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ReCUR

Red Cedar Undergraduate Research
Michigan State University

MICHIGAN STATE
UNIVERSITY

Honors College

2016

Volume 6

ISSN 2375-401X

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About the Cover

The Volume 6 cover of ReCUR illustrates the wide array of subjects studied and researched at Michigan State University. By incorporating images representative of subjects included in this issue, a collage of research diversity and opportunity available at this university is illustrated. Meghan Kuhr and Marta Werbanowska



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About the Contributors

Sex Differences in Pubertally Added Cells in Rat Brains

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Abstract

Adolescence is a time of extensive maturation and concomitant remodeling of the brain, which is associated with the emergence of structural and functional sexual dimorphisms. The medial prefrontal cortex (mPFC) and nucleus accumbens (NAcc) are two brain regions involved in motivated behavior. Rats were used to investigate whether sex differences exist in cell proliferation/survival during puberty in these regions. They received injections of cell birthdate marker bromo-deoxyuridine (BrdU) at the start of puberty and were sacrificed at time points across puberty to quantify the number of BrdU-immunoreactive cells. The density of new cells increased and then decreased with increasing survival time following the injections. Females showed a higher density of new cells, qualified by interactions in early and late puberty. If a structural sex difference is confirmed, and if pubertal hormones are involved in maintaining that difference, then pubertal hormones may play a role in sex differences in behaviors associated with those areas.

Introduction

Adolescence is a critical stage of development during which a child transitions into adulthood. The beginning of the psychological and social maturation of adolescence is concurrent with, but distinguishable from, the onset of puberty, which refers to the activation of the hypothalamic-pituitary-gonadal (HPG) axis. Activation of the HPG axis leads to gonadal maturation, dramatic changes in hormone levels, and their resulting physical changes. These separate processes are closely linked through interactions between the brain and gonadal hormones (Sisk & Foster, 2004). The effects of sex steroids on the brain are classically described through “organization” and “activation.” They first organize the brain’s structure during critical periods of plasticity, through processes including cell proliferation and migration, to produce sexual differentiation that later supports male or female sexual behavior and physiology in adulthood

(Casey, Giedd, & Thomas, 2000; Sisk & Foster, 2004; Ahmed et al., 2008). The sex steroids then selectively activate acute effects during puberty through cellular mechanisms to induce and maintain the expression of sex-specific adult behavior. Activational effects may come or go depending on whether or not the hormone is present (Breedlove & Hampson, 2002).

An important modification to the original organizational-activational hypothesis proposes that gonadal hormones at puberty both organize and activate certain regions of the adolescent brain. Active maintenance of structural refinement results in long-lasting changes that contribute to adult behavioral responses in socially relevant environments (Sisk & Foster, 2004; Sisk & Zehr, 2005; Schulz, Molenda-Figueira, & Sisk, 2009). Instead of a second critical period, puberty can be thought of as an extension of the plasticity that begins prenatally and ends late in adolescence, prolonging what was once thought to be a succinct critical period during early development.

It should be noted that the presence of hormones at puberty is not the only important factor in maturation. For example, hormone treatment alone fails to produce copulatory behavior in prepubertal animals, indicating the need for further physiological development and proper sensory stimuli through social interactions before the adult behavior can be expressed (Södersten, Damassa, & Smith, 1977; Romeo, Schulz, Nelson, Menard, & Sisk, 2003). Additionally, genetic mechanisms independent of hormones may trigger sexual differentiation of the brain and subsequent differences in behavior (Arnold, 1996). It is unclear whether the hormonal changes at puberty are the primary factor in the maturation of an individual’s brain and behavior. It is more likely the result of a dynamic interplay between factors. Hormonal and other physiological changes may alter the brain directly or contribute to the individual’s social experiences and other environmental stimuli during adolescence, resulting in adult behavior and, in certain cases, increased risk for psychopathology (Arnold, 2004).

Sex differences in the susceptibility to certain mental illnesses, such as eating and mood disorders in women, often begin to emerge during adolescence. Therefore, these disorders may be a reflection of pubertal hormones acting on the brain, in addition to potential psychosocial variables that differentially affect females and males (Angold, Costello, Erkanli, & Worthman, 1999; Kaye, 2008). Little is known about whether this vulnerability is established early in development or is due to the remodeling that occurs during puberty, or is a combination of the two.

During puberty, significant developmental changes occur, in the mesolimbic dopamine pathway that modulates patterns of motivated behavior, including risk-taking, reward seeking, and impulsivity. A key part of the mesolimbic pathway is dopamine released from the midbrain ventral tegmental area (VTA), which has widespread projections to regions involved in reward processes and goal directed behavior, particularly the nucleus accumbens (NAcc) and medial prefrontal cortex (mPFC) (Adriani, Morley-Fletcher, Macri, & Laviola, 2003; Ernst, Pine, & Hardin, 2006; Sesack & Grace, 2010).

The PFC and NAcc are two brain regions that play essential roles in motivated behavior. The PFC is critical for many executive functions, including planning, attention, working memory, and behavioral inhibition (Goldman-Rakic, Cools, & Srivastava, 1996). Due to its functional diversity, efforts have been made to map these processes onto specific regions and neural networks. Data from conditioned place preference, intracranial self-stimulation, and drug self-administration studies confirm the role of the mPFC, which includes infralimbic (IL) and prelimbic (PL) regions in motivated behaviors (Tzschentke, 1998). The mPFC is required for detection and extinction of action-outcome contingencies, such as predicting the value of actions (Alexander & Brown, 2011). The role of the NAcc in reward, as a key region involved in motivated behavior, is widely agreed upon (Ikemoto & Panksepp, 1999; Salamone, Correa, Mingote, & Weber, 2005). However, the specific roles of the subdivisions of the NAcc, the core (NAccore) and the shell (NAccshell), are more controversial regarding the distinctiveness of their functions. Some studies suggest that the NAccore is more important in predicting the incentive value of the reward (Salamone, Aberman, Sokolowski, & Cousins, 1999; Di Chiara, 2002). The shell, though perhaps playing a role in arousal, does

not appear to be as critical to Pavlovian learning (Parkinson, Olmstead, Burns, Robbins, & Everitt, 1999). Ample evidence exists for the role of the mPFC and NAcc in motivated behaviors; however, the relationship between these brain regions is also crucial to the demonstration of typical or pathological behavior.

A common model used to explain increased risk-taking and impulsivity in adolescence proposes that there is an early overproduction of axons and synapses that are pruned through late adolescence. The pruning is more prolonged in the PFC compared to the NAcc, meaning that the NAcc matures earlier (Andersen, Thompson, Rutstein, Hostetter, & Teicher, 2000). Therefore an adolescent may respond to the arousal of a rewarding stimulus without the behavioral inhibition that would otherwise come from a more mature prefrontal cortex (Casey, Jones, & Hare, 2008).

It has also been proposed that a sex difference exists in motivated behavior such that males are more likely to engage in risk-taking and reward-seeking behavior than females (Schafer, Miller, & Byrnes, 1999). However, females show more rapid dependence on drugs such as cocaine (Griffin, Weiss, Mirin, & Lange, 1989) and report higher craving when presented with drug associated cues compared to males (Elman, Karlsgodt, & Gastfriend, 2001), independent of sex differences in the pharmacokinetics of the drug (Mendelson et al., 1999). It has been suggested the hormonal fluctuations in females may produce this differential subjective response (Elman et al., 2001). Vulnerability to addiction can produce life-long consequences, prompting the need for further research in its associated brain development and determining what role, if any, hormones play in creating sex differences in development.

One method of investigating structural sex differences is to study differences in cell proliferation. BrdU labeling is one of the most commonly used techniques for studying adult neurogenesis. BrdU is a thymidine analog that acts as a cell birthdate marker by incorporating into the DNA of dividing cells (Taupin, 2007). Therefore, cells labeled with BrdU are new cells that were born around the time of the injection and survived up until sacrifice time. It is important to note that BrdU itself is not a marker of new neurons. Cells labeled with BrdU could also be glial cells or undifferentiated precursors. Further phenotyping can help determine the role of the new cells. The goal of this study was to determine if there is a

sex difference in the density of new cells added to brain regions involved in motivated behavior, namely the mPFC and NAcc. If a structural sex difference exists, and if pubertal hormones are involved in maintaining that difference, then pubertal hormones may also play a role in sex differences in the behaviors associated with those areas. Adolescence is characterized by major changes to neural systems that underlie higher cognitive functions, but these changes may also increase the risk for certain disorders. There are current gaps in the knowledge regarding the development of these brain areas, which highlights the need for further research to ultimately better understand adolescent brain development.

Methods

Animals

The study used 18 male and 18 female Sprague-Dawley rats (Harlan Laboratories) housed in same-sex pairs in clear polycarbonate cages with ad libitum access to food (Teklad Rodent diet no. 8640; Harlan Laboratories, Madison, WI) and water. The rats were housed in a reversed light: dark cycle (lights off at 1300h).

Design

All of the rats were given an intraperitoneal injection with 200 mg/kg BrdU (20mg/mL) at 0800h, 1600h, and 2400h on postnatal day 30 (P30), around the start of puberty. They were later sacrificed with an overdose of sodium pentobarbital (90 mg/kg) at 2d, 4d, 7d, 10d, 14d, or 21d following the BrdU injection, spanning from early to late puberty. The rats were

perfused with 0.9% buffered saline rinse followed by 4% paraformaldehyde in phosphate buffered saline. Brains were post-fixed in 4% paraformaldehyde overnight with a 25-gauge needle placed in the left hemisphere of the cortex and transferred to 30% sucrose. The brains were cut into 30µm sections and stored in cryoprotectant at -20°C. The PFC and NAcc were picked from a 1 in 6 series of sections. A single-label BrdU immunohistochemistry with 3,3'-diaminobenzidine tetrahydrochloride (DAB) as the chromogen was performed. The stained sections were mounted onto subbed and acid-washed slides and then counterstained using VECTASHIELD with 4',6-diamidino-2-phenylindole (DAPI) to fluorescently label nuclei for cell counting. Coverslipped slides were stored at 3°C to prevent fluorescent decay.

Data Collection and Analysis

The regions of the medial prefrontal cortex (infralimbic and prelimbic), cingulate gyrus (for comparison to the mPFC) and nucleus accumbens (core and shell) were traced using Neurolucida software. Boundaries were determined by consulting a rat brain atlas, comparing differences in cellular composition based on fluorescence, and using structural landmarks. Regional tracings were used to determine area in squared microns. Once the regions were traced, BrdU-ir cells were counted in each section using light microscopy to determine the average number of BrdU-ir cells per regional area. A two-way univariate ANOVA was performed for each region of interest using SPSS software to compare the average BrdU-ir regional density per section (dependent variable) in each sex and each survival time (independent variables).

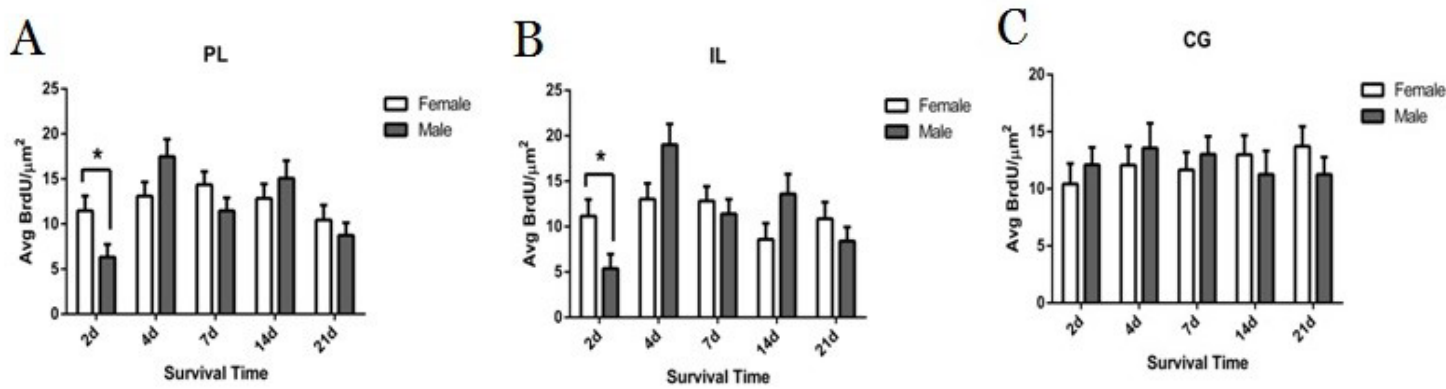


FIGURE 1. Graphs of average BrdU-ir density per Qm2 for each survival time in the prelimbic (A), infralimbic (B), and cingulate (C) regions of the PFC.

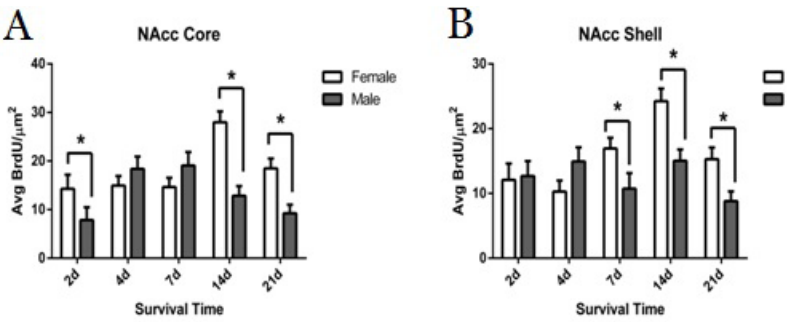


FIGURE 2. Graphs of average BrdU-ir density per Qm2 for each survival time in the core (A) and shell (B) of the nucleus accumbens.

