we could not account for by administering the test shortly after encoding. Following the 5-minute break, participants were then surprised with a test phase, consisting of 275 images, with an equal presentation of targets, lures, and foils across the three valences, and approximately 50% high similarity and 50% low similarity lures. As with the study phase, each image was presented for 2500 ms followed by a 1000 ms fixation cross. The images and fixation cross were centered on the screen with a black background. During this 16-minute phase, participants were instructed to indicate via button press whether the image presented was an "old" image they had previously seen (targets) or a new "new" image they had not seen (foils and similar lures). Participants were instructed to reject similar lure images as "new." They made these indications by pressing the keys ("3" for old; "4" for new), which they were trained on prior to the start of the test phase. An index card remained on the computer to remind participants what each key represented.

Live Auditory Distraction

Each participant's children were supervised in a nearby room in the Family Home and Social Sciences suite in BYU's Richard's Building. For mothers in the experimental condition, a Skype call (audio only) was initiated between the playroom and the testing room to allow participants to hear the live audio feed of their children when the encoding phase required the distraction condition.

During the distracted encoding period for the experimental group, children were encouraged by the supervisor to play in a manner that corresponded with a predetermined episode (see Appendix). Each episode was depicted for children on an individual 11x17 in. poster as a colored image with captions so both reading and non-reading children could understand. During the auditory distraction portion of the mother's study block, the children were encouraged to talk, play and interact with each other and their surroundings in a way natural to them, yet they were also asked to do so with the episode prompts given to them when the poster was held up by the supervisor and as she directed them to certain activities (or if they were uninterested in doing this or too young to understand, they continued free play). The supervisor instructed the children to continuously play, move, and make noise as they wished. The main focus of each episode was a vocal prompt said by the supervisor, such as, "Please do not touch the computers!", "Let's all share!", or "Can you sing your ABCs?" The five episodes took place during one of the study periods for the mother, with one new episode presented approximately every minute. There were additional episodes as time or preference allowed. The intention of the episodes was to maintain as much noise and distraction consistency as possible between each group of children, and also for the experimental condition to closely mirror the noise and activities heard in the prerecorded control condition. In this manner, all participants heard roughly the same content and variability in noise level. While approximately a quarter of the children were quieter or more reserved than others, the majority of the children played along during the distracted condition and responded well to the supervisor's prompts. Participants in the control condition did not have live audio feed to their children during the study, but their children played in the same playroom during the task.

After the 37.8 min mnemonic discrimination task (which included breaks), participants were paid and reunited with their children. For participants in the experimental condition, they may have been under the impression that their children were misbehaving because the supervisor encouraged the children to be noisy and to engage in active play. The supervisor may also have said things during the brief audio feed that indicated the children were touching things or mishandling items in the playroom, such as, “Please don't touch the computers,” or “Uh oh, I can fix that,” after hearing something drop on the floor. Immediately after the testing for the experimental group had concluded, each participant was debriefed that the intention of the audio feed to her children was to have a noisy active atmosphere. The experimenter detailed the activities in the playroom as follows:

> I wanted to let you know that I asked your children to be as noisy and active as they liked. When you heard a noise of something dropping, it was staged and nothing actually broke. Also, no one was touching computers as there were no computers in the room. I also asked them to knock over the blocks and to play with the musical instruments loudly. The sibling rivalry moment was also staged. They did an excellent job following directions and playing.

Score Calculations

Mnemonic discrimination performance was evaluated by calculating corrected lure discrimination (LDI) and corrected recognition (d') indices. The lure discrimination index (LDI) indicates the ability to recognize a lure as new despite its similar appearance to a previously presented target while correcting for response bias. A higher LDI is taken to indicate a better ability to pattern separate. The LDI was calculated as the proportion of “new” responses to lures (i.e., lure correct rejections) corrected by the proportion of “new” responses to old targets (i.e., miss): p(‘New’|Lure) - p(‘New’|Target). Corrected recognition (d') reflects the ability to recall a target in the face of lures while accounting for response bias. D-prime was calculated as the difference of standardized values of the proportion of “old” target responses (i.e., hits) to the proportion of “old” responses to both novel foils and similar lures (i.e., false alarms):

z(‘Old’|Target) - z(‘Old’|Foil and Lure).

Results

No significant differences were found between the experimental and control groups on demographics, BDI scores, or PSS scores, indicating that the random group selection did not introduce any of these potentially confounding variables (See Table 2).

Table 2 Participant Characteristics. Experimental and control groups did not differ significantly on any measure.

Measure	*M* ± *SD*	*Range*	*M* ± *SD*	*Range*
	Experimental		Control	
Number of children	3.53 ± 1.48	2-7	3.46 ± 1.42	2-7
BDI-II	15.57 ± 8.47	2-29	13.11 ± 6.94	1-26
PSS	20 ± 4.80	11-29	18.59 ± 5.50	7-30

Note: BDI-II = Beck Depression Inventory II; PSS = Perceived Stress Scale.

Table 3 Behavioral scores for negative, neutral, and positive stimuli by similarity (high/low) in control and experimental groups reported as means with standard deviations.

	Negative		Neutral		Positive	
Similarity	**High**	**Low**	**High**	**Low**	**High**	**Low**
Responses to similar lures (LDI)						
Control	0.49 (0.20)	0.66 (0.18)	0.60 (0.22)	0.70 (0.20)	0.48 (0.24)	0.60 (0.18)
Experimental	0.55 (0.21)	0.74 (0.16)	0.53 (0.18)	0.71 (0.19)	0.53 (0.19)	0.65 (0.16)
Overall	Negative		Neutral		Positive	
Responses to targets (d')						
Control	2.40 (0.47)		2.58 (0.67)		2.37 (0.63)	
Experimental	2.64 (0.51)		2.52 (0.62)		2.47 (0.53)	

Note: Lures are calculated as proportions and targets as proportions of standardized scores.

