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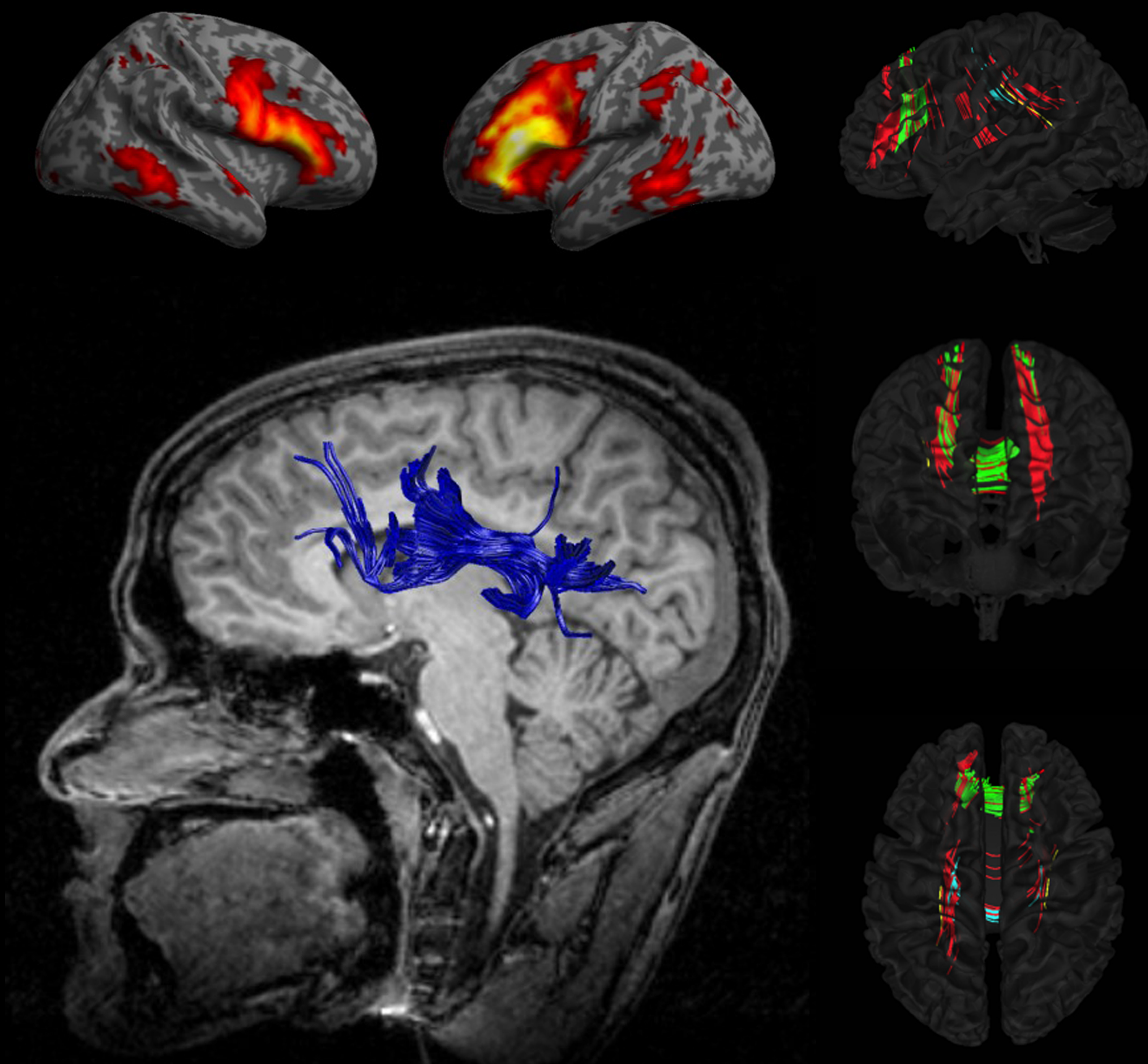

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About the Cover:

Dr. Rajesh K. Kana is a member of the faculty in the Department of Psychology at the University of Alabama and serves as the director for the Center for Innovative Research in Autism. His work focuses on the neuroscience of patients with autism and involves the use of neuroimaging. The cover depicts a collage of various brain scans collected through his research.

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Diagnostic and Sex Differences in Symptom Profile and Cognitive Ability in Autism

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Autism Spectrum Disorder (ASD) is a neurodevelopmental condition, which is primarily characterized by difficulties in social communication along with restricted interests and repetitive behavior. Cognitive measures such as Performance IQ (PIQ) and Verbal IQ (VIQ) may play a significant role in the manifestation of autistic characteristics and may contribute to the increased prevalence of autism in males compared to females. The present study sought to examine the predictive relationship between diagnosis, autistic characteristics, and cognitive abilities. It also aimed to identify the relationship between sex differences and each of these variables. Data used in this study came from the publicly-available Autism Brain Imaging Data Exchange (ABIDE II) database. Linear regressions were used to determine the relationship between diagnosis; sex; VIQ, PIQ, Social Responsiveness Scale (SRS) Total T-score; and Repetitive Behavior Scale Revised (RBS-R) Total T-score. Additionally, logistic regressions were used to determine the potential of these four variables in classifying participants by sex and diagnosis. Diagnosis was found to be a significant predictor of all four variables ($p<0.001$), but sex was only a significant predictor of SRS score ($p=0.019$). In logistic regression analyses, males were correctly classified by the diagnostic group in 97.4% of cases with SRS Total and RBS-R scores as significant predictors ($p<0.0005$; $p=0.003$). Furthermore, autistic participants were classified by sex in 84.1% of cases, with SRS total as the only significant predictor. These findings indicate that social and repetitive behavior symptoms play a significant role in autism diagnosis, whereas intellectual abilities may only peripherally influence it. Moreover, the ability of SRS to classify autistic participants by sex may support the idea that autistic females tend to mask symptoms more than autistic males.

Introduction

Difficulties in social communication as well as restricted interests and repetitive behaviors are the two primary symptom areas in autism [1]. Cognitive measures, such as intelligence, may be critical in determining the manifestation of these symptoms and level of functioning in autistic individuals. PIQ, VIQ, and their potential contribution to overall intellectual functioning seems to differ between autistic and non-autistic individuals [3]. Additionally, cognitive ability may be a contributing factor in one of the most consistent findings: the increased prevalence of autism in males over females [16].

Social communication difficulties involve struggling with emotional reciprocity, nonverbal communicative behaviors in social interaction, and understanding relationships. One study comparing the potential of Autism spectrum Quotient (AQ) scores and SRS-A scores in predicting autism diagnosis found that both measures were better than chance in predicting diagnosis [2]. Restrictive and Repetitive Behaviors (RRBs) include a complex set of behaviors, such as motor stereotypies, daily routines and rituals, repetitive play, preoccupations with particular interests, and compulsive activities related to these preoccupations. RRBs were found to have greater prevalence in autistic children than non-autistic children [12].