Results

A main effect of survival time was present in the prelimbic and infralimbic regions of the mPFC ($p < 0.001$). In both regions, the density of new cells increased at mid-puberty time points, compared to early and late time points, in both males and females. A main effect of sex was also present in the prelimbic and infralimbic regions, qualified by interactions in which females demonstrated a greater density of new cells than males at the two-day post-BrdU injection survival time, $p < 0.049$ and $p < 0.013$ respectively. The cingulate gyrus showed no significant differences in either sex or survival time (Figure 1).

In the nucleus accumbens, a main effect of survival time was present in the core and shell ($p < 0.001$), again showing a general trend of increasing at mid-puberty time points compared to early and late puberty in both males and females. A female-biased main effect of sex was present in the NAccCore, qualified by interactions at the two-day ($p < 0.01$), 14-day ($p < 0.01$), and 21-day ($p < 0.01$) post-BrdU injection survival times. A main effect of sex was also present in the NAccShell qualified by interactions in which females had a greater density of new cells than males at the seven-day ($p < 0.04$), 14-day ($p < 0.01$), and 21-day ($p < 0.01$) post-BrdU injection survival time (Figure 2).

Discussion

The main effect of survival time seen in the mPFC and NAcc indicates that the number of new cells in these regions increases and then decreases with increasing survival time following the injections in both males and females. The increase in BrdU-ir cells after the two-day survival time may be due to proliferation of daughter cells or migration from a cytogenic niche. New cells are continuously added in the forebrain sub-

ventricular zone (SVZ) and the dentate gyrus of the hippocampus. The SVZ lies along the lateral walls of the lateral ventricles and contains the largest known site of cell proliferation, including neurogenesis, in the adult mammalian brain (Gates et al., 1995). New cells migrate away from the SVZ before they undergo differentiation (Eriksson et al., 1998). Due to proximity, the new cells observed likely migrated along the rostral migratory stream from the SVZ, which borders both the PFC and the nucleus accumbens. The decline of new cells in the mPFC and NAcc days to weeks after BrdU could be due to either cell death or migration into another region. A later survival time point in adulthood could elucidate the fate of the pubertally born cells and whether they are surviving until adulthood. Additionally, BrdU serves as a marker of cell proliferation, but does not provide information about the phenotypes of the new cells. Further staining with markers for neurons and glial cells would be required for insight into the functional role of the new cells. The data indicate that a significantly higher density of new cells is present early in puberty in females compared to males in the PL and IL regions of the mPFC and the NAccCore, based on the interactions at the two-day post-BrdU injection survival time. More new cells survived longer in the female NAccCore and Shell, based on the interactions at the later survival times. Interestingly, these results refute previous results from this lab that a male-biased sex difference exists in the PL region of the mPFC and the NAccCore. This difference could be due to the use of average cell density versus average cell count in the regions, which may have taken into account differences in brain size. Therefore, even if males have a higher total number of cells, there may actually be fewer new cells per square micron. Further studies are required to confirm these results.

The current data support a structural sex difference in the prefrontal cortex and nucleus accumbens. To

determine whether pubertal hormones modulate the addition/survival of new cells in these brain regions, one could remove gonadal hormones before puberty with an ovariectomy or castration. If the sex difference is eliminated in the absence of pubertal hormones, it would suggest that the hormones play a role in producing and possibly maintaining the difference. Additionally, a cell metabolic marker, such as c-fos could be used in conjunction with a behavioral task that recruits reward-related brain regions to see if the new cells are being functionally incorporated into circuits. An additional study could investigate whether c-fos expression is correlated with reward magnitude and/or sex differences in behavior.

This study provides a foundation to better understand potential sex differences in brain development during puberty that may be related to differences in emotion, cognition, social functioning, and mental illness susceptibility that emerge in adulthood. The results suggest that females have a significantly higher density of new cells, which proliferate and survive, compared to males in the prelimbic and infralimbic regions of the medial prefrontal cortex and the core and shell of the accumbens. Further studies may examine how pubertal hormones modulate this process and the possible role of the new cells. Differences in structure are generally in place to support differences in function, but knowledge of a system's structure does not necessarily reveal its correlated function. Much more work would be needed to determine functional consequences of a structural sex difference in either of these regions. A couple decades ago, the idea of cell proliferation in brain regions such as the medial prefrontal cortex and nucleus accumbens would have been unheard of. However, this study provides additional evidence that there are new cells being added to these regions in puberty, which could have profound implications for understanding how higher cognitive functions and motivated behavior develop to support adult behavior.

Acknowledgements

I would like to thank Maggie Mohr and Nancy Michael for training me on the techniques used in this experiment. I am also grateful to the Don-Carlos Lab at Loyola University for their collaboration and help in cutting the brain tissue. This research was funded by the NIH and the MSU Provost Undergraduate Research Initiative in the College of Social Science.

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Highlights of Undergraduate Research

Callahan, Courtney, “Experiential avoidance mediates the relation between worry and anxiety sensitivity,” 28th APS Annual Convention, May 26 – 29, 2016.

Gelpi, Grace, North American Saxophone Alliance Biennial Conference, March 7 - 13, 2016.

Glover, Katharine and Stewart, Joel, “The technical and performance characteristics of a low-cost, simply-constructed, black light insect trap,” Entomology 2015, November 15 - 18, 2015.

Herbst, Joseph, North American Saxophone Alliance Biennial Conference, March 7 - 13, 2016.

Hesse, Laura, “Genetic factors contributing to the formation of antibiotic resistant small colony variants,” Midwest Microbial Pathogenesis Conference, September 23, 2016.

Jweiha, Aiya, “Gender uncensored: perceptions of transgender job candidates,” SIOP Annual Meeting, April 13 - 17, 2016.

Lulloff, Jorda, North American Saxophone Alliance Biennial Conference, March 7 - 13, 2016.

Morrison, Claire, “Investigating syllabi for three-dimensional learning,” Society for the Advancement of Biology Education Research National Meeting, July 14-17, 2016.

Peng, Ling, “Attentional change after mindfulness meditation intervention predicts stereotype threat performance: an electrophysiological investigation,” 28th APS Annual Convention, May 26 – 29, 2016.

Sears, Huei, “Property of the roots of tribonacci-type polynomials,” 2016 Joint Mathematics Meetings, January 6 - 9, 2016.

Shinners, John, Murray, Nathan and Pryg, Kasey, “Improving tuberculosis detection using smear microscopy,” GRAAL San Cristobal de las Casas, October 7, 2015.

Swarthout, Scott, “Theatre engine project,” Edinburgh Fringe Festival, August 22-29, 2015.

Valentini, Kelly, “Characterization of fatty acid and mineral composition of selected seeds, nuts and oils in Tanzania,” Experimental Biology, April 2 - 6, 2016.

Vaughn, Patrick, “Age and rate affects the fracture patterns of immature porcine femurs under torsional loading,” American Academy of Forensic Sciences 68th Annual Meeting, February 23 - 26, 2016.

Velasco, Julian, North American Saxophone Alliance Biennial Conference, March 7 - 13, 2016.

Young, Jacob, “Modeling the role of contaminants in the cohort survival of juvenile estuarine killifish (*Fundulus heteroclitus*),” Society of Environmental Toxicology and Chemistry (SETAC), November 1 - 5, 2015.

Zhou, Whitney, “Stereotypes, games and your blade-dancer self: using avatar customization to reduce stereotype threat effects,” Games, Learning, and Society Conference, August 17-19, 2016.

Maternal Control in Infant Feeding Among Ethnically Diverse Low-Income Mothers

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Abstract

A disproportionate number of overweight/obese children in the United States come from low-income minority groups. High levels of maternal control in infant feeding have been associated with decreased infant satiety cues, which increase obesity risk. This study explores levels of maternal control in infant feeding among African American, Hispanic/Latina, and Caucasian low-income mothers. More African American mothers (46%, $n = 109$) than Caucasian mothers (18%, $n = 43$) believed parents should decide how much the baby eats. Hispanic/Latina (51%, $n = 69$) and African American (37%, $n = 50$) mothers reported higher agreement with the importance of the infant finishing the bottle and encouraging eating than Caucasian mothers (13%, $n = 17$). These data suggest greater tendency to pressure infants during feeding in minority populations. Specific interventions related to responsiveness to infant feeding cues and maternal feeding styles need to be tailored to specific racial/ethnic groups to promote infant-centered feeding practices.

Introduction

Childhood obesity is at epidemic proportions in the United States. Population data has shown that an estimated 9.5% (SD = 7.3-11.7) of infants up to two years old have been classified as obese, and approximately 31.7% (SD = 29.2-34.1) of children 2-19 are overweight/obese (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). Obesity prevalence varies among socioeconomic and racial/ethnic groups, with higher occurrence among low-income and minority groups (Dixon, Peña, & Taveras, 2012; Ogden et al., 2010). While evidence shows that prevalence of obesity may be plateauing, the disparity across ethnicities is growing, with particularly high occurrence

of obesity in African American girls and Hispanic/Latino boys (Hughes et al., 2006; Olds et al., 2011). High levels of maternal control in infant feeding have been linked to decreased internal satiety cues in infants (Birch & Fisher, 1998; Gross et al., 2010; Lumeng et al., 2012; Ventura & Birch, 2008), which increases the risk for childhood obesity and poor eating behaviors. Research has shown a greater number of early-life obesity risk factors exist among minority children compared with Caucasian children (Taveras, Gillman, Kleinman, Rich-Edwards, & Rifas-Shiman, 2010). African American and Hispanic/Latino infants are more likely to exhibit rapid weight gain, experience non-exclusive breastfeeding, less sleep, and the early introduction of solid foods. A recent study conducted by Taveras, Gillman, Rich-Edwards, and Rifas-Shiman (2013) found African American and Hispanic/Latino infants also had substantially higher BMI and body fat, and when measured at seven years old, almost twice the rate of obesity compared with Caucasian participants.

Infant feeding is a growing area of research; however, the majority of researchers have focused primarily on the Caucasian, middle-class population. Variance in infant feeding behaviors among ethnic populations has not yet been thoroughly explored, and there is limited research that has examined levels of maternal control over infant feeding as they vary across low-income minority populations. This study compares maternal control over infant feeding across ethnic groups to provide an understanding of how minority populations' feeding behaviors vary and can influence child weight status in order to decrease the risk of obesity in early life.

Parental feeding styles are mostly responsible for an infant food intake (Sherry et al., 2004; Stang, Rehorst, & Golitic, 2004). Research has shown that high-control

parenting styles inhibit children’s ability to self-regulate (Carper, Orlet-Fisher, & Birch, 2000; Costanzo & Woody, 1985). Using variable densities of formula, Fomon (2001) demonstrated how infants naturally possess internal satiety cues and can independently adjust their intake to maintain an average energy balance. Another study showed that infants are capable of regulating their intake based on internal feedback so that even though there was -40% variance between individual meals, the energy intake over a 24-hour period varied only by -10% (Birch & Fisher, 1998).

Parents often assume that infants need help in making feeding decisions and do not allow infants to practice self-control over amounts of food intake. Restricting and controlling infant feeding weakens the infant’s internal response cues to fullness and energy density, which can determine food intake in later childhood (Birch & Fisher, 1998; Fisher & Birch, 2002). Children who have poor self-control mechanisms are more likely to exhibit negative eating behaviors, such as eating in the absence of hunger. Restrictive feeding practices have been associated with higher obesity outcomes at 3 years old (Taveras et al., 2006). Birch and Fisher (1998) suggested that an authoritative parenting style, meaning one that displays high demandingness and high responsiveness, is the best for infant feeding health outcomes. A more recent study reaffirms that high parental responsibility and monitoring combined with low restriction/pressure to eat results in optimal child nutrition (Ventura & Birch, 2008).

Methods

This study used secondary data from a larger research study, that focused on maternal responsiveness, feeding styles, and infant feeding practices with mother-infant dyads from Michigan and Colorado (Horodynski, Brophy-Herb, Olson, Baker, & Rogers, 2009). Data were collected between January 2010 and October 2013. Participant demographic data and responses were obtained from the “Healthy Babies Infant Feeding Questionnaire: Time 1.” During scheduled interviews, trained data collectors obtained mothers’ responses to behavioral questions. Three questions were analyzed and compared across three self-identified ethnicity categories: African American, Hispanic/Latina and Caucasian. For the purpose of our research, the selected items were classified as indicators of maternal control in infant feeding. Response variables were recorded on a Likert scale

of 1 (disagree) to 5 (agree). The middle choice, “neither agree nor disagree,” had very low frequency and, therefore, was dropped in our comparison in order to improve clarity. Results were dichotomized to show percentage agreement with each statement to measure maternal control in feeding by group. SPSS version 22 was used for descriptive data analysis.