Behavioral Analysis

Statistical tests were conducted in R, version 3.6.0, with two-tailed statistical tests being considered significant with alpha < 0.05.

Effect of Distracted Encoding

Our first hypothesis was that distraction would impair LDI and d' scores in both the control and experimental groups. It was anticipated that we would see this with higher behavioral scores for stimuli encoded during the no distraction blocks. Further, we anticipated that the experimental group would have lower LDI scores than the control group, and here did not make an additional hypothesis with d' due to the preponderance of MST studies which mainly focus on the lure index when examining behavioral scores between groups. To test this, we performed two separate repeated measures ANOVAs on the LDI and d' scores with the group (experimental or control) as the between factor, and distraction (white noise and distraction) as a within factor. See Tables 5 & 6 for full ANOVA results (Appendix). Follow up t-tests were used to further characterize the significant main effects and interactions.

As hypothesized, we observed lower LDI scores for the distraction encoding condition (mean ± SD, 0.59 ± 0.16) when compared with the white noise condition (0.62 ± 0.17) [$F(1, 54) = 4.83$, $p = 0.03$] (Figure 1). We found this result with d' also with lower scores for distraction (1.89 ± 0.60) compared with no distraction (2.07 ± 0.65), [$F(1, 54) = 4.97$, $p = 0.03$] (Figure 2). The lack of a significant main effect of group for either ANOVA indicates that we were incorrect in hypothesizing the experimental group would show lower overall LDI and d' scores than the control group. Further, the group by distraction condition interactions were also not significant in either ANOVA, indicating that the experimental group was not more susceptible to the effect of auditory distraction than the control group.

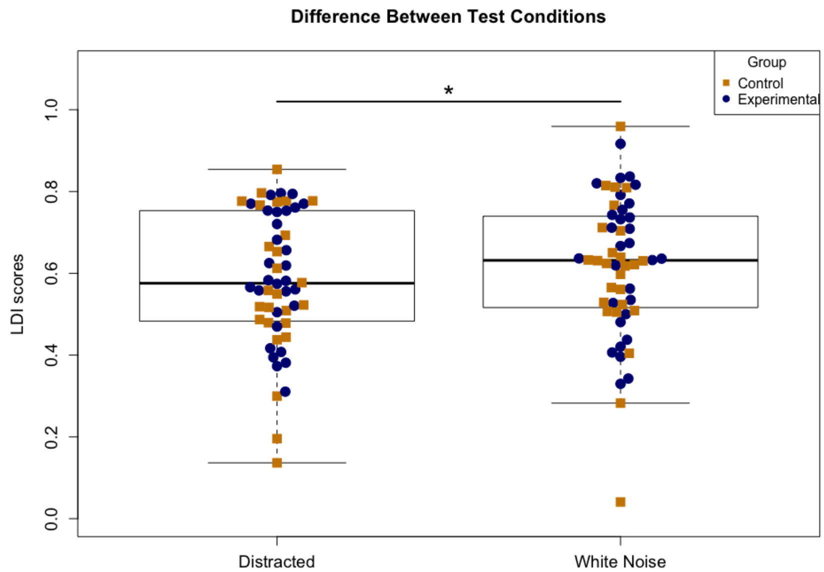


Figure 1 Boxplot of the interquartile range and spread of data with the mid-point line representing the median. Note that all statistics were performed on the means and are not depicted in the figures. LDI Scores during Distraction vs. White Noise. Across both groups, LDI is significantly higher during white noise ($p = 0.03$).

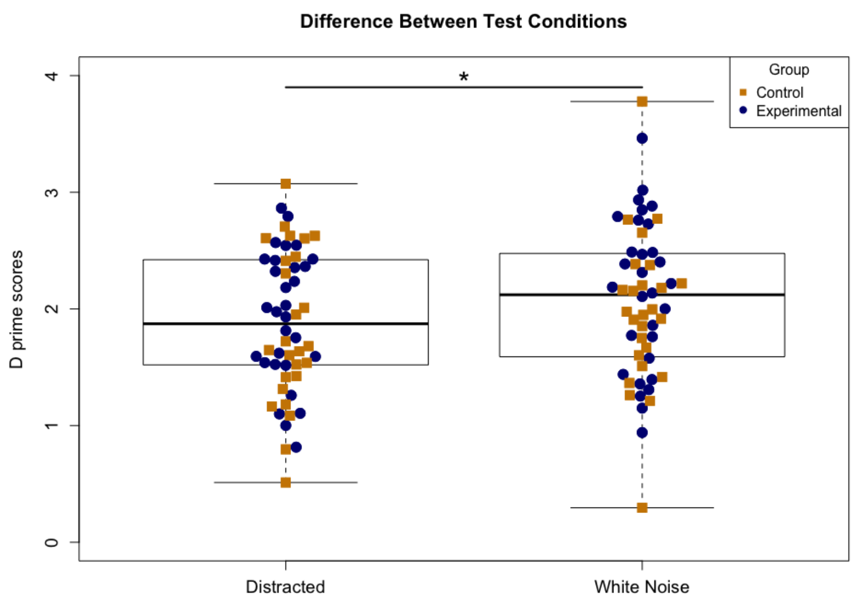


Figure 2 Boxplot of D' by Distraction. White noise had higher d' than Distraction ($p = 0.03$).

Effect of Valence

Our second hypothesis was that the negative stimuli would receive higher LDI scores than neutral or positive stimuli and that this effect would be more pronounced in the experimental group. A repeated measures ANOVA did show a significant main effect of valence on LDI scores [$F(2, 108) = 6.88$, $p < 0.01$]. However, contrary to our prediction, negative images did not receive the highest LDI, rather, neutral was highest (0.63 ± 0.18), followed by negative (0.61 ± 0.18), and then positive (0.57 ± 0.18) (Figure 3). LDI scores for neutral were significantly greater than positive ($t(55) = 3.47$; $p < 0.01$) and negative were also significantly greater than positive ($t(55) = 2.12$; $p = 0.04$) while LDI scores between neutral and negative did not significantly differ ($t(55)=-1.39$; $p = 0.17$).