Previous research exploring the relationship between IQ scores, behavioral measures, and autism diagnosis provides key insights into the relationship between cognitive abilities and autism symptoms. For example, a recent study used the Autism Brain Imaging Data Exchange (ABIDE) neuropsychological and behavioral data to determine whether VIQ, PIQ, and/or IQ discrepancy could be used to predict Autism Diagnostic Observation Schedule (ADOS) scores [6,11]. The ADOS, which relies on direct observation of behavior in semi-structured social situations, is one of the main tools used for autism diagnosis [8]. The Johnson et al. (2021) study found that higher VIQ scores were associated with lower ADOS scores and that PIQ and IQ discrepancy were not significant predictors when the analysis included VIQ [11]. Thus, previous studies have used multiple variables with mixed findings. No studies were identified by this study to have used IQ and social and repetitive behaviors in combination to test their interrelationship and predictability of diagnosis. There is also evidence of sex differences in autism prevalence and presentation for males and females, with increased prevalence reported in males compared to females (approximately 4:1) [17]. Previous research has found that VIQ can be a protective factor against social symptoms in autistic females but not autistic males [15]. In fact, social communication scores, measured by the Social Communication Questionnaire (SCQ), were also found to be significantly higher for autistic boys than for autistic girls [7]. However, a different study found no significant difference between autistic males and females on various measures of social communication. In addition, while there was no difference in an overall measure of RRB severity, there was a significant difference between scores on the restricted behaviors subscale of the Repetitive Behavior Scale-Revised (RBS-R), with males scoring higher than females [14]. Thus, while this evidence points to an association among sex differences and cognitive abilities and symptomatology in autistic individuals, the exact relationship needs to be further explored.

The present study sought to identify the predictive relationship between diagnosis, autistic symptoms (deficits in social skills, restricted interests, and repetitive behaviors), and cognitive abilities (IQ) in a relatively large sample of participants from the ABIDE-II database. This study also aimed to examine the relationship between sex and each of these variables. The findings provided important insights into the social and cognitive profiles of autism in the context of sex differences.

Methods

Participants

Demographic, neuropsychological, and behavioral data were obtained from 365 participants in the publicly-available ABIDE-II database. Participants were selected based on the availability of scores for the following variables in the ABIDE II database: VIQ, PIQ, SRS Total T-score, and RBS-R Total T-score. To remove outliers, data were separated into four groups based on sex and diagnosis. If participants had scores greater than three standard deviations from the group mean for any of the four target variables, they were removed from the dataset. In total, nine participants were removed for excessively high or low scores. The final sample comprised 356 participants, 176 with autism and 180 without (See **Table 1**). These data were collected from the following seven ABIDE II sites: Kennedy Krieger Institute, Katholieke Universiteit Leuven, New York University Langone Medical Center (Samples 1 and 2), San Diego State University, University of California Davis, and Trinity College Dublin.

Materials

All participants were given standardized IQ tests to measure their VIQ, PIQ, and FSIQ. Data collected also included scores on the SRS 1 and 2, a 65-item questionnaire that measures levels of social symptoms commonly seen in those with autism and gives an overall T-score [4,5]. T-scores were also given for five subscales: social cognition, social communication, social motivation, social awareness, and autistic mannerisms. All five subscale T-scores and the total T-score were used for the analysis in this study. Scores on the

Table 1. Demographic information.

	Autistic				Nonautistic			
	Males		Females		Males		Females	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	13.39	6.05	11.27	3.37	11.19	2.42	10.43	1.60
FSIQ	104.78	14.95	103.54	16.38	112.78	11.60	113.50	10.45
VIQ	106.53	16.54	107.46	17.64	116.37	12.30	115.33	13.81
PIQ	105.56	16.19	102.32	17.29	110.48	12.93	108.74	11.54
SRS T-Score	74.42	12.02	80.32	14.76	42.29	4.65	43.22	4.82
RBS-R T Score	24.80	18.49	24.96	17.52	1.02	1.99	0.70	1.18

Note: FSIQ: Full-Scale IQ; VIQ: Verbal IQ; PIQ: Performance IQ; SRS T-score: Social Responsiveness Scale Total score; RBS-R T score: Repetitive Behavior Scale-Revised Total Score.

Table 2. Linear regressions with SRS, RBSR, VIQ, and PIQ as outcome variables and Diagnostic group (Dx) and sex as predictors.

Outcome Var: SRS		**Coefficients**					**Model Summary**			
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R^2	R^2Change	Sig. F Change
	Sex	2.843	1.205	0.063	2.360	0.019	$.868^{a}$	0.754	0.754	0.000
1	Dx Group	-33.192	1.014	-0.877	-32.721	0.000				
Outcome Var: RBSR		**Coefficients**					**Model Summary**			
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R^2	R^2Change	Sig. F Change
	Sex	-0.136	1.652	-0.003	-0.082	0.935	$.680^{a}$	0.462	0.462	0.000
1	Dx Group	-23.883	1.392	-0.679	-17.163	0.000				
Outcome Var: VIQ		**Coefficients**					**Model Summary**			
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R^2	R^2Change	Sig. F Change
	Sex	-0.283	1.894	-0.008	-0.150	0.881	$.303^{a}$	0.092	0.092	0.000
1	Dx Group	9.419	1.595	0.304	5.907	0.000				
Outcome Var: PIQ		**Coefficients**					**Model Summary**			
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R^2	R Square Change	Sig. F Change
	Sex	-2.313	1.856	-0.066	-1.246	0.214	$.179^{a}$	0.032	0.032	0.003
1	Dx Group	5.236	1.563	0.178	3.350	0.001				

RBS-R were also collected from all participants. The RBS-R is a 44-item questionnaire designed to measure levels of repetitive behaviors commonly seen in autistic individuals [13]. It provides an overall T-score as well as T-scores for six subscales: stereotyped behavior, self-injurious behavior, compulsive behavior, ritualistic behavior, sameness behavior, and restricted interests.

Procedure

Using Statistical Package for Social Sciences (SPSS26), linear and logistic regressions were conducted to test the effects of diagnostic group and sex on PIQ, VIQ, SRS Total, and RBS-R Total scores. Four simple linear regressions were done with each variable as the output and sex and diagnostic group in the first block. Participants were then grouped by sex, and logistic regressions were run to assess the effects of RBS-R, VIQ, PIQ, and SRS on the likelihood that participants were grouped into a certain diagnostic group within each sex. Additionally, subjects were separated into diagnostic groups, and logistic regressions were done to assess the effects of RBS-R, VIQ, PIQ, and SRS on the likelihood that participants were grouped into a certain sex within each diagnostic group. It was hypothesized that all four variables would be able to predict diagnosis, based on previous evidence of IQ being related to autism symptoms as well as the link between SRS, RBS-R, and autism characteristics. On the other hand, it was predicted that only SRS and RBS-R would play a significant role in predicting sex, based on previous evidence of sex differences within these scores. Further exploration of sex differences in SRS was warranted because SRS Total was the only variable for which sex was a significant predictor. Therefore, individual regression analyses were run with sex and diagnostic group in the first block and subscale scores as the outcome variable.

Results

Sex, Diagnosis, and Autism Symptoms

The linear regression analyses revealed that sex and diagnostic group contributed to 75.4% of the variance in SRS Total T-score ($p<0.001$), 46.2% of the variance in RBS-R Total T-score ($p <0.001$), 9.2% of the variance in VIQ ($p <0.001$), and 3.2% of the variance in PIQ ($p = 0.003$). Diagnostic group was found to be a significant predictor for all four variables; however, sex was only found to be a significant predictor for SRS Total T-score ($p=0.019$) (See **Table 2**).