Sample

Participants in this study were low-income mothers (N = 495) recruited from two counties in Colorado and three counties in Michigan. All “Healthy Babies” participants were of low socioeconomic status (SES), defined as less than or equal to 185% U.S. poverty level, and therefore qualified for WIC/SNAP governmental food assistance programs. These requirements indicate that all homes could be classified as “food insecure.” Inclusion criteria were that mothers answered at least one of the selected questions; mothers with premature infants were excluded. Participants were categorized into three major ethnicities: African American (n = 182, 37%), Hispanic/Latina (n = 209, 42%), or Caucasian (n = 104, 21%). See Table 1 and Table 2 for study sample demographics.

Results

Results of mothers’ beliefs about infant feeding are shown in Table 3. Nearly half of the African American mothers (46%, n = 99) and one third of Hispanic/Latina mothers (36%, n = 77) believed that the parent should decide how much the baby eats; this is much higher than the 18% (n = 40) of Caucasian mothers who agreed. Caucasian mothers (13%, n = 17) had the lowest agreement rate compared to African American (36%, n = 47) and Hispanic/Latina mothers (51%, n = 66) regarding their belief that their baby should finish all of the milk in the bottle. Hispanic/Latina participants showed the most agreement with the mother’s role in encouraging the baby to eat (46%, n = 174), compared with African American (35%, n = 135) and Caucasian mothers (19%, n = 74). This finding is supported with literature reporting that maternal control feeding is associated with minority ethnicities (Sherry et al., 2004; Taveras et al., 2010).

Discussion

As a secondary analysis, this particular report covers a selected sample of the entire “Healthy

		African American (n = 182)	Hispanic/ Latina (n = 209)	Caucasian (n = 104)	Total (N = 495)
n (%)					
Marital Status	Married	13 (7%)	83 (40%)	38 (37%)	134 (27%)
	Not married	169 (93%)	126 (60%)	66 (63%)	361 (73%)
Education	< High school	39 (22%)	77 (37%)	13 (13%)	129 (26%)
	High school	48 (26%)	75 (35%)	35 (33%)	156 (32%)
	> High school	95 (52%)	59 (28%)	56 (54%)	210 (42%)
M (SD)					
Age (years)		22.5 (4.2)	25.3 (6.1)	24.5 (4.4)	24.1 (5.3)

TABLE 1. Mother Demographics.

		African American (n = 182)	Hispanic/ Latina (n = 209)	Caucasian (n = 104)	Total (N = 495)
n (%)					
Female		88 (48%)	93 (44%)	43 (41%)	224 (45%)
Male		94 (52%)	116 (56%)	61 (59%)	271 (55%)
Age (months)	Male	1.75 (0.94)	1.69 (1.06)	1.81 (1.14)	1.74 (1.06)
	Female	1.62 (0.84)	1.48 (0.87)	1.94 (1.22)	1.63 (0.95)
Birth weight (lbs)		7.17 (0.86)	7.32 (1.01)	7.45 (1.15)	7.29 (0.99)
3-month weight (lbs)		10.74 (2.27)	10.62 (2.46)	10.94 (2.53)	10.74 (2.41)

TABLE 2. Infant Demographics.

	African American (n = 182)	Hispanic/ Latina (n = 209)	Caucasian (n = 104)	Total (N = 495)
Agreement to Statements				
“it’s important for the parent to decide how much a baby should eat”	99 (46%)	77 (36%)	40 (18%)	216 (100%)
“It’s important that baby finishes all the milk in the bottle”	47 (36%)	66 (51%)	17 (13%)	130 (100%)
“It’s important to encourage baby to eat”	135 (35%)	174 (46%)	74 (19%)	383 (100%)

TABLE 3. Mother’s Agreement With Belief Statements.

Babies Through Infant-Centered Feeding” study and, therefore, does not account for all related cofactors or the entire data set. Since only baseline data from Time 1 was used, temporal change in feeding practices and the outcomes of intervention cannot be analyzed. As a basic descriptive study within a larger project, this paper illustrates the infant feeding beliefs of three populations of low-income mothers.

As hypothesized in our study, African American and Hispanic/Latina mothers demonstrated higher levels of maternal control in infant feeding than Caucasian mothers, indicating that African American and Hispanic/Latina mothers support high parental control related to infant feeding decisions. This may take the form of restricting the baby to eat less, pressuring the baby to eat more, or both. Hispanic/Latina and African American mothers showed higher levels of agreement with the importance of the baby finishing the entire bottle and encouraging the baby to eat. Both of these behaviors suggest pressuring feeding styles.

One interpretation of why these differences exist may include cultural factors, such as beliefs and environmental conditions separate from SES, as all mothers were of similar SES. Previous research suggests the influence of culture accounting for much of the disparity in feeding practices and outcomes (Dixon et al., 2012). Breastfeeding, for example, is well-established in the Hispanic/Latina culture and may encourage less maternal control (Brown & Lee, 2013; Gross et al., 2010; Hurley, Black, Papas, & Quigg, 2008). This may explain why fewer Hispanic/Latina mothers agreed that “the parent should decide how much the baby eats” than African American mothers, who tend to breastfeed less (Hurley et al., 2008). The body of research can be somewhat contradictory as low-income Hispanic/Latina populations have also shown maternal pressuring feeding styles, which have been linked to poor infant feeding and self-regulation (Sherry et al., 2004).

Parents’ perception and concern over their child’s health and weight status may differ from the clinically established rates, and these perceptions vary across income and ethnicities (Hughes et al., 2006). When shown pictures of children of different weights and asked at which level they are considered obese, about one-fifth of African American participants chose the largest child as the cutoff for overweight, indicating a different idea of overweight than what is clinically established as healthy (Sherry et al., 2004). Hispanic/La-

tina mothers often worry about not producing enough milk and thus are typically more concerned about underweight than overweight, and may misinterpret infant cues (Gross et al., 2009; Hurley, et al., 2008). Ethnicity, cultural beliefs, perceptions, and age are closely interrelated. Musher-Eizenman, de Lauzon-Guillain, Holub, Leporc, and Charles (2009) hypothesized that cultural differences and socioeconomic status are more closely associated with pressuring children to eat than parenting style. It is important for health professionals to understand these influences on mothers’ infant feeding behaviors in order to promote healthy infant feeding practices. Health professionals need to consider the mothers’ support networks and role models, which can heavily influence maternal infant feeding decision-making (Bentley, Gavin, Black, & Teti, 1999; Hannon, Willis, Bishop-Townsend, Martinez, & Scrimshaw, 2000; Sherry et al., 2004; Wiemann, DuBois, & Berenson, 1998). Socioeconomically disenfranchised mothers often have less access to healthy food and nutrition information, more environmental stressors, and less time to spend feeding their babies. All of these factors can lead to mothers, particularly mothers from African American and Hispanic/Latina populations, not adhering to feeding guidelines. Food insecurity can influence feeding behavior, often promoting control-feeding styles. Low-income mothers tend to show more concern for infant hunger and less concern for overeating (Baughcum et al., 2001). Poor feeding behaviors contribute to childhood obesity prevalence in the United States. Ethnic disparities in child obesity may be linked with early-life risk factors, one of which is high maternal control over infant feeding (Taveras et al., 2010). As our results suggest, African American and Hispanic/Latina mothers exhibit higher levels of maternal control in infant feeding than Caucasian mothers. Interventions in early life could greatly reduce ethnic disparities among childhood obesity prevalence (Taveras et al., 2013). Further research and interventions should focus on the complex network of the beliefs, environments, and cultures that influence a mother’s feeding behavior and should tailor nursing interventions more specifically to minority ethnicities.

Acknowledgements

Thank you to my mentor Dr. Mildred Horodyski for her inspiration and guidance, as well as for allowing me to do a secondary data analysis within her project, “Healthy Babies Through Infant-Centered Feeding”

(USDA NIFA- AFRI grant #2009-55215-05220). I’d also like to thank Kyung Sook Lee for her statistical analyses and the MSU College of Nursing Undergraduate Research Program for funding this research.

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The China Experience

Casey McDougall and Nancy DeJoy

Department of Writing, Rhetoric, and American Cultures

Michigan State University prides itself on the diversity of its student body, and with 7,568 international students from 131 countries enrolled in the fall of 2015, it has reason to be proud. One of the largest international student populations is made up of those students who come to MSU from China, 4,700 in the fall of 2015 alone according to MSU's Office for International Students and Scholars. The MSU arts and cultures theme from February 2015 to August 2016 was "The China Experience."

From colorful quilt displays and the Land of Feathered Dragons exhibit in the MSU Museum, to a specially themed marching band half-time show featuring choreography by Jennifer Wen Ma, to an advertising exhibit on display in the Communications Arts and Sciences Building and a traditional Chinese opera put on by the MSU College of Music and the China Conservatory of Music, Michigan State students were presented with a wealth of opportunities to experience Chinese culture like never before. Through arts and culture at MSU, students have had all year to interact with different facets of Chinese culture.

in an organized and easily accessible way. According to CEC chair Kurt Dewhurst, the CEC "work[s] to create innovative programs, greater connectivity and coordinated presentation of arts and cultural activities on campus and in the broader communities we serve in Michigan, nationally and internationally."



Photo by: Stephanie Cepak

The Honors College's Sharper Focus/Wider Lens faculty panel discusses "Seeing China" in the MSU Union Ballroom on November 16, 2015.

When asked about why "The China Experience" was chosen for this year's theme, Dewhurst said "The CEC had been having discussions about the growing presence of China on the world stage and the increased number of Chinese students on our campus. We agreed that a focus on China would be an especially appealing theme and we proceeded to create a mission statement for the China experience year. The mission established was: "As a globally engaged, research-intensive university, MSU has created The China Experience: An MSU Exploration of Arts & Culture to showcase China-related faculty and student work; to inform and educate the campus and broader community regarding Chinese arts and culture; and foster increased integration of students from China from China into MSU life, as well as expand overall cross-engagement between all cultures involved." According to Dewhurst there was also a "significant commitment to cross-cultural understanding," as well as a desire to connect not only with the Chinese-American students at MSU, but also Chinese American



THE CHINA EXPERIENCE

AN MSU EXPLORATION OF ARTS & CULTURE

populations in the broader East Lansing community. The purpose of the theme was realized as dialogue was fostered around culturally sensitive and important issues.

The tradition of the thematic year continues into the 2016-2017 school year with the focus “WaterMoves MSU,” as represented by the STEAM (science, technology, engineering, arts, and math) programs. The programs will look at water both from scientific and cultural standpoints. As for the future, Dewhurst says: “Overall, we hope the thematic initiatives enrich the learning experience for our students as well as the public. The Cultural Engagement Council is now involved planning an exciting series of experiences on campus and we hope that it will build bridges to achieve lasting impact at the intersection of science, artistic and cultural expression, and community. We hope it will move us all to take the lead in shaping a better tomorrow for the Great Lakes and beyond.”

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Smoke billows above the Spartan Marching Band as it performs “The Art of the March: Cues from Sun Tzu’s ‘The Art of War’” during the football half-time show November 14, 2015. The show featured five musical selections performed by more than 600 people.

The Art of Art

Jack William Burk, Heather Hartmann, Sarah Hopkins, Deshaun Leonard, Alex Hennessy, and Spencer Taylor

College of Communication Arts and Sciences

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The Effect of Mental Effort on Metabolism

Kevin Michael Wheelock, Joshua Lawrence Starkey, and Erica Ariece Wehrwein

Department of Physiology

Abstract

Cerebral metabolism has been shown to vary with cognitive activity. By using indirect calorimetry, this study found that overall metabolic rate increased in a healthy population of young college males and females (ages 18-22) during the completion of arithmetic and spatial reasoning problems. Energy expenditure (EE) was found to be elevated by 19% and 16% ($n = 11$, $p < 0.0001$) during the arithmetic and spatial reasoning tests respectively, compared with the baseline condition during which subjects sat with their eyes closed. Respiratory exchange ratio was found to have decreased slightly from baseline during the spatial reasoning condition (from 0.86 to 0.83, $p = 0.01$), but not the arithmetic condition (from 0.86 to 0.860, $p = 0.99$). When stratified by performance, it was found that high performers on the arithmetic test had significantly lower EE than the low performers. This relationship did not hold for the spatial reasoning test. In conclusion, we demonstrate that whole body metabolism is elevated during increased cognitive demand. Our findings demonstrate that cognitive challenges are a substantial contributor to total EE beyond that achieved with physical work.

Introduction

Metabolism is the biological process of breaking down macronutrients to create energy, in the form of adenosine triphosphate, which drives various cellular processes. In humans, the brain is the most energy dense organ, generating 20% of basal metabolic rate (BMR) despite accounting for only 2% of body weight (Khatri & Man, 2013). On a 2000 cal diet, this translates to 420 cals per day. Although well characterized in the “resting” state, dynamic brain metabolism, especially during normal physiologic activity is not fully understood (Villien et al., 2014). Human and animal studies indicate that cerebral metabolism may increase with mental workload (Owen & Sunram-Lea, 2011; Philippou & Constantinou, 2014). Imaging

studies have shown that cerebral metabolism increases in some areas of the brain during cognitive activity (Hoshi & Tamura, 1993; Hoshi et al., 1994). The use of calorimetry to detect cerebral metabolism was first attempted over 80 years ago by Lennox (1931) who described an increase in oxygen (O_2) concentration and decrease in carbon dioxide (CO_2) concentration in the jugular vein of subjects performing arithmetic problems (Lennox 1931). A similar experiment two decades later failed to replicate this finding (Sokoloff, Mangold, Wechsler, Kennedy & Kety, 1955). More recently, indirect calorimetry has been used to show that metabolic rate increases with mental workload, but a large portion of the change was attributed to cardiovascular activity (Backs & Seljos, 1994).