ANOVA results also showed a group by valence interaction [$F(2, 108) = 3.59$, $p = 0.03$]; however, this interaction was within groups rather than between groups as we had been expecting, with the only interaction in the control group. In the control group, LDI for neutral images was greater than negative ($t(25) = -3.21$; $p < 0.01$), and neutral scores were greater than positive ($t(25) = 4.59$; $p < 0.001$) with no significance between negative and positive images ($t(25) = 1.09$; $p=0.284$). Within the experimental group, we did not see any differences between valences: (Negative - Positive: $t(29) = 1.88$; $p = 0.07$; Negative - Neutral: $t(29) = 0.84$; $p = 0.40$; Neutral - Positive: $t(29) = 1.10$; $p = 0.28$). We did not find significance with valences between groups (Negative: $t(54)=1.40$; $p = 0.17$; Neutral: $t(54)= -0.54$; $p = 0.59$; and Positive: $t(54)= 1.06$; $p = 0.29$).

Questionnaires and Behavioral Outcomes

For our third hypothesis, we performed regression analysis to test whether PSS and BDI negatively correlated with behavioral outcomes. In a model with both PSS and BDI as predictors to the outcome overall LDI, we discovered that PSS was a significant negative predictor of LDI ($p < 0.001$) with each one standardized unit increase in PSS associating with a -.016 decrease in

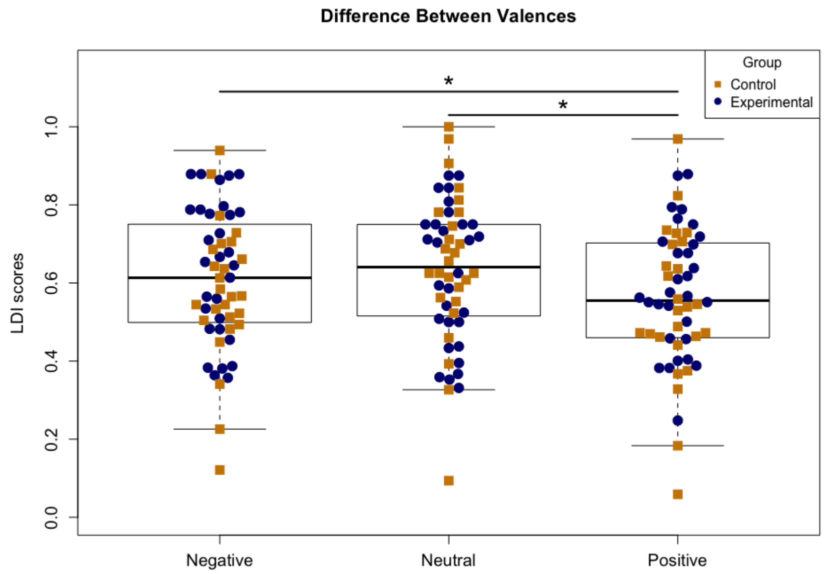


Figure 3 Boxplot of LDI by Valence. Negative and neutral have higher LDI than positive. (Neg-pos: P = 0.04, neu-pos: p <.001, neg-neu: p = 0.17).

LDI with a standard error of .0046; however, BDI was not a significant predictor ($p = 0.87$). With d', we also found that PSS score could predict overall d' ($p < 0.001$), with every one-unit increase in standardized PSS correlating with a -0.054 change in overall d' with a standard error of 0.085. BDI did not predict a change in overall d' ($p = 0.75$).

We next examined whether our results were similar to Leal and colleagues (2014) who found that increasing depression scores (BDI-II) positively correlated with lure discrimination for negatively-valenced stimuli. Regression analysis determined that in our study, LDI scores for negatively-valenced stimuli did not correlate with BDI ($p = 0.10$).

Effects of Distraction on EDA and Heart Rate

For our fourth pair of hypotheses, we estimated that the distraction condition would differ from the white noise condition in terms of EDA and heart rate. We found that EDA was higher in the distracted condition (7.72 ± 5.57) than in the white noise condition (6.67 ± 5.05), $t(55) =$

2.38; p = 0.02 (Figure 4). However, heart rate did not significantly differ between the distraction (75.49 ± 11.57) and white noise (74.85 ± 11.10) conditions, t(55) = 0.21; p = 0.83 (Figure 5).

And our final hypothesis was that those with higher BDI and PSS scores would respond to the task with more stress demonstrated by elevated EDA and heart rate. We found this to be true of EDA, but not heart rate.

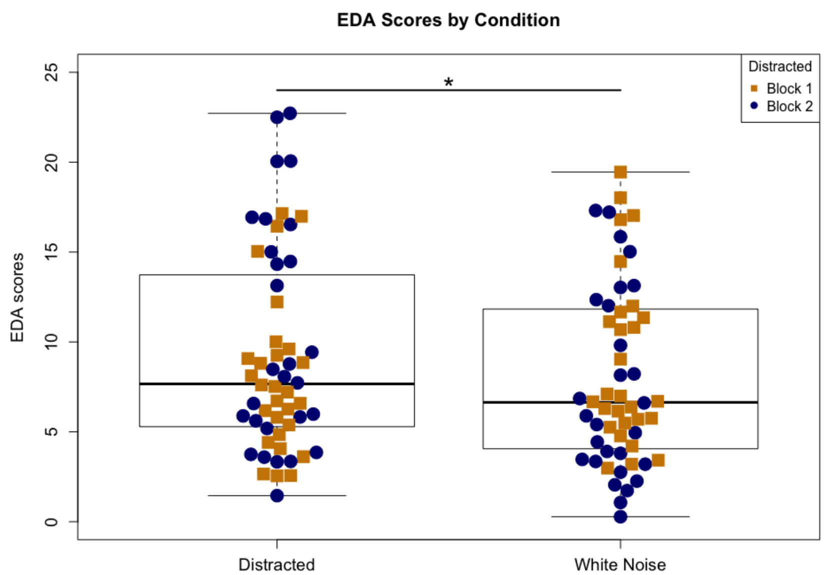


Figure 3 Boxplot of EDA Between Conditions. EDA is measured in microsiemens (µS).