Classification by Diagnosis and Sex

<u>*Classifying into Diagnostic Group*</u>

When classifying male participants into their diagnostic groups, the logistic regression model was statistically significant, $X^2=10.376$, $p<0.0005$. The model explained 93.8% (Nagelkerke R^2) of the variance in the diagnostic group and correctly classified 97.4% of cases. SRS Total ($p<0.0005$) and RBS-R Total ($p=0.003$) were both significant predictors of the diagnostic group. For females, the logistic regression model was statistically significant, $X^2=1.306$, $p<0.0005$. The model explained 92.1% (Nagelkerke R^2) of the variance in the diagnostic group and correctly classified 97.6% of cases. Neither SRS Total nor RBS-R Total was a significant predictor of diagnostic group within-sex, though SRS Total approached significance ($p=0.063$).

<u>*Classifying into Male/Female*</u>

When classifying autistic participants by sex, the logistic regression model was statistically significant, $X^2=10.135$, $p=0.044$. The model explained 9.3% (Nagelkerke R^2) of the variance and correctly classified 84.1% of cases. SRS Total ($p=0.007$) was the only significant predictor variable. When classifying non-autistic participants by sex, the logistic regression model was not significant ($p=0.263$).

Sex and Diagnosis Predicting Social Symptoms

Since sex was found to be a significant predictor for SRS Total T-scores, and SRS Total T-score to be a significant predictor in classification based on diagnosis and sex, a follow-up regression was conducted with the five SRS subscale scores as the output variables. Diagnostic group was still a significant predictor for each subscale ($p<0.001$). However, sex was only a significant predictor for the communication ($R^2=0.727$; $p=0.043$) and cognition (R^2=0.732; p=0.042) subscales of SRS (See **Table 3**).

Discussion

The findings of this study suggest that autism symptom-related variables (social responsiveness, repetitive and restricted patterns of behaviors and interests), and not cognitive profiles (IQ), are more successful in the diagnostic classification of participants. There are diagnostic group differences for all four variables; however, only the symptom-related variables (SRS and RBSR) were successful in classifying male participants by diagnosis. The SRS and RBS-R significantly predicting autism diagnosis should not come as a surprise, as these measures are built around targeting the key facets of autism diagnosis: symptoms in the social and restricted behaviors domains. The fact that IQ was not as successful in predicting autism diagnosis may be due to the relatively implicit nature of cognitive abilities in general. While the intellectual abilities targeted in IQ measurements are more global and implicit, behavioral measures (social and repetitive behaviors) are more tangible and directly observable. Hence, the predictability of more observable measures can be stronger than that of implicit cognitive ability, which has a say in autistic symptoms, but is not the symptoms themselves. This is also evident from findings that both PIQ and VIQ can influence SRS scores, as IQ is more of an internal factor rather than an overt behavior [10,15]. In short, while intellectual abilities may play a significant role in the manifestation of symptoms in autism, the diagnostic predictability may depend more on observable behavioral differences.

In contrast, neither cognitive nor symptomatic variables were significant in classifying female participants into the diagnostic group, though this could be due to the relatively smaller female sample in this study. It is also important to note that the diagnostic group only explained a small portion of the variance in PIQ and VIQ, indicating that other factors may have a greater influence. The mean FSIQ for autistic and non-autistic participants were relatively similar (see **Table 1**) and roughly average. This limited variability between autistic and non-autistic IQ scores, and relatively average IQ scores in general, may lead to a weaker significant relationship between diagnosis and IQ. The relatively average IQs could be due to the fact that those with below average IQ scores may have difficulties participating in the data collection and hence may not have met the inclusion criteria for studies in ABIDE II, which involves fMRI scans. Additionally, higher SRS scores in autistic females, relative to males, seemed to be driven by two subscales in particular, communication and cognition. This difference contributed to the fact that SRS was the only factor that contributed to the ability to classify autistic participants by sex. This result is consistent with the idea that in order to receive an autism diagnosis, females may need to exhibit more severe difficulties perhaps due to increased masking or camouflaging of symptoms [9]. Furthermore, the model for sorting nonautistic participants by sex was nonsignificant, indicating that there are no associated sex differences for nonautistic participants.

Conclusion

Overall, the findings of this study indicate that cognitive measures may not have as direct and significant a role as behavioral symptom measures in determining autism diagnosis. Furthermore, sex differences within autism seem to relate primarily to social communication difficulties, and there is evidence that masking plays a role in the social abilities of autistic females. Future research should further examine the role of intellectual abilities in the manifestation of autistic characteristics, as well as explore how these findings may change with an analysis of a larger autistic female sample.

Table 3. Linear regressions with SRS subscales as the outcome variable, and diagnostic group (Dx) and sex as predictors.

O Var: Awareness T		**Coefficients**						**Model Summary**		
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R Square	R Square Change	Sig. F Change
	Sex	1.238	1.372	0.032	0.902	0.368	.776[a]	0.602	0.602	0.000
1	Dx Group	-26.389	1.191	-0.780	-22.165	0.000				

O Var: Cognition T		**Coefficients**						**Model Summary**		
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R Square	R Square Change	Sig. F Change
	Sex	2.470	1.211	0.059	2.040	0.042	.855[a]	0.732	0.732	0.000
1	Dx Group	-31.330	1.051	-0.861	-29.806	0.000				

O Var: Communication T		**Coefficients**						**Model Summary**		
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R Square	R Square Change	Sig. F Change
	Sex	2.486	1.222	0.058	2.035	0.043	.852[a]	0.727	0.727	0.000
1	Dx Group	-31.317	1.034	-0.860	-30.274	0.000				

O Var: Motivation T		**Coefficients**						**Model Summary**		
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R Square	R Square Change	Sig. F Change
	Sex	1.379	1.304	0.037	1.057	0.291	.769[a]	0.592	0.592	0.000
1	Dx Group	-24.631	1.104	-0.774	-22.305	0.000				

O Var: Mannerisms T		**Coefficients**						**Model Summary**		
Step	Predictor	B	Std. Error	Beta	t	Sig.	R	R Square	R Square Change	Sig. F Change
	Sex	2.454	1.406	0.052	1.745	0.082	.835[a]	0.697	0.697	0.000
1	Dx Group	-33.545	1.190	-0.842	-28.181	0.000				

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Modification of Thin-Film Composite Reverse Osmosis Membranes with Linear Diamines for the Improved Rejection of Urea

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The cross-linked nature and excellent charge exclusion properties of reverse osmosis (RO) membranes render them widely useful in industry for the removal of large molecules and ions. However, due to the rapid and imperfect nature of the interfacial polymerization (IP) reaction used to synthesize RO membranes, the polyamide layer contains sizeable free volume holes and uncross-linked carboxylic acid groups that limit the ability of the membrane to reject smaller contaminants based on size-exclusion alone. This leaves RO membranes unable to reject small, neutral, and uncharged molecules (SNUs), like urea, at adequate levels to produce potable water. Therefore, the goal of this study was to improve the size-exclusion properties of RO membranes to produce a membrane that can reject both salt and urea in one cohesive step. It was hypothesized that the flexibility of linear diamines facilitates their coupling to free carboxylic acid groups on the polyamide surface to improve the size-exclusion properties of the membrane by decreasing the free volume hole size. To test this hypothesis, the polyamide layer of the commercial DuPont XLE RO membrane was modified with various linear diamines including diaminopropane, diaminobutane, and diaminohexane. The mechanism of this modification included activating the free carboxylic acid groups using carbodiimide chemistry and applying one of the diamines with or without heat. Then, the modified membranes were tested for water permeance, NaCl rejection, and urea rejection using a dead-end stirred cell. The results showed that combining the application of linear diamines with heat treatment significantly improved urea rejection as well as the size-exclusion properties of commercial RO membranes.