Glucose is the main energy source for the brain. Compared with other tissues, brain tissue has very low glycogen content. Turnover of the small amount of glycogen is also very slow, about 1-2% of the glucose utilization rate (Oz et al., 2007). Thus, cerebral energy demands must be met by a continuous supply of blood glucose. It has long been reasoned that glucose supply must change to meet the metabolic demands of the brain. Studies have demonstrated that consumption of a sugary drink before various cognitive tests can improve cognitive function in memory, verbal and spatial reasoning, and mathematical skills (Scholey, Harper, & Kennedy, 2001; Owen & Sunram-Lea, 2011; Philippou & Constantinou, 2014). It has also been demonstrated that peripheral blood glucose levels fall during the performance of mental tasks (Scholey, Laing, & Kennedy, 2006; Perlmutter et al., 2009). The effect of glucose loading on cognitive performance appears to vary depending on the testing conditions; certain tasks are more readily improved with glucose loading (Scholey et al., 2001), and the difficulty of tasks appears to affect the magnitude of improvement in performance (Kennedy & Scholey, 2000). Glucose also seems to improve performance to a greater extent in healthy elderly and cognitively impaired subjects compared to healthy, young subjects (Messier, 2004; Philippou & Constantinou, 2014).

Human studies that have directly examined dynamic cerebral metabolism are wide in scope of methodology. Early research using arterial catheters or blood draws to determine brain oxygen consumption (VO_2) and carbon dioxide production (VCO_2) during mental activity reported conflicting findings (Lassen, 1959). Newer neuroimaging studies have allowed for a more precise measurement of cerebral blood flow and VO_2 , which is strongly correlated with metabolism (Hoshi & Tamura, 1993). Hoshi and Tamura (1993) demonstrated that during mental arithmetic blood flow to the frontal region of the brain increased, but only when the subject had difficulty solving a problem. Individuals that solved a problem easily did not have the same change in blood flow. The same study also demonstrated that there was over and under-compensation of cerebral blood flow during the mental activities, meaning some areas of the brain received reduced blood flow while others received more. This indicates that the sum of cerebral EE may be constant; when one area of the brain becomes more active, another area decreases activity.

Human studies of cerebral metabolism have been conducted in numerous ways. Indirect calorimetry is a much simpler and more affordable measurement than brain scans, and is less invasive than an arterial catheter. Therefore, we used indirect calorimetry to measure changes in metabolism during mental exercises in young, healthy humans. Our study is a proof-of-concept that indirect calorimetry is sensitive enough to detect changes in overall metabolism resulting from thought exercises, and also tests the impact of spatial and arithmetic problem solving on whole body metabolism.

Methods

Overview

We first measured individual subjects' seated, resting metabolic rates by monitoring them using a PowerLab A/D converter and AD Instruments gas analyzer with spirometer (AD Instruments) while they were prompted to perform a series of cognitive tests. PowerLab data was stored in real time using LabChart software (AD Instruments, v7). Using the spirometer and gas analyzer, we obtained ventilation (V_e ; L/min), VO_2 (ml/min), VCO_2 (ml/min), respiratory exchange ratio (RER), and energy expenditure (EE; kJ/min).

Subjects

Test subjects were recruited members of the Department of Physiology, or were acquaintances of the researchers. A total of 11 subjects were recruited (four male and seven female). The age range was 18-22 years old. Ten of the 11 subjects were Michigan State University students, while the other was an employee. Subjects stated that they were non-smokers. All subjects were of a normal physical activity level (neither sedentary nor involved in high intensity training) and were not obese (body mass index < 30 kg/m²).

Test Conditions

Conditions were the same for each test subject. Testing was done between 8 and 11 a.m. on weekday mornings. Subjects were told to refrain from eating or drinking beverages other than water the morning of the experiment. Each test took place in the same laboratory, and subjects were seated on a stool at the same computer/PowerLab for all testing. The tests were presented in the same order to each subject. All tests were completed in one continuous run, with a one-minute break between each condition to explain the next test. Upon arriving at the lab, subjects were immediately seated at the testing station and fitted with a gas analyzer mask tightly covering the nose and mouth. Different mask sizes were used depending on the person to ensure a tight fit. The subject was then told to close his/her eyes and breathe into the mask for five minutes. This served to bring the air in the machine to equilibrium and allowed the subject to become accustomed to the apparatus. Data from this period was not used in the final analysis. At the end of this period, the testing began.

Metronome Control

Each subject was told to tap the “5” key on the numeric keypad in time with a metronome beat of 60 beats/second for a period of three minutes. In an effort to limit the cognitive effects on metabolism during this test, subjects were asked to clear their minds of all other thoughts and close their eyes. This condition served as the control condition for our study.

Mathematical Test

The first cognitive test was a mathematical drill. A brief explanation was given to each subject about how to answer the problems. Subjects were also told not to move except for entering the answers with one

hand on the keyboard and were not allowed to write or do manual calculations. Finally, it was emphasized that the test did not have a time limit. Each person was given the same set of 50 arithmetic problems generated from the website math-aids.com (Figure 1). The problems covered addition, subtraction, multiplication, and division. These problems were entered into a Microsoft Word document, and the subjects entered the answers into this same document.

Name : _____ Score : _____

Teacher : _____ Date : _____

Mixed Problems 5 Minute Drill

$\frac{7}{x \ 8}$	$\frac{4}{- \ 2}$	$\frac{198}{+ \ 11}$	$\frac{285}{+ \ 19}$	$\frac{200}{+ \ 20}$	$\frac{4}{+ \ 20}$	$\frac{6}{x \ 2}$	$\frac{19}{+ \ 6}$	$\frac{11}{x \ 3}$	$\frac{17}{+ \ 16}$
$\frac{221}{+ \ 17}$	$\frac{18}{- \ 16}$	$\frac{10}{- \ 5}$	$\frac{4}{- \ 1}$	$\frac{40}{+ \ 10}$	$\frac{19}{x \ 14}$	$\frac{96}{+ \ 16}$	$\frac{20}{+ \ 10}$	$\frac{2}{+ \ 4}$	$\frac{7}{- \ 2}$
$\frac{11}{+ \ 1}$	$\frac{19}{+ \ 2}$	$\frac{17}{x \ 2}$	$\frac{1}{x \ 3}$	$\frac{18}{- \ 15}$	$\frac{1}{x \ 13}$	$\frac{323}{+ \ 17}$	$\frac{4}{- \ 3}$	$\frac{8}{- \ 4}$	$\frac{3}{+ \ 5}$
$\frac{32}{+ \ 16}$	$\frac{13}{+ \ 12}$	$\frac{14}{+ \ 1}$	$\frac{17}{x \ 5}$	$\frac{35}{+ \ 7}$	$\frac{19}{+ \ 5}$	$\frac{12}{- \ 3}$	$\frac{19}{- \ 2}$	$\frac{7}{- \ 2}$	$\frac{88}{+ \ 8}$
$\frac{19}{+ \ 6}$	$\frac{120}{+ \ 10}$	$\frac{19}{x \ 3}$	$\frac{20}{x \ 13}$	$\frac{280}{+ \ 20}$	$\frac{12}{- \ 5}$	$\frac{14}{- \ 8}$	$\frac{2}{x \ 19}$	$\frac{11}{- \ 4}$	$\frac{16}{+ \ 16}$
$\frac{6}{+ \ 13}$	$\frac{4}{+ \ 2}$	$\frac{15}{x \ 17}$	$\frac{16}{+ \ 9}$	$\frac{14}{- \ 9}$	$\frac{18}{x \ 3}$	$\frac{18}{+ \ 6}$	$\frac{8}{+ \ 20}$	$\frac{18}{- \ 13}$	$\frac{16}{- \ 14}$
$\frac{14}{x \ 3}$	$\frac{8}{+ \ 15}$	$\frac{162}{+ \ 18}$	$\frac{20}{x \ 15}$	$\frac{5}{- \ 2}$	$\frac{18}{- \ 2}$	$\frac{165}{+ \ 11}$	$\frac{289}{+ \ 17}$	$\frac{77}{+ \ 7}$	$\frac{8}{x \ 4}$
$\frac{13}{- \ 7}$	$\frac{42}{+ \ 6}$	$\frac{99}{+ \ 9}$	$\frac{5}{x \ 16}$	$\frac{48}{+ \ 4}$	$\frac{9}{x \ 19}$	$\frac{19}{+ \ 17}$	$\frac{4}{x \ 5}$	$\frac{196}{+ \ 14}$	$\frac{18}{+ \ 9}$

FIGURE 1. Sample of the arithmetic test used for experiment. Subjects were given page one of the test in a PDF and filled in the blanks in a Microsoft Word document.

Spatial Reasoning Test

The second test was the spatial reasoning test. Again, the subject was instructed how to enter his/her answer into the computer, in this case by either pressing “S” if the shapes were identical or “D” if they were different. The spatial test was obtained from PEBL software. Subjects were presented with a sequence of image pairs on the computer and were required to decide if each pair contained identical images. The shapes used were two-dimensional. Subjects were told that there was no time limit on this test, as with the arithmetic test, and were allowed all the time they needed to complete the 64-problem set. The software used for this test randomly generated a new problem set each time, so subjects did not all receive the exact same problems. Following completion of this test the data collection was finished, and subjects were dismissed.

Data Collection and Analysis

Physiological data was imported into Microsoft Excel from LabChart software. Performance data was generated manually by recording the number of correct answers on each test along with the time required to complete that test, which was recorded using a stopwatch. This information was then entered into Excel. The data was then imported into SAS 9.3 (SAS Institute, Cary, NC) for analysis.

EE and RER were analyzed using a two-way repeated-measures ANOVA with a Tukey post-hoc test. Statistical significance was determined using $\alpha = 0.05$. Data from each subject was pooled together and then stratified by the test condition. Mean and standard error were also calculated (Figures 2 and 3). The performance conditions were calculated by dividing the subjects into two groups using an adjusted arithmetic and spatial reasoning score, which was equal to the number of problems correct divided by the total test time. The median arithmetic and spatial scores were calculated for all subjects; the low performing group was defined as being below the median, while the high performing group was defined as those who performed above the median. The median observation was not used (Table 1). Differences between each groups' mean EE, which was averaged over all conditions, were analyzed using an unpaired students' t-test. Respiratory rate (RR) was averaged over the time period of each test condition for each subject. This data was then pooled for all subjects and analyzed using a two-way ANOVA with a Tukey post-hoc adjustment.

Results

The average pooled EE was 6.52, 7.75, and 7.55 kJ/min for the control, arithmetic, and spatial conditions, respectively. A two-way RM-ANOVA test for variance was highly significant, with a p-value of $<.0001$. A Tukey post-hoc analysis revealed that EE for the control condition was significantly lower than both the arithmetic ($p < .0001$), and spatial conditions ($p < .0001$), while the two test conditions did not significantly differ from one another ($p = 0.936$) (Figure 2).

The average RER was 0.856, 0.860, and 0.831 for metronome, arithmetic and special conditions, respectively. A two-way ANOVA and Tukey's post-hoc analysis was highly significant ($p = .0028$). The Tukey test showed that the control and arithmetic conditions did not significantly differ ($p = 0.9964$),

Test	Low Performance	High Performance	Difference	P-Value
	EE	EE	(low minus high)	
	(kJ/min)	(kJ/min)		
Arithmetic	8.44 (1.45)	6.02 (1.64)	2.42	<.0001
Spatial	7.27 (2.0700)	7.63 (1.82)	-0.36	0.07

TABLE 1. Mean EE stratified by test performance. High arithmetic performers had lower EE than low performers ($p < 0.0001$). Subjects were grouped by their calculated score for both arithmetic and spatial tests. The high performance group was defined as scoring greater than the median, while the low performance group scored below the median. Performance measures are given as the mean EE over the duration of the experiment for all subjects and conditions combined.

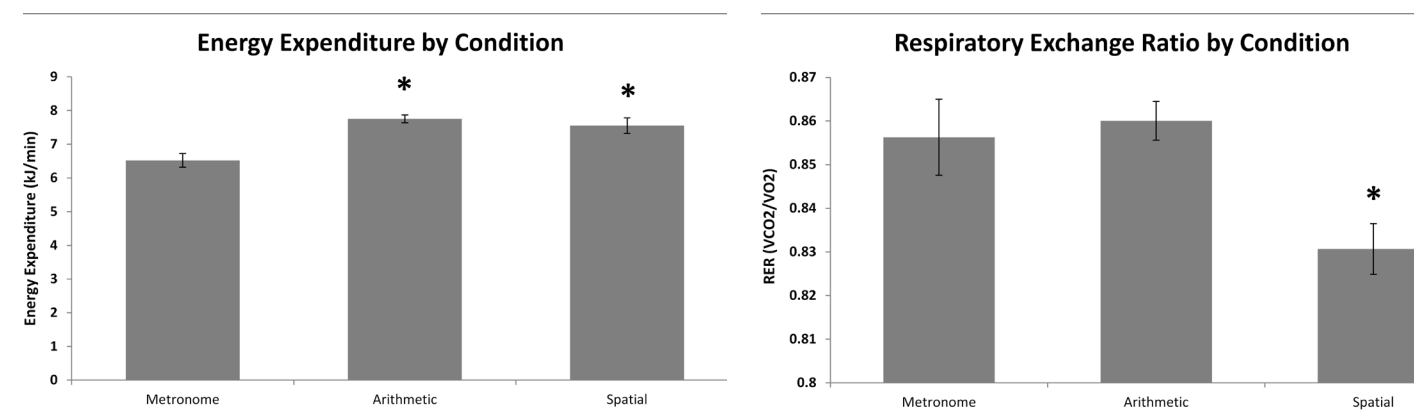


FIGURE 2. The arithmetic and spatial conditions both lead to a significant increase (* = $p < .0001$, $n=11$) in energy expenditure compared with the metronome control condition but were not different from each other.

but the spatial condition differed significantly from both conditions (arithmetic, $p = 0.01$ and control, $p = 0.03$) (Figure 3).