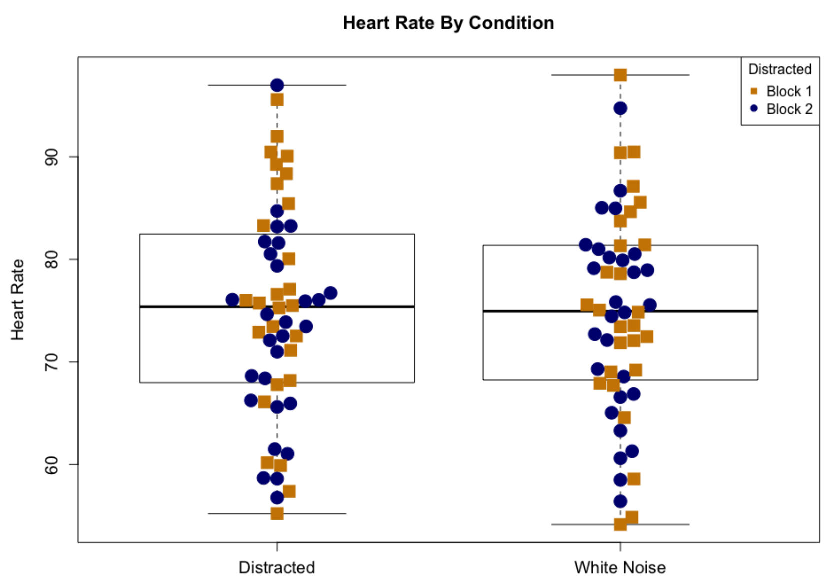


Figure 4 Boxplot of Heart Rate Between Conditions.

For EDA, we used regression analysis and found that increasing PSS scores were related to increasing EDA [$F(1, 54) = 6.49$, $p = .01$] with every one standardized unit change in PSS resulting in a 1.65(μS) increase in EDA.We then did a regression analysis of BDI scores and EDA [$F(1, 54) = 9.25$, $p < .001$] with a one unit standardized change in BDI associated with a 1.92(μS) change in EDA. Regression analysis of BDI scores and heart rate did not show significant results [$F(1, 54) = 0.85$, $p = 0.36$]; neither were PSS scores significant predictors of heart rate [$F(1, 54) = 1.21$, $p = 0.28$].

Exploratory Analysis of LDI

In our final effort to look at potential stress modulation of learning, we regressed overall LDI and EDA, and separately, negative LDI scores and EDA to see if significant relationships existed between stress responses and behavioral scores. No overall effect was seen across groups, but between groups the experimental group showed overall LDI and EDA significance during distraction (p=0.034) with a one-unit change in distraction EDA associating with a -0.011 change in LDI scores that were encoded during distraction. Also, regression of negative overall distraction LDI and distraction EDA showed significance in the experimental group (p=0.031) with a one-unit change in EDA associating with a -0.014 change in negative lure scores. No significances were found between LDI and EDA in the control group or during the white noise condition.

Further results came from the repeated measures ANOVAs on LDI scores with the group (experimental or control) and as the between factor, and similarity (high and low similarity), valence (positive, negative, and neutral), and distraction (white noise and distraction) as within factors (Table 4, Appendix).

There was a significant main effect of similarity [F(1, 54) = 145.39, p < 0.001]. As expected, we see higher LDI scores for lower similarity than for higher similarity (t(55)=12.36; p < 0.001) (Figure 6).

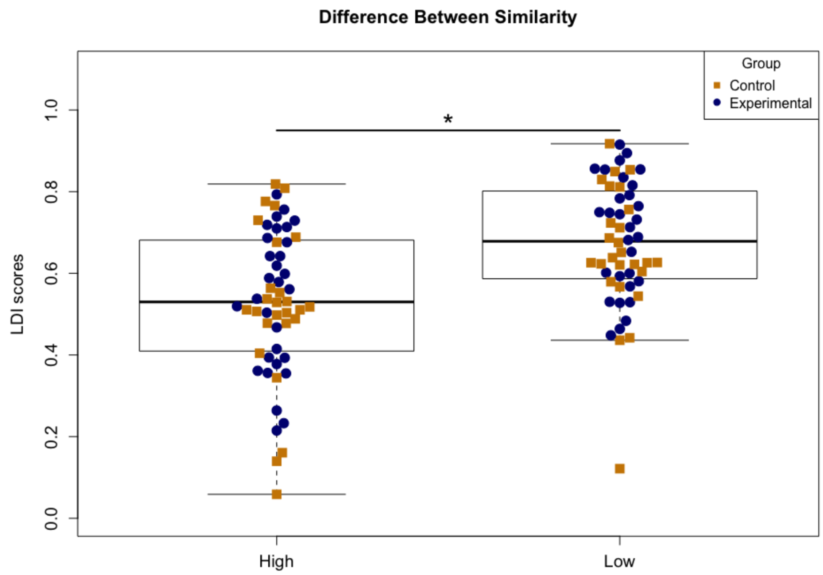


Figure 5 Boxplot of LDI Scores by Similarity. Low similarity stimuli have higher LDI than high similarity (p <.001).

Exploratory Analysis of BIOPAC Measurements and Questionnaires

Physiological measurements of heart rate and EDA were obtained with BIOPAC's Bionomadix wireless brace and were recorded and analyzed with BIOPAC's Acqknowledge software 4.0. Scores from the BDI and the PSS were generated from each test's score guidelines.