Introduction

Nitrogen fertilization has increased by 500% since the 1960s due to the doubling of global food production [2]. To maintain this increased demand, urea is produced in excess for use as a nitrogen fertilizer. It is predicted that annually, 140 million excess tons of urea are produced worldwide [6]. As a result of the widespread use and mass production of urea, the management of waste from urea production plants has become a major environmental and economic issue. Recently, improved environmental safeguards have limited the maximum recommended concentration of urea to 10 mg/L or ppm [6]. Wastewater streams from urea plants often exceed this limit. The discharge of these urea-concentrated streams into the environment greatly affects water quality due to eutrophication [6]. Eutrophication is the excessive enrichment of a body of water with nitrogen, resulting in a nutrient-induced overabundance of algae and plants. When the excess plant matter decomposes, oxygen is consumed in the process, which leads to hypoxic waters that are harmful to animals. The mass production of urea, its harmful environmental effects, and strict environmental regulations all suggest a need for an efficient and cost-effective method to separate urea from water.

Many methods have been developed for the treatment of urea-contaminated wastewater, including thermal hydrolysis, decomposition by strong oxidant, absorption, and electrochemical oxidation [1]. However, these methods are generally inefficient because they require high capital costs, consume great amounts of energy, and/or deteriorate in performance during long-term use [1]. Biological treatments for urea wastewater have also been developed because they are both eco-friendly and energy conservative [1]. However, implementing these treatments requires a high operational cost and is accompanied by an increased production of sludge [1]. Sludge is the residual semi-liquid mixture resulting from the treatment of industrial wastewater. Membrane-based filtration is a possible alternative solution to the shortcomings of these methods.

Membrane filtration technologies such as nanofiltration and reverse osmosis (RO) are simple to use, cost-effective, stable, predictable, and capable of simultaneously removing other solutes [4]. However, membrane rejection of molecules and ions is complicated by its reliance on both size and charge exclusion mechanisms. The charge exclusion properties of RO membranes facilitate their ability to reject ionic solutes, such as salts. However, without modification, RO membranes are generally insufficient in their rejection of small, neutral, and uncharged molecules (SNUs), like urea. This is due to shortcomings in their size-exclusion mechanisms caused by uncross-linked carboxylic acid groups and aggregate free volume holes. Therefore, it is of interest to improve the size-exclusion ability of commercial RO membranes to utilize the advantages of membrane filtration technology in the rejection of urea and other SNUs.

The purpose of this study was to improve the size-exclusion properties of RO membranes to generate a useful technology for the rejection of urea. The study tested the hypothesis that the flexibility of linear diamines would help to facilitate the coupling of amine groups to the free carboxylic acid groups on the polyamide surface to reduce the free-volume hole size. This hypothesis was tested by modifying the polyamide layer of RO membranes by activating the free carboxylic acid groups with carbodiimide chemistry and conjugating the activated carboxylic acid groups with diaminopropane (DAP), diaminobutane (DAB), or diaminohexane (DAH). The membranes were characterized using attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR), and the performance of these membranes was evaluated for water permeance, NaCl rejection, and urea rejection.

Materials and Methods

Materials

Crystallized urea (ACS grade, ≥ 99%), β-(N-Morpholino) ethanesulfonic acid buffer (MES, anhydrous, ≥ 99%), 1,4-Diaminobutane (DAB, ≥ 98%), 1,6-Diaminohexane (DAH, ≥ 98%), and 1-(3 Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride (EDC, ≥ 98%) were used as received from VWR. Sodium chloride (NaCl, ≥ 99%), 1,3-Diaminopropane (DAP, ≥ 99%), and 4-(2-Hydroxyethyl)piperazine-1-ethanesulfonic acid buffer (HEPES, ≥ 99.5%) were used as received from Sigma Aldrich (Millipore-Sigma). N-Hydroxysuccinimide (NHS, ≥ 98%) was used as received from TCI chemicals. Deionized (DI) water was obtained from a Millipore Synergy UV water purification system. Commercial polyamide thin-film composite RO XLE membrane was provided by Dupont Water Solutions. This membrane consisted of a polyester fabric backing, a polysulfone support layer, and a fully aromatic polyamide selective layer with no coating.

Membrane Modification

The XLE membranes were provided as flat sheet rolls and stored dry until use. **Figure 1** shows a schematic of the modification process. Before surface modification, each membrane was immersed in DI water on a VWR Standard Analog Shaker for at least 30 min and cut into

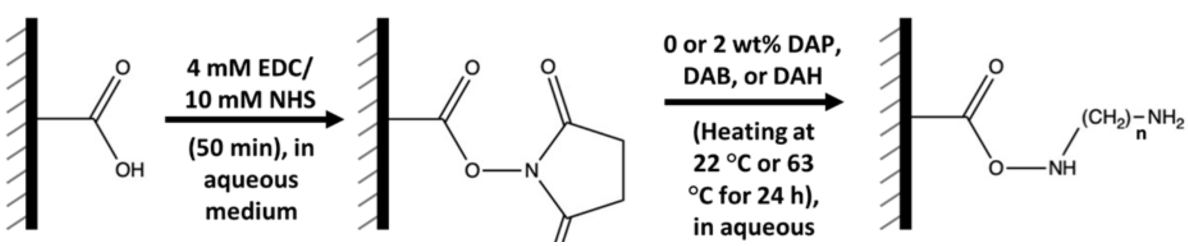

Figure 1. Modification of polyamide layer reaction schematic. EDC/NHS was used to activate the carboxylic acid groups of the polyamide layer to allow for linear diamine coupling using heat.

circles with an area of 19 cm^2 using a pre-cut stencil. 0.078 g of EDC, 0.115 g of NHS, 2.922 g of NaCl, and 97 g of aqueous 10 mM MES buffer solution were weighed on a ME403E precision balance (Mettler Toledo) and added to a 250 mL beaker. The solution was covered with Parafilm and aluminum foil and stirred for 10 min. The rinsed membrane was then submerged in the stirred solution. The beaker containing the immersed membrane was covered with Parafilm and aluminum foil and placed on a VWR Standard Analog Shaker for 50 min to activate the free carboxylic acid groups on the polyamide layer.

A 0 wt% or 2 wt% diamine solution was made by weighing 0.876 g NaCl, 97 g of 10 mM HEPES buffer, and either 0.0 g or 2.0 g DAP, DAB, or DAH on the ME403E precision balance. This solution was added to a 250 mL beaker and stirred to homogeneity. The activated membrane was submerged in the diamine solution. The 250 mL beaker containing the membrane and diamine solution was topped with a glass Petri dish, covered with aluminum foil, and placed on a VWR hot plate integrated with a temperature indicator. The VWR hot plate was left off or set to a temperature of 80 °C. A thermocouple was used to find the actual temperature of the diamine solution, which was 22 °C when the hot plate was off and 63 °C when the hot plate was set at 80 °C. The membranes were kept in the solution at 22 °C or 63 °C for 24 h. Following modification, the membranes were rinsed by filling the beaker with DI water five times. The membranes were then cut down to 14.6 cm^2 using a pre-cut stencil, transferred to a clean beaker, stored in DI water, and isolated from light at least overnight until testing. The membranes will be discussed with the acronyms provided in **Table 1**. It should be noted that the EDC/NHS activated membranes were not tested as a control because the hydrolysis of the NHS ester can happen in a matter of minutes to hours depending on the solution pH [3].

Table 1. Acronyms for the XLE membranes.