As mentioned previously, subjects were divided into two groups: high performing and low performing. The median value was not included, yielding two groups of five for both the math and spatial reasoning test. The low performing groups averaged 8.44 and 7.27 kJ/min for the arithmetic and spatial conditions, respectively.

The averages were 6.02 and 7.63 kJ/min for the high performing groups. An unpaired t-test showed that the high performing arithmetic group had significantly lower EE than the low performing group ($p < 0.0001$), while the high performing group on the spatial reasoning test displayed

FIGURE 3. Spatial reasoning task had a reduced respiratory exchange ratio (RER) compared to control and arithmetic conditions (* = $p < .05$, $n=11$). The metronome and arithmetic conditions were not significantly different from each other.

a non-significant ($p = 0.0746$) elevation of EE. The mean RR for the metronome, arithmetic, and spatial conditions was 15.52, 18.46, and 16.45 kJ/min, respectively. No significant difference was found between the three testing conditions ($F = 1.77$, $p = 0.19$).

Discussion

Fluctuations in brain metabolism are not fully understood. This study builds on prior evidence that mental exercises do lead to an increase in overall EE. The effect size was relatively large; there was a 19% and 16% increase in EE for the arithmetic and spatial reasoning conditions respectively, compared with the baseline resting condition. We attribute this difference to the mental challenge of the activities themselves because subject movement during the testing was limited to typing on the keyboard. Our control

condition attempted to account for this small amount of movement by having subjects tap a key on the keyboard in time with a metronome beat; the movement from this act was similar to entering the answers to the problems from each activity. The metronome had the added benefit of occupying subjects with a simple task that did not require a great amount of mental effort, thus making it a good control task.

We observed a performance effect on EE during the arithmetic testing condition: Individuals who had a higher accuracy and finished the test quicker expended less energy than those who took more time on the test and had lower accuracy. While we are not aware of other studies that have found such an effect using methodology similar to ours, performance effects have been shown in other ways. Hoshi and Tamura (1993) found that subjects who struggled to solve an arithmetic problem extracted more oxygen from the blood in the frontal hemisphere of the brain. Greater task difficulty is also related to higher peripheral glucose uptake, implying that greater cognitive demand from more difficult activities requires more energy (Kennedy & Scholey, 2000). Although subjects in our study all took the same arithmetic test, difficulty is relative; those who found the test easier may have required less energy to complete the problems. In contrast to these findings, Perlmutter et al. (2009) found that subjects who performed better on cognitive testing increased their peripheral glucose uptake, implying an increase in EE. We did observe a slight increase in EE in high performing subjects on the spatial reasoning test, but this did not reach statistical significance ($p = 0.0746$). RER was measured to attempt to determine the tissue source of the observed change in EE. RER can be used to discern which macronutrients are being consumed for energy. An RER of 1.0 is indicative that only glucose is being used, while an RER of 0.7 indicates fat is being metabolized. In this study, we hypothesized that an increase in RER would be observed because the brain primarily uses glucose as fuel. RER was unchanged from the metronome to arithmetic condition, but declined slightly during the spatial reasoning test. While this rejects our hypothesis, it could also indicate that free glucose was consumed during testing which required the use of elevated lipolysis in other tissues. Other studies have shown that difficult cognitive activities lead to a slight decrease in blood glucose levels (Scholey et al., 2006; Perlmutter et al., 2009). It is unclear what effect this phenomenon ultimately has on RER.

Brain scanning technology (near-infrared spectroscopy, PET scans, and MRIs) has shown that blood flow to different areas of the brain changes during difficult mental exercises. Increased oxygen consumption has also been shown in areas of the brain where blood flow is not increased (Hoshi & Tamura, 1993). What is not clear from the imaging studies is whether or not a measurable difference in whole brain metabolism exists. It has been shown that cerebral metabolism increases in some brain areas but decreases in others, potentially indicating that cerebral blood flow merely shifts to the areas of the brain where it is needed. If this is the case, change in overall cerebral metabolism would not be detectable through calorimetry (Hoshi et al., 1994; Villien et al., 2014).

It is likely that a portion of the increase in EE that was observed resulted from sympathetic activity. Studies that have measured respiratory and cardiac factors during mental testing found increased respiratory rate (RR) and heart rate during mental exercises (Bucks & Seljos, 1994). Bucks and Ryan (1994) observed that faster respiration was associated with higher difficulty memory tasks. Increases in catecholamines and cortisol have also occurred after performing a mental arithmetic task (Fibiger, Evans, & Singer, 1986). While our study did not measure cardiovascular factors or hormonal changes, RR was measured. RR can act as a proxy for sympathetic outflow. It has been widely accepted that there is coupling between the respiratory system and sympathetic activity. Respiratory sinus arrhythmia is a classic example of the coupling of respiration with sympathetic outflow to the heart. During inspiration, heart rate is increased; during exhalation, heart rate is slowed (Eckberg, 2003). Respiration is also coupled with vasoconstriction, another result of sympathetic outflow (Wallin, Hart, Wehrwein, Charkoudian, & Joyner, 2010). Respiratory rate is affected by elevated CO₂ levels resulting from increased EE, which was observed in this study. Despite these facts, we did not observe any significant elevation in RR during this study. Both the arithmetic and spatial reasoning tests had a small increase in RR compared with the control condition, so it is possible that our sample size was too small to detect a significant difference. Future studies will need to measure sympathetic activity more directly to discern how it is affected by cognitive exercises.

Strengths of this study include the use of well-validated indirect calorimetry methodology and tightly

controlled testing conditions. Potential weaknesses include subject selection by convenience sample, randomly generated problems for the spatial reasoning test, and lack of data on sympathetic nervous system activity. The spatial reasoning test was generated from a software suite that did not give us the ability to force the software to use the same problems for each test. However, given that 64 problems were randomly generated, it is unlikely that some tests were systematically easier than others. As we only measured respiratory rate for a marker of sympathetic outflow, we do not have a complete picture on the physiological processes that were occurring in subjects during testing. Despite these weaknesses, our testing conditions were well controlled, and the increase in EE that we saw from the arithmetic and spatial reasoning activities was highly significant. The data collected for this study indicates that cerebral metabolism may increase from mental activity. We also found that the high performers on the arithmetic test had a lower EE than low performers. We did not observe this relationship with the spatial reasoning test. We attempted to use RER to determine the type of macronutrients being metabolized during the study and found an apparent shift from carbohydrates towards fat at the end of the testing period; this may indicate that free blood glucose was metabolized by the brain early in the study. We conclude that mental exercises do give rise to an appreciable increase in overall metabolism, but further study is needed to pinpoint the source of this increase.

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The Contribution of Childhood and Adult Abuse to Women Offenders’ Risk for Continued Substance Abuse

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Abstract

Numerous studies have been conducted showing that suffering from abuse, in both childhood and adulthood, poses a risk factor for developing substance abuse problems later in life among some populations. However, research demonstrating this relationship among women is limited. This study collected data from specialized Michigan caseloads of 402 women who were on probation and parole. Measures of whether or not they had suffered physical or sexual abuse in either childhood or adulthood and whether or not they struggled with current or prior substance abuse were examined. The results show that suffering from child abuse, more so than adult abuse, is a strong predictor of developing substance abuse problems later in life; this relationship held true even after controlling for other known predictors of substance abuse. This study provides information on which women on probation and parole are most likely to continue misusing substances.

Introduction

Some prior research sparked interest to explore the connection of women offenders’ prior abuse and their current substance abuse in order to fill the gap in the literature for the female population. In 1999, Grilo, et al. conducted a study of psychiatric in-patients who had reported histories of childhood abuse. The group that suffered from childhood abuse reported significantly higher levels of substance abuse problems than the no abuse group, even after controlling for the variables depression and age. A study completed by Herrenkohl and colleagues in 2012 found that there was a significantly higher percentage of adult substance abuse in people who were involved in the child welfare system, such as Child


Protective Services, as compared to the comparison group of those not in the child welfare system.

The present study examines the relationship between experiencing abuse and the development of substance abuse problems. To strengthen the analysis, the control variables of age, income, education, employment, current mental illness, and prior substance abuse were added to the analysis in order to rule out the possibility that they explain any significant connection.

Methods


Available data were used for the analysis. The sample was comprised of 402 women who were on probation or parole for a felony offense. These respondents were recruited through the state of Michigan’s specialized female probation and parole caseloads. The sample is racially and ethnically diverse with 198 identifying as white, 12 white Hispanic, 147 black, 10 black Hispanic, one Pacific Islander, four Native Americans, 44 Multi-racial women, and eight women who did not disclose their racial or ethnic groups. The ages of the respondents span a range of 18 to 60 years, with a mean age of 33.9. All of the women reported histories of substance abuse. Adequate income and employment were barriers for the overwhelming majority of the sample, with 327 of the women reporting an annual income of less than \$10,000 and 57 reporting an annual income of more than \$10,000. Seventy participants were employed full-time, 220 were unemployed but stated they were able to work, and the remaining women were either employed part time or unable to work due to children.

The data were collected via semi-structured in person interviews with the individual women. They were asked numerous questions regarding



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the barriers they have faced since being on probation and parole and their relationships with their agents. The variables of child abuse, adult abuse, and substance abuse were measured with scales.

The frequency distributions and missing values for each variable and scale were first examined, and they were all found to be approximately normal in their distributions. There were just a few missing values so no mean substitutions were necessary. One woman had missing data on the child and adult abuse scales, but no means substitution was used; instead the woman’s data was removed from the analysis. Thus, the final analysis is from a sample of 401 women. The reliability of the scales was measured using Cronbach’s alpha based on standardized items; the alpha levels ranged between .6 to .8. The descriptive statistics for each variable and scale can be viewed in Table 1.

The bivariate correlations for each measure and scale included in the analysis were examined in order to see which variables are related to each other. Then, the variables of age, income, education, and em-

ployment were controlled for since these are other known predictors of developing substance abuse issues as identified by prior research. The income variable measured whether or not the woman made more than \$10,000 a year, education was indicated by whether or not the woman had a high school diploma, and employment was measured by whether or not she held a full-time job. The control variables can be related to both the independent and dependent variables, and thus need to be held constant in order to examine the relationship between the variables.

Since prior research shows that mental illness is a strong predictor of substance abuse, this factor was controlled for at the time of the interviews; results upheld previous research with the relationship of the current mental illness variable to substance abuse, $p < 0.001$. A final control variable, prior substance abuse, was added because past behavior has been shown to be a predictor of current behavior. Therefore, a strong test of whether child or adult abuse is related to current substance abuse is whether the relationship remains significant after controlling for prior substance abuse.

Variable	Mean	Std. Dev.	Min/Max	Reliability (for scales)
Dependent Variable				
sub abuse scale (current)	4.515	2.97	0 to 8	0.61
Main Focus Variables				
child abuse scale	0.833	0.866	0 to 2	0.70
adult abuse scale	0.796	0.805	0 to 2	0.60
Control Variables				
age	33.870	10.527	18 to 60	
education	0.689	0.463	0 to 1	
income	0.813	0.390	0 to 1	
employment	0.174	0.38	0 to 1	
mental health scale (current)	0.418	0.494	0 to 1	0.77
Recidivism				
arrests (12 months from T1)	0.31	0.691	0 to 5	
convictions (12 months from T1)	0.24	0.568	0 to 3	

TABLE 1. Descriptive statistics for selected independent variables and dependent variables from wave 1 (N = 401).

	Model 1 (childabuse)			Model 2 (adultabuse)			Model 3			Model 4		
	b		β	b		β	b		β	b		β
Intercept	0.969			0.973			0.562			0.675		
child abuse	0.319	***	0.194				0.196	*	0.120			
adult abuse				0.329	***	0.186				0.135		0.076
age							-0.006		-0.046	-0.007		-0.051
education							-0.015		-0.005	-0.061		-0.02
income							0.160	*	0.044	0.169		0.046
employment							-0.488	**	-0.130	-0.454	*	-0.121
mental ill current							0.597	**	0.120	0.661	***	0.23
prior sub abuse							0.096		0.200	0.087	***	0.181
F	15.640	***		14.296	***		9.838	***		9.239	***	
R2	0.038			0.035			0.149			0.141		
R2 adjusted	0.035			0.032			0.134			0.126		

TABLE 2. Regression models of predictors of substance abuse.