Across the four groups: control block 1, control block 2, experimental block 1, and experimental block 2, there was no difference in BDI or PSS scores (F(3,52) = 0.43; p = 0.73 and F(3,52) = 0.59; p = 0.63; respectively). This confirms there is no confounding variable of depression or anxiety (Figures 7 & 8).

Nor is there a difference in EDA or heart rate across the four groups for the white noise condition (F(3,52) = 1.57; p = 0.21; F(3,52) = 1.34; p = 0.27) or when distracted (F(3,52) = 1.73;

p = 0.17; F(3,52) =1.84; p=0.15) (Figures 9 and 10). Therefore, there is no confounding variable of EDA or heart rate.

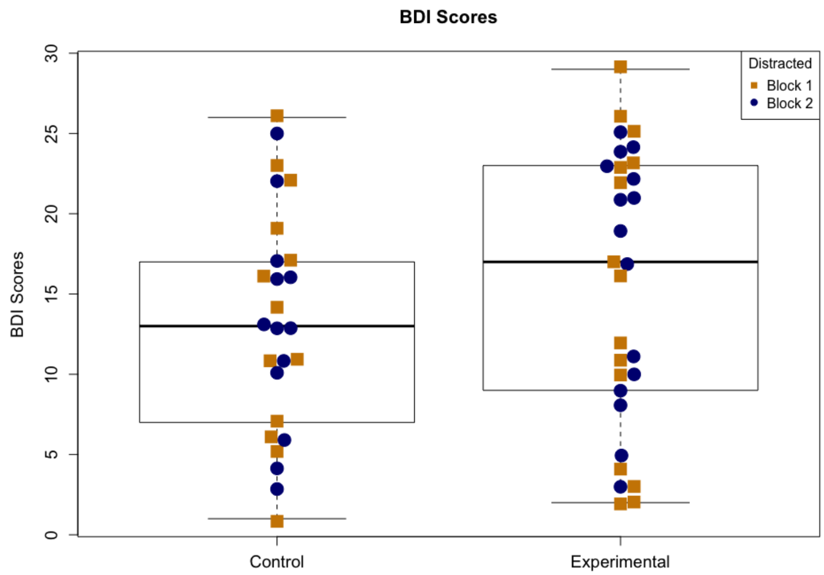


Figure 6 Boxplot of BDI Scores Balancing Across Four Groups.

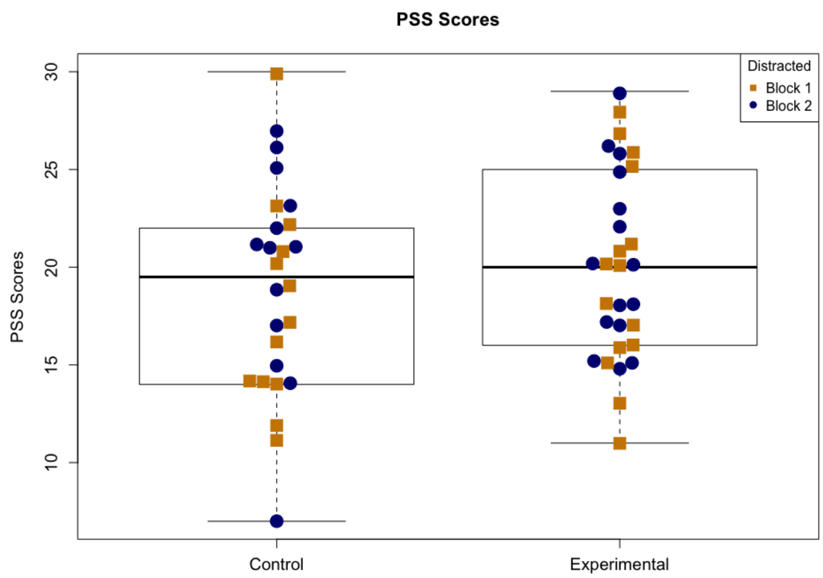


Figure 7 Boxplot of PSS Scores Balancing Across Four Groups.

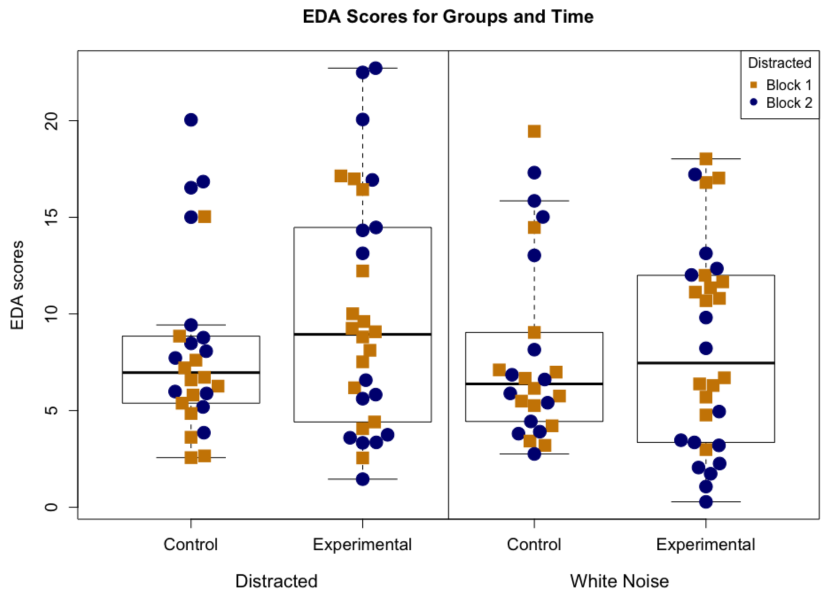


Figure 8 Boxplot of EDA by Group, Time, and Condition.

Figure 9 Boxplot of Heart Rate by Group, Time, and Condition.