Membranes	EDC/NHS	Modification Temperature	Amine
Control XLE	Not used	Not modified	None
XLE-63	Not used	63 °C	None
XLE-NHS-22-DAP	Used	22 °C	DAP
XLE-NHS-63-DAP	Used	63 °C	DAP
XLE-NHS-22-DAB	Used	22 °C	DAB
XLE-NHS-63-DAB	Used	63 °C	DAB
XLE-NHS-22-DAH	Used	22 °C	DAH
XLE-NHS-63-DAH	Used	63 °C	DAH

Membrane Characterization Using ATR-FTIR

ATR-FTIR was used to characterize the surface chemistry of the control and modified XLE membranes. The measurements were done using a Perkin Elmer Spectrum 2 ATR-FTIR spectrometer equipped with a diamond ATR crystal in the range of 400-4000 cm-1. Data was processed by Spectrum 10 software. Each spectrum was collected for 32 scans at a resolution of 4 cm^{-1} and was baseline and ATR corrected with the Spectrum 10 software. A background of the ATR crystal was taken before each set of samples was tested to ensure the crystal was clean.

Membrane Testing

A Sterlitech HP4750 dead-end filtration cell (Sterlitech, USA) with a cell volume of 270 mL and an effective filtration area of 14.6 cm^2 was used to test the control and modified XLE membranes. The filtration cell was pressurized to 150 psig using compressed nitrogen gas or air

(AirGas). The performance of the membranes was tested using a DI water solution, a 2,000 ppm NaCl solution, and a 500 ppm urea solution. Each solution was allowed to permeate through the membrane for 30 min to achieve steady state before the collection of permeate began. Approximately 10 g of permeate was collected for each test. The time required to obtain the permeate was recorded to calculate the flux through the membrane. Three or four membranes of each type were tested for statistical relevance. The water permeance (A) of each membrane during each test was calculated using **Equation 1**:

$$A = \frac{Flux}{Pressue} = \frac{m}{a * t * P} \quad (1)$$

where m is the mass of the permeate, a is the testable membrane area, t is the permeate collection time, and P is the gauge pressure. The units of A are in $L/m^2/h/bar$ or LMH/bar.

The conductivities of the feed and permeate NaCl solutions were measured using a VWR Traceable Bench/Portable Conductivity Meter. A calibration curve was made as a function of salt concentration to ensure measurements were taken in the linear range of the conductivity meter. The salt rejection was then calculated using **Equation 2**:

$$R = \left(1 - \frac{C_p}{C_f}\right) * 100\% \quad (2)$$

where C_p and C_f are the permeate and feed conductivities, respectively.

The urea feed and permeate were each diluted two times using DI water, and the absorbances of the diluted solutions were determined using a HACH DR6000 UV-VIS Laboratory Spectrophotometer at 195 nm wavelength using quartz cuvettes (VWR), similar to Cheah and coworkers [7]. A calibration curve was made as a function of urea concentration to ensure measurements were taken in the linear range of the UV-VIS. The urea rejection was then calculated using **Equation 3**:

$$R = \left(1 - \frac{\mathrm{Abs_p}}{\mathrm{Abs_f}}\right) * 100\% \quad (3)$$

where Abs_p and Abs_f are the permeate and feed absorbances obtained from the UV-VIS, respectively.

Statistical Analysis

The results of the membrane testing for each type of modified membrane were analyzed using a two-sample t-test assuming equal variances to determine if the mean values for the modified membranes were statistically different from the mean values for the control XLE membrane. Additionally, the XLE-63 membrane was compared to the XLE-NHS-63-DAP, XLE-NHS-63-DAB, and XLE-NHS-63-DAH membranes. Excel® (Microsoft O365 Version 16.58) was used for all statistical analyses. Statistical testing was performed for the pure water permeance data, the NaCl rejection data, and the urea rejection data. In this analysis, alpha was set to be 0.05 (95% confidence), and the compared membranes were determined to be statistically different if alpha was greater than the p-value.

Results and Discussion

Membrane Characterization

The XLE membrane surface was activated with carbodiimide chemistry. The activated carboxylic acid groups of the NHS-ester intermediate were coupled with either DAP, DAB, or DAH. This process formed a new polyamide bond. The formation of this bond was confirmed by the ATR-FTIR data. **Figure 2** shows the ATR-FTIR spectra of the control and modified XLE membranes. The increase in the peaks in the aliphatic $-CH_2-$ stretching region of 2800-3000 cm^{-1} confirmed the conjugation of the linear diamines with the free carboxylic acid groups on the membrane. The XLE-NHS-22-DAH membrane exhibited the greatest aliphatic stretching, which was expected due to the greater number of C-H bonds in DAH compared to DAP and DAB. The control XLE and XLE-63 membranes exhibited the lowest $-CH_2-$ stretching because they were not modified with aliphatic amines. Therefore, these membranes had the fewest number of C-H bonds. It was also observed that membranes modified at room temperature exhibited greater stretching than membranes modified at a hotter temperature. This suggests that the thermal rearrangement of

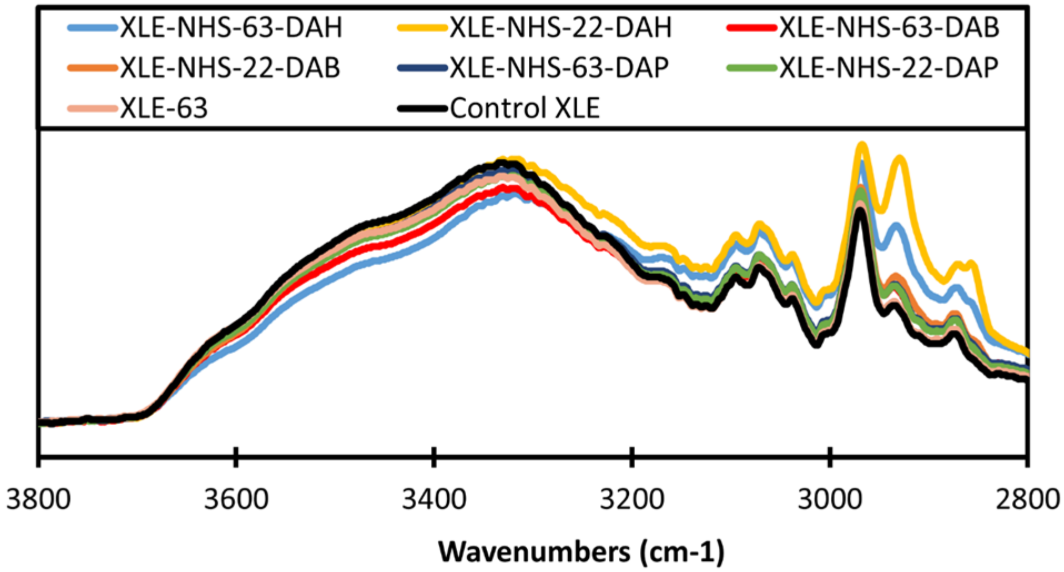

Figure 2. ATR-FTIR spectra of control XLE membrane and XLE membranes modified with 2 wt% DAP, DAB, and DAH at 22 °C and 63 °C or modified with only heat at 63 °C.
Note: To view this figure in full color, please visit the digital archive at https://joshua.ua.edu/archive.html.