Finally, both child abuse and adult abuse were entered as independent variables in a multivariate linear regression. There were four different models of regression and the dependent variable in each model was current substance abuse. The four steps in entering the independent variables were: child abuse, adult abuse, child abuse with control variables, and adult abuse with control variables. The control variables, which were factors expected to influence current substance abuse, included age, education, income, employment, current mental illness, and prior substance abuse. Table 2 shows the results for all four regression models, with significant variables highlighted.

Results

At the bivariate level, both childhood abuse and adulthood abuse were strong predictors of current substance abuse. These relationships remained intact even after controlling for the woman’s age, income, education, employment status, current mental illness, and prior substance abuse. This finding results in even

greater confidence that there is a strong relationship at the bivariate level between experiencing physical or sexual abuse, in childhood and/or adulthood, and then developing substance abuse problems later in life.

However, after running a multivariate linear regression the results verify that child abuse is a stronger predictor than adult abuse of current substance abuse because in the full model, which includes all of the predictors, the beta for adult abuse becomes non-significant while the beta for child abuse remains significant. The initial finding of a connection between adult abuse and current substance abuse was spurious due to the control variables. Thus, the original relationship between adult abuse and current substance abuse was explained by whether the woman was employed full time, had current mental illness, and/or prior substance abuse. Among all of the variables, current mental illness showed the strongest correlation to current substance abuse. However, even when controlling for mental illness, a history of child abuse was still a significant predictor of current substance abuse.

Discussion

The original research question was whether being a victim of childhood and/or adulthood abuse predicted current substance abuse. This research found that child abuse was a stronger predictor than adult abuse for current substance abuse. This relationship remained significant after controlling for the variables of age, education, income, employment, current mental illness, and prior substance abuse. All seven of these variables are other known predictors of substance abuse as found in prior research. There is substantial research showing the strong relationship between childhood abuse and substance abuse; thus, further research should focus more on prevention and rehabilitation strategies. The present research also found that the strongest predictor of current substance abuse was current mental illness. Future research is needed to explore the varying impacts of different types of mental illnesses on the development of substance abuse.

There are a few implications based on the results of this study. First, when looking at substance abuse cases it is crucial to determine if someone was a victim of physical and/or sexual abuse, especially if the abuse occurred in childhood. With this information, substance abuse rehabilitation programs might provide individualized services in order to obtain the best patient outcomes. Furthermore, prevention programs for substance abuse need to begin as early as elementary school in order to educate children on the gravity of these problems. In addition, substance abuse prevention programs should begin as soon as an entity within the child welfare system, such as Child Protective Services, receives knowledge of a child abuse case.

Acknowledgments

I would like to acknowledge Dr. Merry Morash and Miriam Northcutt Bohmert for their guidance in conducting this research; and I would like to thank the Provost Undergraduate Research Initiative for funding my research and allowing me this unique opportunity as an undergraduate student.

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Review: Can Environmental Fluctuations Affect Breeding Behavior in Fish?

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Abstract

Gasterosteus aculeatus, or three-spined stickleback, are a species of fish that rely heavily on sexual signals during mate selection. Males have bright throats and blue eyes, exhibit specific behaviors when the female is near, and build nests to protect the eggs. Females use these signals in order to grade the quality of each male and decide if he is worth the investment of her eggs. Males are able to change the intensity of their throat and body color when near a female, but the degree of change is dependent on the male and potentially on the surrounding environment. Aquatic areas experiencing the effects of global climate change, invasive species, and increasing rates of development often affect the behaviors of fish and wildlife. Reviewing past and current trends of stickleback sexual-signaling behavior related to their environment is useful for planning management strategies for stickleback habitat and potentially other species reliant on specific breeding behaviors.

Introduction

Gasterosteus aculeatus, more commonly known as three-spined stickleback fish, are an interesting species to study during their breeding season. Their name refers to the spine prominent on their back. However, three-spined sticklebacks, in particular the males, portray other intriguing characteristics. Although they look dull or gray most of the year, during the breeding season males take on brilliant hues of orange and red at their throats and their eyes turn blue (Bakker, 1992; Bakker & Bern, 1994). These sexual signals are referred to as secondary sexual characteristics and are used in courtship trials as a way to “signal” to their female counterparts about the quality of the males (McLean, Bishop, & Nakagawa, 2012). Secondary sexual characteristics can be seen in many different species. Fiddler crabs and guppies are two other commonly studied species that rely on sexual signaling during courtship rituals to decide on their mate in

the wild (Zhu, Won Kim, & Choe, 2012; Head, Wong, & Brooks, 2010). Though much has been understood about the uses of these sexual signals through lab or controlled experiments, there is currently little insight as to how a changing environment may influence the decision process for males and females in the wild. Different environmental factors play into the success rates of breeding fish, such as visibility, predator risk, and turbidity (Candolin, 1996; Candolin, Salesto, & Evers, 2007; Head et al., 2010). Aquatic environments are easily influenced by outside forces, such as pollution and invasive species and can change the conditions that affect breeding fish. In other words, the sexual signals that were readily used in one set of environmental conditions may not be as effective in another set. This begs the question: Is there an advantage to being able to change sexual-signal intensity within these changing environments? Recent studies have taken on the challenge of observing breeding behaviors under varying environmental conditions. Stickleback fish are prime study organisms due to their easily observed mating rituals, both in the lab and in the field. Through reviewing these studies, the importance of knowing the extent of the phenotypic plasticity of stickleback fish is apparent. Not only are there advantages and disadvantages to the fish involved, but also potential long-term effects to stickleback populations and the aquatic communities involved. Since sexual selection is a driving force in the characteristics of male stickleback fish, environmental fluctuations that hinder the breeding process will have an effect at the population level. The scale and consequences of that effect are still uncertain, but past research has shown it is an area worth investigating.

Breeding Behaviors in Three-Spined Stickleback

Reproduction in three-spined sticklebacks is an extravagant ritual that is easy to entice in a laboratory setting and observe in the wild. Males are the primary caregivers for the offspring and are also responsible for

attracting females to their nest (Bakker & Milinski, 1991; Bakker, 1992; Milinski & Bakker, 1990; Candolin & Vlieger, 2013). Male sticklebacks prepare for the breeding season by building a nest out of algae, other plant material, and sand (Candolin & Vlieger, 2013). They then remain by their nest to protect it from predators and other males while waiting for females to come into their territory. Another strategy used by some males is to take advantage of nesting males by “sneaking” into their nest after a female drops her eggs and trying to fertilize as many as possible before the nesting male is able to chase him away (Candolin & Vlieger, 2013). This can be a costly strategy for males, but still makes it possible to have multiple successes throughout the season. When a female enters the territory of a nesting male, a very fast series of behaviors and sexual signals occur. The sexual signals include bright coloration and olfactory cues from the male. He often bites the female, does zigzag motions with his body, and tries to lead her to his nest (Candolin & Vlieger, 2013). If the female responds positively to his advances, she will follow him to the nest where the male will show the nest to her. If she accepts the nest, she will swim into it and drop her eggs, with the male following behind her to fertilize them. After that, the male remains to protect the eggs and fan water rich with oxygen into the nest until the eggs hatch. The female, however, has no involvement with parental care (Bakker & Milinski, 1991; Bakker, 1992; Milinski & Bakker, 1990; Candolin & Vlieger, 2013). Males may have multiple reproductive events throughout a season though not all of them will be successful. The sexual signals the males provide are important in the decision process of the female. Some males are able to quickly alter the quality of their signals, particularly coloration, which creates potential challenges and benefits for the females in different environments.

Sexual Signaling: Importance and Uses

Male sticklebacks use a combination of sexual signals to convey their quality to females. There are a couple of theories as to why males use so many sexual signals, but it is difficult to distinguish these relationships in experiments. One theory is that the different signals provide the females with different information related to the quality of the male (Morrell, Hentley, Wickens, Wickens, & Rodgers, 2011). The other hypothesis is that females have multiple receivers, so males use multiple signals to reach them (Morrell et

al., 2011). It is difficult to create laboratory experiments to test these relationships, but the overall consensus is that having several sexual signals is a good way for males to indicate their quality (Morrell et al., 2011). However, not all of the signals are weighted equally during mate selection. Differences in female preference between species and environmental factors often change the amount of energy males put into their different signals and behaviors (Morrell et al., 2011; Braithwaite & Barber, 2000; Boughman, 2001).

Coloration in stickleback males is one of the primary characteristics traced throughout the breeding season in courtship studies. When the breeding season nears, males display red at the throat region, and their eyes become more intensely blue (Bakker 1992; Bakker & Bern, 1994). Some males also become more blue or green in the body. Researchers create a color scale to grade the intensity of the throat and eyes in order to be able to make comparisons during the breeding season (Bakker & Bern, 1994). It is important to note the coloration of the males because past research has shown color is an important factor in the female decision process. Males with brightly colored throats were more likely to have a female release her eggs in their nest than males with less intensely colored throats, both in laboratory and natural experiments (Bakker, 1992; Bakker & Bern, 1994; Milinski & Bakker, 1990). In some populations of stickleback fish, throat color is one of the most important factors. The combination of environmental barriers and female selection contribute to the emergence of stronger sexual signals in males. For example, benthic (bottom-dwelling) stickleback males tend to not have as bright coloration as limnetic males (Boughman, 2007). In each population, females exhibited different color preferences when selecting males; limnetic females were drawn to males with redder throats, whereas benthic females had no significant trends for sexual selection related to color (Boughman, 2007).

The selection for more brightly colored throats and extravagant secondary sexual characteristics, in general, has two possible theories. First, the female directly selects for the trait due to a direct benefit to herself, and second, there is an indirect genetic benefit that gets passed on to the offspring (Candolin, 1999). For example, a previous study found that parasitized males were unable to put as much energy into their coloration, and females were less likely to choose them over brightly colored males (Milinski & Bakker,

1990). Parasitized males may not be able to provide for the offspring as well as a fit male, which suggests that relying on brightly colored throats is a useful strategy for females to improve the survivability of their offspring. However, not all males that display brightly colored throats are necessarily of a higher quality. In the previous study although there was a preference for brighter throat color in males only in one location were the males actually in better physical condition (Bakker & Bern, 1994). There is also a thought-provoking discussion on the potential of males “cheating” or dishonestly displaying sexual signals. In some cases, it was possible that the male had strong genetic material, but had already gone through a breeding cycle and would not be as able to care for its offspring (Candolin, 1999). However, there are other cases when males in poor condition put more effort into displaying when the predation risk was higher, or when they had been deprived of food (Candolin, 1999). Since the likelihood of survival decreased, it was suggested that low quality males put more effort into their coloration in order to attract a mate, either to eat the eggs/offspring to improve their own condition or because they would have fewer overall chances for success (Candolin, 1999). Though there are potential ways for the selection process to be distorted based on throat color, the overall strength of selecting mates has been enough to keep the system stable (Candolin, 1999). Other sexual signals provided through courtship may help to reduce the chance for “cheaters” and also to keep the system stable in changing environments where throat color may not be an effective strategy.

Environmental Changes and Sexual Signals

Why is it important to keep the breeding behaviors and sexual signals of male stickleback fish in mind when considering environmental changes? As the research shows, breeding is a complex process that relies on many visual and olfactory cues in order to achieve success. While all of the signals contribute to the likelihood of a successful mating encounter, male coloration seems to be one of the major factors females are drawn to if the difference is substantial (Boughman, 2001; Boughman, 2007; Braithwaite & Barber, 2000; Morrell et al., 2011; Milinski & Bakker, 1990). So what happens, then, if the environment changes in a way that makes visibility limited or being more colorful disadvantageous?

Both natural and human-induced changes to the environment can strongly influence sexual selection and the reproductive systems of the animals involved (Guillette et al., 1994). Increasing cases of eutrophication and turbidity is one example of a human-induced change that directly affects the success of stickleback males and other aquatic organisms that rely on sexual signaling (Järvenpää & Lindström, 2004). Human-induced changes are particularly concerning because they occur so rapidly and can outpace the rate of adaptation within a species (Heuschele, Salminen, & Candolin, 2012). A natural and sometimes human-induced environmental change is a sudden increase in the number of predators. This can result from the introduction of a nonnative or invasive species, but monitoring predatory species in general is important from a management standpoint. Both environmental changes have the potential to change the way female mate choice occurs, which can spill into the structure of future populations. Research in this area is limited, but recent studies have highlighted its importance in relation to mate encounter and the direction of sexual selection (Kokko & Mappes, 2005; Heuschele et al., 2012).

Environmental Change: Eutrophication

Eutrophication is a growing concern in areas where three-spined sticklebacks breed. Eutrophication occurs when outside nutrients are introduced to aquatic environments and cause an influx of algae (Candolin et al., 2007). Human activity has contributed to excess nutrient runoff into many aquatic environments (Larsson, Elmgren, & Wulff, 1985). Though this could provide more nesting material and protection from predators for males, it creates a visibility challenge for females since bright throat color is a major factor when deciding on a mate for females (Bakker 1992; Bakker & Bern, 1994). It was found that when exposed to conditions similar to those of eutrophication, throat intensity did not change on average for males but courtship intensity increased (Candolin et al., 2007). However, females did not change their responsiveness to the increased activity. Thus, the cost of courting females deepened in regards to energy spent by the males (Candolin et al., 2007). While the females did not respond much differently, the time spent considering male candidates did increase when females were visually impaired



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(Candolin, et al., 2007; Engstrom-Ost & Candolin, 2007). However, the overall mate encounter rate did drop in another study that examined female selection in impaired waters (Heuschele et al., 2012).