Discussion

In this study, we sought to understand the role of short-term stress exposure on memory that we know to be dependent on the hippocampus. Distraction and stress induction studies are numerous and investigate the ability of participants to cognitively function during disruptive or emotionally taxing settings (Balderston et al., 2017; Bernstein et al., 2019; Cunningham et al., 2018; Dobbs et al., 2011; Hayashi et al., 2012; Jones et al., 2011; Schwabe et al., 2012; Smith & Thomas, 2018; Tateuchi et al., 2012; Wirkner et al., 2013; Wolf, 2012). Exposure to stress and emotion when learning is challenging to study, because time-dependent physiological stress mechanisms act in seemingly opposite ways with the basolateral amygdala (BLA) at the forefront known for its modulatory role in memory encoding and consolidation during emotionally charged scenarios (McGaugh, 2004; Schwabe et al., 2012). Stress can act to enhance memory when it is close in context and time of learning, but it has also been shown that stressful episodes can be highly distracting to learning as they reduce executive functioning and draw attention toward threating information (Balderston et al., 2017; Schwabe et al., 2012; Weymar, Schwabe, Low, & Hamm, 2012; Smith & Thomas, 2018).

This study examined MST performance of mothers during stressful distraction and marks the first time to our knowledge that this group has been the focus of an MST. Our results support the overall assumption that noise from children results in statistically lower MST scores and elevated physiological stress responses (EDA).

White Noise and Behavioral Outcomes

The findings outlined in this paper demonstrate that MST performance (both LDI and d') was highest when studying occurred during white noise presentation, which represented a neutral unemotional setting. The effect of distraction was the basis of our first hypothesis, and we found this in our sample; however, we did not find that the experimental group had poorer encoding during distraction than controls. Testing for both groups occurred during white noise, and the white noise study block was randomly assigned to participants in either block 1 or block 2 with the alternate study block receiving distraction audio. Stimuli shown during the white noise block yielded higher retrieval with both LDI and d’ indices.

Elsewhere in literature, brief high decibel presentation of white noise (>100dB) is used to induce the startle reflex (Balderston et al., 2017) and prolonged exposure to high decibel white noise is considered stressful and may cause hearing damage (Sturm, Zhang-Hooks, Roos, Nguyen, & Kandler, 2017). But presentation of white noise in this task was at a mild level, further verified by participants’ significantly depressed electrodermal activity—a physiological marker of the stress response—during white noise compared with the distraction condition.

Distracting Noises

As mentioned above, we found that noise from children significantly disrupted encoding of stimuli in groups of mothers, but we found no difference in test outcomes between groups when we used their own versus others’ children for audio. The process of irrelevant noise presentation as a predictor of behavioral outcome generally posits that noise will orient attention away from the task (Sokolov, 1990; Tateuchi et al., 2012), reducing processing resources and strength of stimuli encoding (Beaman, 2005). Another consideration is whether or not noise can be habituated and will thus decrease its negative impact on encoding with time, which generally occurs with repetitive sounds (Jones et al., 2011). Due to the varying modulation of sounds from children, we expect that habituation did not occur and that irrelevant noise continued to distract and negatively impact encoding (Jones et al., 2011). Our results are consistent with other research which shows that aversive or distracting noises noticeably hinder learning and memory

(Dobbs et al., 2011; Furnham & Strbac, 2002; Hygge, Evans, & Bullinger, 2002; Morey et al., 2009).

Valenced Stimuli

For our second hypothesis, we expected negative lure retrieval to be higher than neutral or positive, but we did not find this in our sample. The main effect for LDI with valence was that both negative and neutral valences had higher LDI scores than positively valenced stimuli, with neutral images accounting for the highest retrieval overall. Our finding that neutral content was the best retrieved overall is supported in other studies which show that participants are better at recalling neutral images, likely because generalization leading to false memory tends to occur more often when stimuli are emotionally charged (Brainerd & Bookbinder, 2019; Brainerd et al., 2008; McKeon et al., 2012; McMakin et al., 2020; Starita et al., 2019). Here, both groups likely generalized during distraction resulting in higher neutral scores.

Emotionally valenced stimuli are regularly used during behavioral tasks to understand whether emotion effects memory accuracy (Dolcos et al., 2013; Kensinger & Corkin, 2003; Leal et al., 2014; McKeon, Pace-Schott, & Spencer 2012; Payne et al. 2007). With valenced word recall lists, participants often falsely recall negative words at significantly higher rates than neutral or positive words (Brainerd & Bookbinder, 2019; Brainerd, Stein, Silveira, Rohenkohl, & Reyna, 2008). The assumption is that confidence, valence, and arousal related to emotionally charged stimuli are partially responsible for increased false memories (Brainerd & Bookbinder, 2019), and that these are the known factors which likely contribute to the formation of a generalization of the stimuli (Brainerd, Holliday, Reyna, Yang, & Toglia, 2010) rather than a detailed recollection to promote exact retrieval.

However, many other studies of stress and valenced stimuli (particularly with pictures, which use different neural processes than with words) demonstrate that under stressful conditions negative stimuli are recalled at higher rates due to their arousing nature acting on the amygdala and strengthening hippocampal encoding processes (Dolcos, F., Denkova, & Dolcos, S., 2012; McGaugh, 2004). This was the basis for our second hypothesis: that the experimental group would demonstrate their increased stress hearing their own children compared with the control group and would thus retain negative images at higher rates, but we did not find this to be the case in our task. Our only group by valence interaction was within the control group with neutral images that were retained at significantly higher rates than both negative and positive images.

Although not a part of the larger ANOVA models, as reported in the results as an exploratory analysis there was a significant negative relationship between negative behavioral scores and stress responses (EDA) in the experimental group. This is not the negative enhancement in a stressed group as we expected, but it does indicate that negative stimuli and stressors have a relationship.