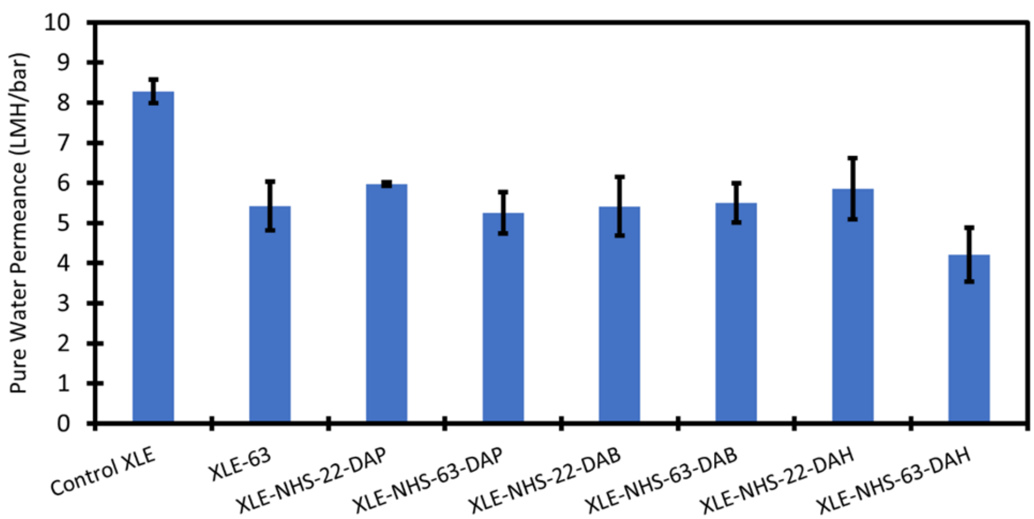

Figure 3. Pure water permeance of the control and modified XLE membranes. The error bars represent one standard deviation among at least 3 membrane samples.

the polyamide layer may in some way inhibit the coupling of diamines to the free carboxylic acid groups on the polyamide layer.

Membrane Performance

Membrane performance was assessed by testing the pure water permeance, salt rejection, and urea rejection of both the control and the modified XLE membranes. **Figure 3** shows the results of the pure water permeance testing. It was determined via statistical analysis that the pure water permeance of each modified XLE membrane had a statistical decrease from the control XLE membrane. The average pure water permeance values for the control and modified XLE membranes can be seen in **Table 2**. The statistical decrease in pure water permeance between the control and modified XLE membranes may be explained by improved cross-linking and a likely decrease in the free volume hole size within the polyamide layer. This improved cross-linking was likely brought about via amine coupling and/or thermal rearrangement.

The ability of the control and modified XLE membranes to reject NaCl is displayed in **Figure 4**. The average NaCl rejection of the control XLE membrane was found to be 86.5%. This value was lower than the expected value of 97% provided by the manufacturer. It is probable that this difference in the NaCl rejection of the control XLE membrane can be attributed to concentration polarization consistent with dead-end filtration, which is not seen in less sensitive cross-flow filtration [5]. The average NaCl rejection values for the control and modified XLE membranes can be seen in **Table 2**. Statistical analysis revealed that the salt rejection for the XLE-63, XLE-NHS-22-DAP, XLE-NHS-63-DAP, XLE-NHS-22-DAB, XLE-NHS-63-DAB, and XLE-NHS-22-DAH membranes were statistically similar to the control XLE membrane. Conversely, it was determined that only the XLE-NHS-63-DAH membrane NaCl rejection had a statistical increase from the control XLE membrane. Based

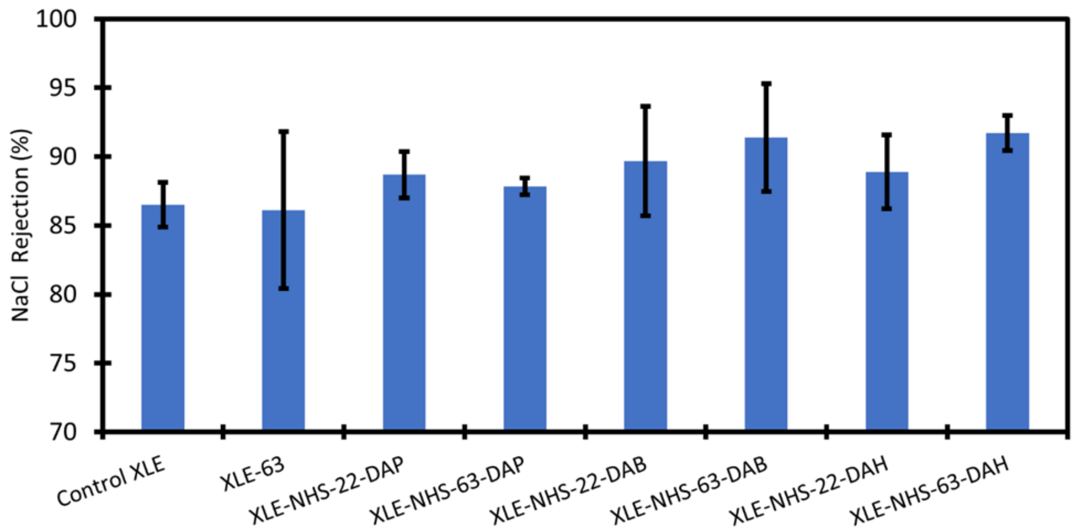

Figure 4. Salt rejection of the control and modified XLE membranes. The error bars represent one standard deviation among three or four membrane samples.

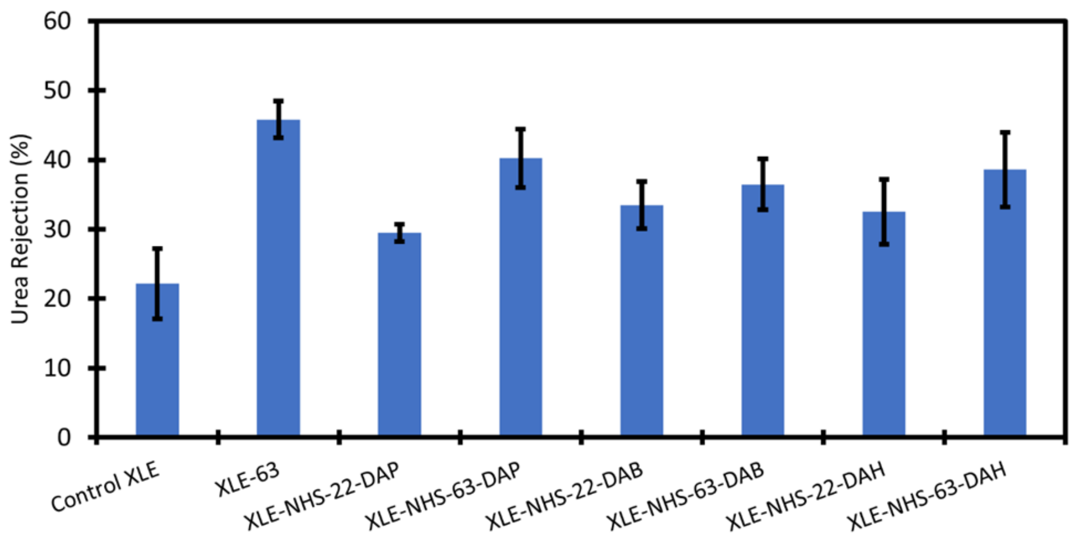

Figure 5. Urea rejection of the control and modified XLE membranes. The error bars represent one standard deviation among three or four membrane samples.

on the Donnan Exclusion Effect, it would be expected that the salt rejection of the modified XLE membranes would decrease from that of the control XLE membrane because, by reacting free carboxylic acid groups, the negative charge is decreased on the surface of the membrane. According to the Donnan Exclusion Effect, the negatively charged carboxylic acid groups can prevent anions (in this case Cl^-) from going through the membrane, which is the dominant ion to reject for NaCl. However, the overall maintenance or improvement of the NaCl rejection for the modified XLE membranes as compared to the control XLE membrane suggested that replacing this negative charge with positively charged amine groups that can extend away from the membrane surface and prevent cations (in this case, Na^+) from going through the membrane is just as sufficient or better in reference to the charge exclusion properties of the membrane. This demonstrates that the modified XLE membranes remained sufficient for the rejection of salt from water.