In such examples, adjusting the intensity of some sexual signals versus others has potential benefits. Rather than spending extra energy to increase ineffective courtship behaviors, placing more energy into nest quality or olfactory cues may increase the chances of success with each female encounter. Such a strategy could also benefit the females. Although not being able to rely on throat color may increase the chances of encountering a parasitized male, using olfactory cues could reduce the chances of finding a poor quality male that was signaling dishonest coloration (Milinski & Bakker, 1991). On the other hand, research has also shown that when there are visual impairments, male-male competition is relaxed, and more instances of “cheating” occur. Males may signal dishonestly about their quality, which can translate into the survival and fitness of the offspring (Candolin, 2000; Wong, Candolin, & Lindström, 2007).

Studies on other fish species that rely on sexual signaling show similar results. Cichlids in the Great Lakes of Africa also rely on visual sexual signals (Seehausen, Van Alphen, & Witte, 1997). In areas where turbidity increased, there was much less selection based on coloration, and the reproductive barriers broke down (Seehausen et al., 1997). Similar patterns were observed in other fish species where visual cues were no longer the major selection factor, which, in turn, relaxed how strong the sexual selection trends were on the sexual signals (Wong et al., 2007; Candolin et al., 2007; Järvenpää & Lindström, 2004; Candolin, 2004).

Eutrophication is a serious issue that may have more influence on stickleback populations, a species that relies heavily on sexual signaling, than originally determined. Eutrophication, however, is not the only consequence from outside stimuli that may have a strong effect on stickleback populations.

Environmental Change: Increased Predator Density

Invasive species or sudden increases in predatory species are another potential concern for courtship if stickleback predators become more prominent. There have been several studies demonstrating how

increased predation risk influences courtship and mate selection in other species. In fiddler crabs, for example, females gave preference to males that created larger nests when a predator was present (Zhu, Won Kim, & Choe, 2012). Since the nests gave potential shelter from an attack, it is hypothesized that the females took advantage of the direct safety benefit (Zhu et al., 2012). When predators were not present, mate selection was more related to the time during the breeding season with many different responses to nest size (Zhu et al., 2012). In another population of fiddler crabs females were more likely to select males that built hoods at the front of their nests (Kim, Christy, & Choe, 2007). It is thought that the hood provided an extra space for the female to get to safety in the presence of a predator (Kim et al., 2007). The increased risk of predation had an observable effect on the selection process for fiddler crab females. In both cases, an adjustment of courtship intensity provided a direct benefit to the female and potentially also to the male. Even though courtship was more energetically costly, males that built larger and more elaborate nests improved their chances for success in areas with increased predation risk (Zhu et al., 2012; Kim et al., 2007). It is likely that male fiddler crabs also helped their own survival in the process.

Among stickleback males, predator presence also causes an adjustment in courtship behaviors. Although there was no difference in coloration, male sticklebacks did adjust the frequency of certain actions (Candolin 1997). Males were more likely to zig (move in a sharp diagonal motion) near a female rather than frequently try to lead her to his nest (Candolin, 1997). There was also an overall decrease in energy put into courtship when a predator was near (Candolin, 1997). These results suggest that it was advantageous for males to adjust the intensity of their courtship; they reduced their exposure to predators and did not reveal the location of their nest through frequent leads (Candolin, 1997). Despite that coloration did not adjust in the presence of predators, it is possible that keeping throat color the same helped offset the costs of intense courtship bursts by staying at a higher level of attractiveness. In all of the cases, having the ability to modify sexual signaling under varying predator presences was potentially advantageous in increasing survival while making the most of breeding opportunities. Selecting males that are able to successfully survive in a predator-rich environment may give their offspring a

greater chance of survival even though female sticklebacks may not gain direct protection from the adjustments. However, decreased courtship activity overall may create adverse long-term effects on stickleback populations; therefore, further study is required.

Discussion and Conclusions

Phenotypic plasticity when it comes to sexual signals has costs and benefits. In some cases it may increase the ability for a population to persist under sudden environmental changes. Research has shown that there is potential for stickleback fish, and other species with strong sexual selection trends, to adjust the intensity of their various sexual cues. On the other hand, there is the potential for more instances of “cheating” and dishonest sexual signaling to win out during female selection (Kokko & Heubel, 2008; Greenfield & Rodriguez, 2004). Stickleback fish are a good study species since their breeding behavior is so easily observed, and sexual selection is a strong driver in their characteristics. However, other species can have their breeding behaviors change with fluctuating environments. The collared flycatcher *Ficedula albicollis* and the waxmoth *Achroia grisella* are two other examples of species with distinct sexual traits that develop differently in fluctuating environments (Jia et al., 2000; Qvarnstrom, 1999). Though there are many examples of changes in sexual signals, there have not been many studies looking at the potential advantages or downfalls of these differences (Greenfield & Rodriguez, 2004; Qvarnstrom 2001).

With climate change being an increasingly studied subject, influences of shifting environmental factors are becoming more relevant and visible. Breeding behaviors and sexual signaling are topics that should become more prominent in the climate change discussion. Differences in sexual signaling and selection among stickleback populations due to environmental change could lead to long-term changes in the structure of communities involved as well. A recent study looked at how changes in the number and diversity of sticklebacks may influence prey and organisms in lower trophic levels (Des Roches 2013). When the number of fish was manipulated, there was a greater change seen in lower trophic levels than in stickleback food sources (Des Roches 2013). On the other hand, differences in stickleback diversity were more likely to create changes in their prey populations (Des Roches, Shurin, Schluter, & Harmon, 2013). Since mate selec-

tion plays an important role in each scenario, it will be important to monitor stickleback courtship activity in environments currently undergoing changes. Sticklebacks and other aquatic species are currently facing challenges related to environmental change and responding by using multiple reproduction strategies. The influence such changes will have on future stickleback population ecology and community structure is still largely speculation based on past research, but if observational studies and overall interest continue to grow, even more insight can be gained on the intricacies of stickleback mate selection and evolution. The research presented shows that there is an incentive to use three-spined stickleback fish as a study species. While it is a difficult relationship to target in a laboratory setting, more research on how stickleback fish change behavior patterns, olfactory cues, and visual cues in response to environmental fluctuations is a worthwhile and encouraged endeavor.

Acknowledgements

I would like to thank Dr. Janette Boughman and Emily Weigel for giving me the opportunity to work in the MSU stickleback lab, and for their continuing guidance and support. Also, thank you to all of the lab members who encouraged me and taught me so much during my year with them.

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2015 and 2016 National and International Fellowship and Scholarship Recipients

Each year, MSU undergraduates and alumni are awarded highly competitive national and international fellowships and scholarships. In this issue of ReCUR, we introduce recent recipients of these prestigious awards.

The National and International Fellowships and Scholarships (NIFS) Office, administered by the Honors College, helps interested undergraduate and graduate students to pursue major national and international opportunities by providing information and direct support throughout the competitive application process. More information is available at nifs.msu.edu



Ashley Archer is an Honors College junior majoring in fisheries and wildlife in Lyman Briggs College who earned the nationally competitive Udall Scholarship in 2016. She is the 12th Udall Scholar from MSU.

The Udall Foundation awards scholarships to college sophomores and juniors for leadership, public service, and commitment to issues related to American Indian nations or to the environment. Each year, the foundation awards up to \$5,000 for educational expenses to students in the United States.

Archer interned for the U.S. Department of Agriculture’s Animal Plant Health Inspection Service in Wisconsin and is a member of the MSU Fisheries and Wildlife Club.

“My career goal is to research and implement effective natural resource management techniques, to ensure the longevity and sustainability for future generations of all people,” Archer said.

She is from Howell, Michigan and a graduate of Brighton High School.



Rebecca Carlson is an Honors College senior majoring in chemical engineering in the College of Engineering and Chinese in the College of Arts & Letters has received the Goldwater Scholarship in 2015.

Carlson hails from Rockford, Michigan, graduating as valedictorian of Rockford High School. Prior to that, she lived in Italy for 14 years.

Carlson is a member of the student editorial board for the Red Cedar Undergraduate Research Journal, tutors in the College of Engineering Residential Experience (CoRe) and is a member of Women in Engineering and Bridges International. She is also the recipient of an MSU Alumni Distinguished Scholarship.

“I am very humbled to receive this award, which is a testament to the wonderful support and encouragement that I have received from students and faculty alike at Michigan State,” Carlson said. “I am grateful for the chance to participate in research and learn from outstanding mentors.”



Zane Crawford has been awarded the Computational Science Graduate Fellowship from the U.S. Department of Energy (DOE). Crawford graduated with his bachelor’s degree in electrical engineering from MSU in 2015 and is now pursuing his doctorate at Michigan State University with a research focus on computational electromagnetics.

The fellowship is administered by the Krell Institute and supports approximately 70 students who are pursuing doctoral degrees in fields that use high-performance computing to solve complex science and engineering problems.

The program includes an annual stipend of \$36,000, full tuition and fees, an academic allowance, and a 12-week practicum at a DOE site with access to DOE supercomputers.

“I am overjoyed at the opportunity to focus on research topics that truly interest me thanks to the support of a fellowship,” Crawford said. “Furthermore, I see these awards as not just recognition of my accomplishments and my potential for future success, but recognition and a reflection of the people and communities that have inspired me and molded me into the person I am today.”

Crawford was also awarded a National Defense Science and Engineering Graduate Fellowship and a Department of Defense Science, Mathematics, and Research for Transformation (SMART) Graduate Fellowship, but declined both in favor of the Computational Science Graduate Fellowship.

He was a member of the Honors College Dean’s Advisory Council, Honors College Programming Board, Honors Students Actively Recruiting (H-STAR), the electrical honors society, Tau Beta Pi, and the electrical engineering society, IEEE - Eta Kappa Nu.

Crawford’s undergraduate research focused on surface representations for electromagnetic scattering surfaces and on integration methods for an electromagnetic equation solver acceleration method.



Thomas Grubb is an Honors College senior majoring in advanced mathematics in the College of Natural Science and economics in the College of Social Science. He was named a Goldwater Scholar in 2016, making him MSU’s 43rd Goldwater Scholar since the scholarship program was established by Congress in 1986.

The Goldwater Foundation seeks scholars committed to a career in science, mathematics, or engineering who display intellectual intensity and who have the potential for significant future contribution in their chosen field.

“Being named a Goldwater Scholar is a direct reflection of the support and opportunities I have received while at Michigan State,” Grubb said. “I am honored to receive this award and grateful to my teachers, peers and family who have made this possible.”

Grubb worked as a research assistant for the National Superconducting Cyclotron Laboratory as a freshman. In 2014, he performed research on mathematic patterns and statistics as part of the MSU Undergraduate Research Institute in Experimental Mathematics. Most recently, he conducted research in probabilistic methods at East Tennessee State University.

He is from Haslett, Michigan and graduated from Haslett High School.



Andrew Joseph was accepted into the Presidential Fellows Program in 2015, making him MSU’s 9th Presidential Fellow.

The Presidential Fellows Program offers up to 75 top undergraduate and graduate students from leading colleges and universities across the country a year-long opportunity to study the U.S. Presidency, the public policymaking process, and the Chief Executive’s relations with Congress, allies, the media, and the American public.

“Net neutrality and freedom of speech online have become the topics of heated debate in Congress and by President Obama,” Joseph said. “I would like to be a Presidential Fellow in order to prepare myself to address these topics through new policies and regulations as well as research the history of previous presidential and congressional decisions influencing the telecommunications and media sector.”

Joseph graduated with degrees in media and information in the College of Communication Arts and Sciences and Arabic in the College of Arts & Letters. He’s from Farmington Hills, Michigan.

Joseph has previously been awarded the Foreign Language and Area Studies Fellowship from the U.S. Department of Education, as well as the Ira & Jennie Greene Endowed Scholarship from the Department of Communication in the College of Communication Arts and Sciences.

He has worked as a video team crew member for WDBM in East Lansing, as well as camera operator for MSU Spartan Vision.



Megan Kechner graduated from the Honors College with degrees in neuroscience from Lyman Briggs College and psychology from the College of Social Science and is the second Goldwater Scholarship recipient for the year 2015.

Kechner is from Davison, Michigan and a graduate of Davison High School. She is a research assistant, working in Professor Michelle Mazei-Robison’s lab determining the specific signaling changes in the human brain that contribute to addiction and mood disorders. Kechner also interned at the Silvio O. Conte Neuroscience Research Center at Vanderbilt University. She’s is a member of the Society for Neuroscience, the MSU’s Neuroscience Club and presented research in November 2014 to the Society for Neuroscience. Kechner is a recipient of the Lyman Briggs College Undergraduate Research Award.

“To be recognized as a Goldwater Scholar means a great deal to me,” Kechner said. “I have found so much enthusiasm for research and it has been one of the most influential aspects of my academic career. I am overjoyed to be surrounded by such exceptional opportunity and mentorship here at Michigan State.”



Varsha Koduvayur graduated from the Honors College with degrees in international relations and comparative cultures and politics from James Madison College and Arabic from the College of Arts & Letters; she was awarded a nationally competitive research assistant fellowship through the Carnegie Junior Fellows Program within the Carnegie Endowment for International Peace in Washington, D.C. in 2015.