We suggest that we did not see the effect of negative valence between groups or overall as expected, because we lacked power in subject number and stimuli count. With more power, such as removing all positive stimuli and instead increasing negative and neutral bins, we believe we would be able to demonstrate a significant effect of negative image retention.

Physiological Stress Response, BDI, and PSS

Our third hypothesis that PSS negatively correlates with LDI and d’ was supported, but BDI did not significantly correlate with behavioral outcome. This may be because the PSS asked participants to subjectively rate how stressed they felt, and this perceived stress reactivity is more easily translatable into how one might be bothered by noise and activity while trying to accomplish a task than the subjective rating of depression. For instance, the PSS asks questions about the ability to control irritations, coping with life events, temper, and accomplishing tasks. Whereas the BDI asks questions about guilty feelings, loss of pleasure, and whether or not one feels punished. The former questions seem highly relatable to our task condition, whereas the latter do not, likely resulting in the correlation between behavioral scores and perceived stress, and no correlation between behavioral scores and perceived depression.

Our third post-hoc hypothesis was also not supported—our results do not correspond with those of Leal and colleagues (2014) who found that increasing BDI scores were positively associated with negative lure performance. We believe this may be because we had a smaller representation of participants with moderate BDI-II scores and entirely eliminated potential participants with severe BDI-II scores.

As part of an exploratory analysis, regression analysis of overall LDI scores and EDA stress responses in the experimental group showed a significant negative correlation. Additionally, regression analysis of negative LDI scores and EDA responses in the experimental group showed a significant negative correlation. This likely indicates that the type of stress induction in the experimental group (hearing their own children) had a significant negative relationship with the mothers' ability to carry out the behavioral task, and this was noticeable with overall scores and negative scores.

Finally, with our fourth hypothesis, we did find that higher PSS and BDI scores could predict increased EDA, as is supported in literature with higher BDI and PSS correlating with the increased physiological stress response of elevated EDA (Lin, H.-P., Lin, H.-Y., Lin, W.-L., & Huang, 2011).

As speculated, EDA was significantly elevated during distraction blocks compared with white noise blocks. However, contrary to our hypothesis based on data from other studies (Fisher & Newman, 2013; Taelman et al., 2009) heart rate did not vary based on block type. Additionally, EDA did not differ between experimental and control groups which suggests that live audio of a mother's own children did not evoke a more prominent sympathetic stress response than prerecorded audio of someone else's children.

Similarity

Images that were similar but not identical to targets were divided into equal bins of high and low similarity, and lure scores were broken down according to high and low similarity for analysis. And as foreseen, low similarity images had higher LDI scores than high similarity images. Low similarity indicates that the image was less similar to the original target presentation, and high similarity indicates that the two images closely resembled one another. Similarity assignment was preassigned and further validated by Leal et al. (2014) with their data collection and analysis of an independent sample who completed subjective similarity ratings.

Limitations and Future Directions

The task we designed considered several major components of stressors and distraction: preexisting stress and depression indices, emotionally valenced stimuli, and noise from children. While it was at times challenging to consider these variables, we feel that our models accounted for each element and made it possible to separate the effects of each. Our task design was intended to best replicate emotionally taxing settings in which mothers often function in daily life with distracting noises, high needs of young children, and their own mental state. The study also was designed in this manner to replicate valenced stimuli and stress tasks which show various trends in stimuli retrieval depending on the valence of the image and the type and timing of stress induction.

Future studies with mothers, the MST, and distraction could consider a behavioral task with only negative and neutral stimuli to increase the number of images in each bin, since these are often the two valences of interest in stress modulation studies (Cunningham et al., 2018; McCullough, & Yonelinas, 2013; McKeon et al., 2012).

Another consideration for future directions is the timing of retrieval. Testing immediately following retrieval tells us different information than testing later, such as the next day or the following week. The stress response likely remains elevated with testing following encoding, especially with genomic glucocorticoid activity. The key question in testing the following day would be whether negative encoding which was presented during stressful distraction would show significant enhancement when compared with neutral stimuli, as other studies demonstrate (Leal et al., 2014; Weymar et al., 2012).

Finally, the most outstanding question as a follow-up to this study is whether or not AMY-HPC activity significantly differs between distraction and no distraction, and between mothers who hear their own children and mothers who hear recordings of other children. Such a task would mirror other fMRI studies which look at AMY-HPC activity during stress and learning (Dolcos et al., 2013; McEwen et al., 2016; Morey et al., 2009; Shin & Liberzon, 2010; Vaisvaser et al., 2013). With our belief that the experimental group will demonstrate higher negative LDI retrieval than the control group with greater power, we expect to find that AMY-HPC BOLD activity will be increased during distraction compared with controls.

It is important to note that our sample of mothers did not represent a clinical population and potential participants with high levels of reported depression were excluded from the study (BDI > 29). This was necessary, because it is understood that those with high depression may perform more poorly on the MST compared with non-depressed controls (Camfield, Fontana, Wesnes, Mills, & Croft, 2018; Leal et al., 2014; Leal, Noche, Murray, & Yassa, 2017; Shelton & Kirwan, 2013). Participants did represent a large range of depressive symptoms, with scores ranging from 1-29 (mean score $\pm$ SD, 14.5 $\pm$ 7.8), but because we excluded the severe category, we had no representation of scores from 30-63. Our results are thus not interpretable with MST depression studies where higher depression is linked to greater disturbance to noise (Yoon, Won, Lee, Jung, & Roh, 2014) or studies such as Bernstein et al.'s (2019) study on aversive noise vs. social stress in a high anxiety group, because their clinical group was more sensitive to social stressors than sounds, and aversive sounds did not significantly affect MST scores.

Conclusion

Stress induction during encoding has the power to modulate learning and can impair or improve behavioral performance depending upon timing, individual variability, task design, and physiological stress mechanisms acting on learning centers in the brain (particularly the AMY and HPC). We demonstrated in this task with a sample of mothers of young children that stress induction in the form of distracting audio from children served to decrease encoding of stimuli resulting in poorer behavioral performance than without distraction. Participants' stress response during distraction was further demonstrated with increased EDA compared with the no distraction condition.