The rejection of urea for the control and modified XLE membranes is depicted in **Figure 5**. The average urea rejection values for the control and modified XLE membranes can be seen in **Table 2**. It was determined via statistical analysis that the urea rejections of the XLE-63, XLE-NHS-63-DAP, XLE-NHS-22-DAB, XLE-NHS-63-DAB, XLE-NHS-22-DAH, and XLE-NHS-63-DAH membranes had a statistical increase from the control XLE membrane. It was also found that only the urea rejection of the XLE-NHS-22-DAP membrane was statistically similar to that of the control XLE membrane. The statistical increase in urea rejection for the modified membranes demonstrates that both diamine coupling (except for DAP) and thermal rearrangement improved the ability of the XLE membrane to reject urea.

The average urea rejection of each of the membranes modified at 63 °C was higher than the average of their 22 °C counterparts. Furthermore, the XLE-63 modified membrane exhibited the greatest average urea rejection of all the membranes tested. It was determined via statistical analysis that the urea rejection of the XLE-63 membrane had a statistical increase from the XLE-NHS-63-DAB membrane but was statistically similar to that of the XLE-NHS-63-DAH and the XLE-NHS-63-DAP membranes. This suggests that the thermal rearrangement of the polyamide layer was a more significant factor than linear diamine coupling in the ability of modified XLE membranes to reject urea.

Conclusion

In this study, a method for the modification of commercial XLE membranes via carbodiimide activation, linear diamine coupling, and heat treatment was developed to improve the ability of the membranes to reject urea. DAH, DAB, and DAP were used as the

Table 2. Average pure water permeance, NaCl rejection, and urea rejection of the control and modified XLE membranes. The error represents one standard deviation among three to four membrane samples.

Membranes	Average Pure Water Permeance (LMH/bar)	Average NaCl Rejection (%)	Average Urea Rejection (%)
Control XLE	8.3 ± 0.3	86.5 ± 1.6	22.1 ± 5.1
XLE-63	5.4 ± 0.6	86.1 ± 5.7	45.8 ± 2.7
XLE-NHS-22-DAP	6.0 ± 0.0	88.7 ± 1.7	29.5 ± 1.2
XLE-NHS-63-DAP	5.3 ± 0.5	87.8 ± 0.6	40.2 ± 4.2
XLE-NHS-22-DAB	5.4 ± 0.7	89.7 ± 4.0	33.5 ± 3.4
XLE-NHS-63-DAB	5.5 ± 0.5	91.4 ± 3.9	36.5 ± 3.6
XLE-NHS-22-DAH	5.9 ± 0.8	88.9 ± 2.7	32.5 ± 4.7
XLE-NHS-63-DAH	4.2 ± 0.7	91.7 ± 1.3	38.6 ± 5.4

linear diamines in this study. The membranes were modified at either room temperature (22 °C) or 63 °C. The control XLE membrane had an average urea rejection of 22.1%. The modified XLE membranes had 29.5–45.8% average urea rejection, depending on the diamine used and whether the membrane was subjected to heat treatment. The increase in the urea rejection was mainly attributed to the hot water bath treatment and likely thermal rearrangement of the polyamide layer on the Angstrom scale. Additional testing will be performed with more diamines of varying lengths and structures to determine how diamine length affects SNU rejection. Furthermore, Positron Annihilation Lifetime Spectroscopy measurements will be used to quantify the change in free volume hole size of the polyamide layer and its implications in SNU rejection. The results of this study provide an easy framework to increase the rejection of urea, and therefore other small, neutral molecules, by polyamide membranes, which is needed to maintain or achieve compliance with new, stricter environmental regulations. Additionally, an increased urea rejection to > 70% is needed for artificial kidneys.

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The Roles of Lutein in Visual and Cognitive Function Across the Lifespan

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Lutein is a carotenoid that is stored in the macular pigment of the retina and is known to play a role in eye health. Higher lutein intake is associated with increased macular pigment density, which protects the retina from oxidative damage. Recent studies have shown that lutein may play a role in cognitive health, acting similarly as an antioxidant in neural tissue. This review assesses current research about the effects of lutein on cognitive and macular function throughout the lifetime. During the first 12 years of life, lutein promotes the development of the eyes and brain, though the mechanisms of these actions are not fully understood. As individuals age, lutein plays a protective role for both brain tissue and macular tissue. As an antioxidant, lutein protects these tissues from oxidative stress and subsequent damage. Lutein is a multifunctional carotenoid that plays both supportive and protective roles on both macular and neural tissue throughout the lifetime.

Introduction

Lutein is a carotenoid widely known for its role in eye health and function. Along with its isomer, zeaxanthin, lutein is stored in the macula of the eye, acting as an antioxidant to protect macular tissue from damage [3]. Lutein cannot be synthesized in the human body but is present in many green leafy vegetables, fruits, avocados, and eggs [12,17]. Once ingested, lutein is absorbed by the small intestine and carried to the liver by chylomicrons, lipoproteins specializing in transport. In the liver, lutein is packaged into lipoproteins that are sent to peripheral tissues. Before the lutein reaches these peripheral tissues, it is considered to be circulating as serum lutein. This serum lutein circulates in the blood until it is released for accumulation [10]. In the past, researchers believed that lutein preferentially accumulated only in macular tissue. However, it is now understood that lutein accumulates both in macular and brain tissue [3]. In the eye, lutein accumulates in macular tissue, where it acts as an antioxidant. In this role, lutein protects the retina and macular tissue from oxidative damage. For example, blue light oxidation can damage the retina. Lutein prevents this damage by donating electrons to the free radicals produced by blue light, neutralizing those free radicals and protecting the macular tissue [9]. Lutein plays a similar role in brain tissue, where it is concentrated in the hippocampus as well as the frontal and occipital cortices [13]. These regions of the brain are focused on learning, memory, and neurotransmission. Lutein's antioxidant properties protect these areas, paving the way for proper brain development.

Lutein levels are known to decrease with age, which has been found to contribute to age-related macular degeneration [18]. Decreased macular lutein may indicate lower neural levels of lutein. Decreased lutein in brain tissue may be related to the decreased cognitive function often associated with aging [10]. This indicates that increased lutein intake in older individuals has widespread benefits and demonstrates the importance of maintaining an appropriate lutein intake from a young age to prevent severe decreases in cognition for the future.

Lutein accumulation in the macular tissue is measured by assessing the optical density of the macular pigments (MPOD) [8]. Increased MPOD has been noted in individuals with increased consumption of lutein and zeaxanthin. High accumulation of lutein in the macular tissue indicates that lutein levels may be high enough to provoke the deposition of excess lutein in additional tissues such as neural tissue [8]. According to recent studies, the actions of lutein in these neural depositions may lead to improved cognitive function. The purpose of this comprehensive review is to explore the current research on lutein's role in cognitive and macular function throughout the lifetime. This paper will discuss the functions and mechanisms of lutein in older adulthood, young adulthood, and infancy and childhood and provide directions for future research.