The Carnegie Endowment for International Peace is a private, nonprofit organization dedicated to advancing cooperation between nations and promoting active international engagement by the United States. Each year, the endowment offers 10-12 fellowships from a pool of nominees from nearly 400 participating colleges. Carnegie junior fellows work as research assistants to the endowment’s senior associates.

“I am thrilled to be working at the Carnegie Endowment for International Peace (CEIP) as a junior fellow for the Middle East program. My work at the CEIP will provide a strong foundation for the future of my career in international relations, which I hope to further by entering government service after graduate studies in international relations and Arabic,” Koduvayur said. “I am so grateful for my incredible family, the MSU Honors College, James Madison College, and the National/International Fellowships and Scholarships Office who guided and supported me through this endeavor.”

She is from Auburn Hills, Michigan, having graduated from Avondale Senior High School.



Sarah Kovan is a graduate of the Honors College with degrees in comparative cultures and politics from James Madison College and human biology from the College of Natural Science; she is MSU’s 17th Rhodes Scholar since the award began in 1904.

The Rhodes Trust, the oldest of the major international competitive award foundations, provides 32 of the most outstanding undergraduates in the United States an opportunity to study at the University of Oxford in England.

“Being named a Rhodes Scholar is an incredibly amazing and humbling experience, and I couldn’t have gained this recognition without unending support from the MSU community,” Kovan said. “As a scholar-athlete, I’m most proud of the accomplishments I have achieved in collaboration with my teammates, like our most exciting wins. It is in these successes, and in the camaraderie created in those moments, that make me proud to be a Spartan athlete.”

Kovan was a starting midfielder and honorary captain of the MSU women’s soccer team, earning Academic All Big-Ten Awards in 2012, 2013, and 2014, along with the 2015 Big Ten Distinguished Scholar Award and MSU Scholar-Athlete Award. During her time at MSU, Kovan participated in study abroad experiences Israel and Spain and in the Michigan State University Osteopathic Medical Scholars Program. She earned a James Madison College fellowship to conduct independent research exploring the need for and sustainability of interest-free loans for poor women in Sri Lanka and worked as a research assistant under Professor Andrea Freidus, conducting an ethnographic study on the consequences of undergraduate medical volunteerism. Kovan was chapter coordinator for Michigan State Students Today Leaders Forever, an organization that fosters leadership through service, relationships and actions.

Kovan is from Okemos, Michigan and graduated from Okemos High School.



Hannah MacDonald earned a competitive scholarship from the National Oceanic and Atmospheric Administration (NOAA) in 2016. She is an Honors College junior majoring in environmental geosciences in the College of Natural Science,

NOAA’s Hollings Scholarship provides financial support for one year of academic study and a full-time internship position at a NOAA facility during the summer. MacDonald is the 7th MSU student to receive a Hollings Scholarship.

“I am deeply honored to be an Ernest F. Hollings Scholarship recipient,” MacDonald said. “I am thrilled about the future opportunities that this scholarship program will provide me. This scholarship will allow me to further pursue my education and follow my passion for marine conservation.”

MacDonald is a member of the Residential Initiative on the Study of the Environment (RISE), and currently interns at the Aquatic Animal Health Laboratory.

She is an education programmer for the Thunder Bay National Marine Sanctuary and was named volunteer of the year in 2014. MacDonald also received an honorable mention for the Udall Scholarship.

MacDonald is from Alpena, Michigan and is a graduate of Alpena High School.



Raeuf Roushangar, won a prestigious Paul & Daisy Soros Fellowships in 2015 for New Americans – an honor that comes with up to \$90,000 stipend. He is a Michigan State University graduate student studying biochemistry,

Roushangar was one of 30 winners of the premier graduate school fellowship for immigrants and children of immigrants. The recipients, cho-

sen from a pool of 1,200 applicants, were selected for their potential to make significant contributions to U.S. society, culture, or their academic field.

Roushanger said about winning the fellowship: “It will give me freedom. Without the financial burdens, I’ll be able to focus on my research. It will also give me a lifelong connection to other Soros fellows. That will open many doors.”

In his first year at MSU, he founded an international nonprofit organization to bring medical supplies to poor communities: Generate Help 2 Heal Generations. GH2HG has collected and shipped more than \$500,000 worth of medical supplies from the U.S. to poor communities around the world.

Roushanger’s dedication has earned him many honors including the Clinton Global Initiative University, MSU’s Pamela J. Fraker Undergraduate Scholarship, MSU Leader of the Year and many others.

He plans to finish his doctorate at MSU where he is working with George Mias, physicist and geneticist, on research that focuses on omics technologies and their applications in personalized/precision medicine.



Joshua Schnell was awarded the nationally competitive Beinecke Scholarship in 2015, which pays for graduate studies in the arts, humanities and social sciences.

Schnell is a graduate of the Honors College with degrees in anthropology from the College of Social Science and religious studies from the College of Arts and Letters. Schnell is MSU’s second Beinecke Scholar since 2011. He will receive \$4,000 immediately prior to entering graduate school and an additional \$30,000 while attending graduate school. He plans to earn a doctoral degree in bioarcheology or Mesoamerican archaeology.

“Being awarded a Beinecke Scholarship means more to me than I could hope to put into words,” Schnell said. “This award not only allows me to continue my education and to help make changes in the world, but the funding security that accompanies it will allow me greater freedom in

applying to and selecting a graduate program. This scholarship will ensure that I find the perfect fit in a program that will provide opportunities, challenge me, and foster academic, professional, and personal growth. I am proud to be named a 2015 Beinecke Scholar.” In addition to his classroom and research activities, Schnell was involved in the Campus Archaeology Program, Meta-Religious Inquirer’s Club of MSU, the MSU Undergraduate Anthropology Club and the MSU Paranormal Society.

He has also been the recipient of the Cole Excellence Award from the Honors College, the Honors College Alumni Association Scholarship, the Charles Hayden Kelly Scholarship from the College of Social Science, and the Samuel Jay Hartt Award from the College of Arts and Letters.

Schnell hails from Howell, Michigan, having graduated from Howell High School.



Shelbie Shelder is an Honors College senior majoring in nutritional sciences in the College of Agriculture and Natural Resources, specializing in epidemiology and global public health, and earned one of 80 nationally competitive Udall Scholarships in 2015.

The Udall Foundation awards scholarships to college sophomores and juniors for leadership, public service, and commitment to issues related to American Indian nations or to the environment. Each year, the foundation awards up to \$5,000 for educational expenses to students in the United States. Shelder is MSU’s 11th Udall Scholar.

She is an intern at the Michigan Department of Community Health, and previously served as an undergraduate research assistant for the Bio-Computational Evolution of Action Center.

A Charles Drew Science Scholar, Shelder is president of MSU chapter of the American Indian Science and Engineering Society, and a student representative for the American Public Health As-

sociation’s American Indian, Alaska Native, Native Hawaiian Caucus. She is the recipient of the Future

Leaders Mentoring Scholarship through the Department of Food Science and Human Nutrition.

“Words cannot describe how thankful I am for all the support and encouragement from my research mentors, professors, and advisors that I have received throughout the application process,” Shelder said. “It is an honor to be awarded the Udall Scholarship. The Udall Foundation and I share the same passion for improving and addressing the overall well-being of American Indian people in the United States. Thank you Udall Foundation for enabling this opportunity.”

Shelder hails from Muskegon, Michigan and is a graduate of Reeths Puffer High School.



David Zoltowski was one of 14 students nationwide to be awarded a Churchill Scholarship in 2015. He is MSU’s 17th Churchill Scholar.

Zoltowski graduated from the College of Engineering with a degree in electrical engineering. Zoltowski hails from West Lafayette, Indiana, graduating from West Lafayette High School. He was captain of the MSU Varsity Swimming and Diving team, a Big Ten Distinguished Scholar and Academic All-Big Ten.

Established in 1959, the Winston Churchill Foundation’s Scholarship Program offers 14 American students of exceptional ability and outstanding achievement the opportunity to pursue graduate degrees in engineering, mathematics, or the sciences in Churchill College at the University of Cambridge in England.

“I am honored to be named a Churchill Scholar and look forward to making the most of my experience at Cambridge in all areas of life,” Zoltowski said. “I want to thank all members of the MSU community who have supported me in my endeavors.” He was a research assistant to Professor Se-

lin Aviyente in the Communications and Signal Processing Lab, a member of MSU’s Student-Athlete Advisory Council, Tau Beta Pi, Eta Kappa Nu and an Honors Times Two mentor.

Zoltowski was also the recipient of the MSU Honors College National Scholarship, Walter R. Yates Memorial Scholarship and Arthur J. Harris Memorial Scholarship.

Editor’s Note:

Two MSU students also received honorable mentions for the Goldwater Scholarship in 2015: Christine Isaguirre, an Honors College sophomore majoring in biosystems engineering in the College of Engineering, and Aaron Oom, an Honors College junior majoring in biochemistry and molecular biology in Lyman Briggs College.

MSU also had two students receive honorable mentions for the Goldwater Scholarship in 2016: Honors College junior Laura Azouz, who is majoring in chemical engineering in the College of Engineering; and Honors College junior Hananiel Setiawan, who is majoring in physics in the College of Natural Science.

About the Contributors



Heather Hartmann is the editor for *Box Pro Magazine*, a business resource for Affiliates and Coaches within the CrossFit industry. Hartmann graduated from Michigan State University in 2014, with a bachelor's degree in journalism and with high honors. *Box Pro* is one of four publications under the Peake Media umbrella,

a company that is based in Louisville, Kentucky. On top of running the digital and print aspects of the magazine, Hartmann is also the video lead for the company, covering leadership events across the country and producing media for all four magazines' websites. Hartmann also conducts photo shoots for the cover of *Campus Rec Magazine* at various campus recreation facilities across the U.S. If she isn't behind the lens or pen for her job, she is either doing CrossFit, serving her church, writing a novel or having an adventure with her camera at her side.



Sara Hughes graduated from Michigan State University with a bachelor's degree in criminal justice and psychology in December 2015. As an undergraduate, she worked with Dr. Merry Morash and Dr. Sandi Smith on their research regarding women

on probation and parole, the communication styles of their agents, and subsequent recidivism rates. Hughes also spent a semester in Australia and New Zealand studying comparative politics and criminal justice systems, and a semester in Washington, DC interning as a domestic violence victim advocate for the non-profit DC SAFE. She now works as a full-time Research Assistant on the Suicide Prevention Intervention for at Risk Individuals in Transition (SPIRIT Trial) with Dr. Jennifer Johnson. Her work includes conducting clinical interviews with inmates at the Genesee County Jail. Hughes will be pursuing a master's of social work in the Fall of 2017.



Kelly Kenyon is a graduate from the Honors College with degrees in nursing and interdisciplinary social sciences: health and society and a specialization in bioethics. She is an active member of Sigma Theta Tau International Honor Society of Nursing. She volunteered with nursing research as an

undergrad and spent two years working with MSU nursing researcher Millie Horodyski on projects related to infant feeding practices among low-income mothers. She maintains a wide range of interests including public health and medical ethics and plans to incorporate them into her future nursing career.



Anna Reh-Gingerich graduated from the College of Natural Science with a bachelor's degree in zoology and a marine biology concentration. While she was an undergraduate at MSU, she assisted Emily Weigel and Dr. Janette Boughman with a sexual selection study that focused on reproductive behavior throughout a breeding season in male three-spined stickleback fish. She presented their research findings at BEACON, UURAF, and the Midwest Ecology and Evolution Conference, where she won "Best Undergraduate Poster." Post-graduation, she spent time reviewing other topics related to sexual signalling in three-spined stickleback and water quality, which inspired this review article. Her interest in the effects of water quality expanded and she is now a graduate student at the University of North Carolina Wilmington, pursuing a master's in coastal and ocean policy. She is looking forward to pursuing a challenging, yet rewarding career in watershed management and raising public awareness about the effects of poor water quality.



Susie Sonnenschein graduated from MSU in 2014 with bachelor's degrees in neuroscience and psychology. During her time at MSU, she worked in Dr. Cheryl Sisk's laboratory, which focuses on studying the role of pubertal hormones in shaping the adolescent brain. Specifically, Susie's project looked at sex differences in the addition of new cells to the rat prefrontal cortex and nucleus accumbens across puberty. Susie received fellowship funding from the College of Social Science for the project and a Travel Award through the Honors College to present her findings at the Society for Behavioral Neuroendocrinology conference in June 2013. Susie is currently a graduate student in the University of Pittsburgh's Center for Neuroscience PhD program, under the mentorship of Dr. Anthony A. Grace, where she is studying the effects of antipsychotic drugs on the dopamine system in an rodent model of schizophrenia.



Kevin Wheelock graduated with high honor from Lyman Briggs College at Michigan State University in May 2014 with a bachelor's degree in physiology and a specialization in global public health and epidemiology. Wheelock is currently a post-baccalaureate fellow with the National Institutes of Health in Phoenix, AZ studying diabetes and diabetic kidney disease in American Indians.

His research has focused on childhood risk factors for future diabetes development and, in adults, discovering new biomarkers to better identify individuals at risk of diabetic kidney disease. The results of this work have led to multiple publications. Wheelock has been accepted into the University of Michigan Medical School class of 2020.



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