Although there is a foundation of research indicating under stressful conditions negative stimuli may be retained at higher rates than other stimuli, we did not find this and attribute it to a lack of power. However, lure discrimination for negative stimuli was higher than for positive stimuli. In the experimental group, we found that their stress response (EDA) could negatively predict overall LDI and negative LDI scores, which provides evidence for our argument that hearing one's own children can be more distracting to learning than hearing another's children. Additionally, preexisting self-reported stress of participants negatively predicted behavioral scores, indicating a relationship between perceived stress and distractibility from children. Also, self-reported depression and stress levels translated into increased participant stress responses in terms of EDA. This tells us that perceived stress and depression can be verified with physiological measurements during the MST.

The main intent of this study was to better understand mothers of young children as they seek to learn and function intellectually while they have children who are at distracting and physically demanding ages. We applaud the women who participated and the many more who were interested in this study as they sought to understand more about themselves and their intellectual capabilities as they simultaneously juggle parenting their children. We understand first-hand the often-stressful parenting circumstances that make it difficult to find time or the desire to focus on oneself as an individual, but we encourage parents to continue pressing forward to achieve individual growth while also caring for the needs of their family.

It would be our greatest regret that parents read this study and take away from it what they cannot accomplish with kids at home. Quite the contrary, we invite you to revisit the data and see the incredible cognitive power these mothers had during this mentally taxing task as we deliberately had children making loud and distracting noises—their scores were not zero and they were very close to scores during the no distraction condition.

Stress and distraction are a part of daily life, particularly during parenting years, and it is our greatest hope that parents will fight the urge to give up on themselves and their own growth during this time and will instead find even small ways to learn and achieve on an individual level. We believe that as this strength and joy from learning grows within us, we will become even more successful parents.

Appendix

Table 4 Results for the repeated measures ANOVA on LDI scores with group as between factor and target-lure similarity, stimulus valance, and distraction encoding condition as within factors. (*p<.05).

Effect	DFn	DFd	F	p	p<.05	ges
Group	1	54	0.51	0.4787		0.0048
Distraction	1	54	4.83	0.0322	*	0.0045
Valence	2	108	6.88	0.0015	*	0.0165
Similarity	1	54	145.39	0.0000	*	0.0941
Group x Distraction	1	54	0.11	0.7431		0.0001
Group x Valence	2	108	3.59	0.0309	*	0.0087
Group x Similarity	1	54	1.88	0.1761		0.0013
Distraction x Valence	2	108	0.46	0.6299		0.0009
Distraction x Similarity	1	54	0.28	0.5992		0.0002
Valence x Similarity	2	108	2.83	0.0635		0.0033
Group x Test Type x Valence	2	108	2.63	0.0763		0.0053
Group x Test Type x Similarity	1	54	0.06	0.8031		0.0000
Group x Valence x Similarity	2	108	1.17	0.3131		0.0014
Test Type x Valence x Similarity	2	108	2.04	0.1348		0.0026
Group x Distraction x Valence x Similarity	2	108	3.89	0.0233	*	0.0050

Table 5 ANOVA Results for D' Group × Distraction × Valence. Main effects of Distraction and Valence (*p<.05).

Effect	DFn	DFd	F	p	p<.05	ges
Group	1	54	0.39	0.5361		0.0045
Distraction	1	54	4.97	0.0300	*	0.0061

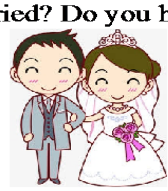
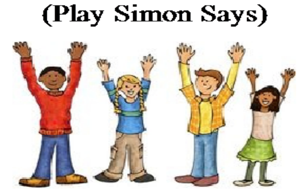
Valence	2	108	5.35	0.0061	*	0.0167
Group x Distraction	1	54	0.02	0.8911		0.0000
Group x Valence	2	108	2.94	0.0571		0.0093
Distraction x Valence	2	108	0.56	0.5748		0.0014
Group x Distraction x Valence	2	108	2.45	0.0909		0.0061

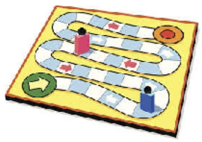
Table 6 Descriptive Statistics for LDI Similarity by Group and Valence. Only high similarity neutral stimuli showed significance between groups, with higher LDI in the control group (p = 0.008).

For between group comparisons

Group	Similarity	Valence	T	DF	p
Distraction	Low	Negative	0.54	57.87	0.5918
		Neutral	0.64	54.36	0.5244
		Positive	0.25	57.69	0.8037
	High	Negative	-0.43	55.75	0.6675
		Neutral	2.47	56.63	0.0165
		Positive	0.37	56.41	0.7116
White Noise	Low	Negative	0.61	50	0.5448
		Neutral	0.47	49.53	0.6431
		Positive	0.03	49.33	0.9763
	High	Negative	0.11	48.05	0.9155
		Neutral	-0.8	46.89	0.4272
		Positive	1.83	44.76	0.0744

Child Episodes

(Singing rollercoaster, low to high)  	(Play tag) 
"Are you married? Do you have any kids?" 	"I had that first. Give it back." 
(Kids singing) 	(Playing with rhythm music instruments) 
"He's going to color on the wall." 	(Building block tower. Someone knocks it over.) 
"She's biting the toy." 	"10-9-8-7-6-5-4-3-2-1 … BLAST OFF!" 
"Mooom!" 	(Play Simon Says) 

"Please, don't touch the computers." 	Broken object noise. "Uh oh!" 
"He's cheating!" 	"I'm bored." 
"If you could have the best dinner in the world, what would you eat?" 	"What is the most fun place you've ever been to? 
Copy Cat Game with Sounds 	(Push a toy button fast/repetitively and sing with it for one minute) 

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