Methods

EBSCO, PubMed, and ScienceDirect were used. Keywords used in the literature were "lutein" and "cognition" and "older adult" or "younger adult" or "infant." Only peer-reviewed articles published from 2015-2022 and written in English were considered. Focus was given to ensuring that the research was specific to multiple age groups to fully assess lutein's role in different life stages. Almost all studies were randomized control trials, with the exception of one standard intervention study. For data analysis, a one-way ANOVA and a two-tailed t-test were used to determine the statistically significant difference between intervention and control groups. The chi-square test and Spearman's correlation were utilized to assess whether study results were directly related and to compare expected results to outcomes.

Results and Discussion

In Older Adults

As previously mentioned, lutein is known to serve as an antioxidant in macular tissue. As an antioxidant, lutein is able to protect the macula from the potential oxidative damage of light that enters the eye. Recent studies indicate that it may do the same in neural tissue, preventing abrupt cognitive decline associated with aging [8,9,10]. Intervention studies conducted in older populations measured MPOD, serum lutein, and cognitive function at baseline and then again following an intervention period with a high lutein diet or supplement. Compared with control groups given placebo interventions, individuals with higher intakes of lutein were found to have higher serum and MPOD levels of lutein as well as improved scores on tests measuring cognition [11,17]. A majority of the cognition tests focused on visual memory and processing, reaction time, cognitive flexibility, and executive function [6,10,11]. The results of these cognitive tests demonstrated that higher levels of lutein are associated with improved visual memory and processing, cognitive flexibility, and overall executive function.

In each research article, the levels and supplementation of both zeaxanthin and lutein were measured and provided [6,8,10,11]. Research shows that zeaxanthin plays a role very similar to lutein in the macular tissue [3]. Zeaxanthin is also found in foods similar to those containing lutein. It should be noted that while each study focused on lutein, zeaxanthin was included and measured as well. Hammond et al. utilized lutein and zeaxanthin as an intervention group and then added lutein-only and zeaxanthin-only intervention groups [8]. However, at follow-up, levels of each substance individually in groups treated with either zeaxanthin or lutein were very similar to the levels observed in the group that included both lutein and zeaxanthin. Consequently, the three groups were merged for statistical testing into a single intervention group to compare to the placebo group. This reveals that zeaxanthin may have a supportive role in the action of lutein or may serve as an alternative to lutein to prevent cognitive and macular decline. In addition, the study by Hammond et al. shows the overwhelming improvement in executive function after a 12-month intervention period of lutein and zeaxanthin supplementation as compared to a placebo intervention [8].

Following lutein and zeaxanthin supplementation, MPOD scores and serum lutein and zeaxanthin levels increased [6,8,10,11]. This increase in both stored and circulating lutein and zeaxanthin indicates that lutein and zeaxanthin were able to reach neural tissue. Following lutein and zeaxanthin supplementation, older adults experienced increased scores on cognitive tests measuring visual memory and processing, reaction time, cognitive flexibility, and overall executive function.

In Younger Adults

Lutein and zeaxanthin supplementation in younger populations has been shown to have a preventative role in cognitive decline rather than serving as a treatment to improve declined cognition [7,13]. Healthy stores and circulating levels of lutein achieved at a younger age may decrease the need for supplementation and cognition treatment as individuals age [12,14]. Similar to findings for older adults, studies measuring lutein supplementation and cognitive function found that increased lutein levels were associated with increased scores on cognitive functioning tests [15]. Lutein's supplementation, mechanisms, and actions were intertwined with the actions of zeaxanthin, similar to studies conducted in older adults [7,14,15,18].

Studies found that higher levels of lutein and zeaxanthin in younger populations was most closely associated with increased verbal and visual memory [14,15,17]. It is important to reiterate lutein's role in macular health. As lutein protects the macula, it also supports visual memory. Its role in macular and neural health as an antioxidant and anti-inflammatory agent demonstrates the importance of maintaining adequate stores and circulating levels of lutein as a multifunctional carotenoid [2]. Maintaining adequate stores at a younger age may prevent the need to supplement later in life [5,15]. Thus, maintaining adequate lutein levels throughout the lifetime could exhibit protective effects and slow or prevent the natural cognitive and visual decline that comes with age. Stringham et al. found that macular carotenoids such as lutein and zeaxanthin interrupt the pathway that free radicals use to damage brain-derived neurotrophic factor (BDNF), a protein that impacts nerve growth and health [18]. Lutein and zeaxanthin oxidize free radicals, reducing the inflammatory response to those free radicals that damages neural tissue. In this context, lutein and zeaxanthin protect neural tissue to maintain cognitive function in younger adults. This is an interesting contrast to older populations and offers a broader view of the role lutein and zeaxanthin play throughout the lifetime.

In Infants and Children

Lutein may also impact the cognition and macular development of infants and children. Lutein intake begins when a child is in gestation and is based on the mother's intake. While there is not currently abundant research in this area, upcoming research is beginning to focus on studying the role of lutein in cognitive and macular development in early life stages. Picone et al. concluded that fetuses had the highest gestational levels of lutein during weeks 33-36 of gestation [13]. During this time, the central nervous system develops in the fetus, supporting the hypothesis that lutein plays a major role in the cognitive development of individuals beginning during gestation. As an antioxidant, lutein may protect the growing brain of infants and children, which allows for proper development. Addo et al. conducted a randomized control trial to test the hypothesis that maternal carotenoid supplementation during gestation will improve the lutein stores of infants after birth [1]. Results of this study provided further insight into when lutein intake is most important during gestation and its impact on the cognitive and macular health of the infant after birth.

Lutein is abundant in breastmilk and is transferred from the mother to the infant through breastfeeding, indicating the need for adequate maternal intake of lutein [22]. Schaefer et al. found that lactating mothers experienced an increase in plasma lutein levels following supplementation [16]. These maternal stores would then be passed to the infant through the mother's breast milk. It is known that infants fed with formula alone tend to have lower lutein levels compared to those that are breastfed [2,4,20]. This supports the hypothesis that maternal lutein stores are important in the early utilization of lutein to promote healthy development of an infant's eyes and brain. This hypothesis indicates a gap for future studies due to the lack of current research in the utilization of maternal lutein stores by a fetus during gestation. In infants, lutein largely collects in brain and macular tissue, where it is able to support healthy brain and eye development throughout childhood. For example, lutein may act as an anti-inflammatory agent in brain tissue to allow for decreased systemic inflammation and increased growth of neurons [21]. As an anti-inflammatory agent, lutein is able to promote growth of the brain and overall brain development. This again supports the rationale that lutein provides protection so that the developing brain can reach its highest functioning potential.

Furthermore, Tanprasertsuk et al. found a correlation between stARD3 concentration and lutein levels in infants that suggests lutein supplementation promotes the development of the infant brain [19]. StARD3 is a protein responsible for lipid transportation within neurons, and its decline is associated with neurological diseases such as Alzheimer's disease. The increase in stARD3 that is correlated with increased lutein levels may indicate stARD3's role in the healthy brain development in infants. Lieblein-Boff et al. found that higher lutein levels are correlated with increased levels of the fatty acids utilized to produce myelin in the infant brain [9]. Additionally, this study concluded that lutein acts as an antioxidant in the macula to protect an infant's eyes from blue light damage. Therefore, lutein promotes both cognitive and macular development.

Moreover, lutein may be more necessary at a younger age due to the high demands of brain development during infancy and childhood [21]. The antioxidant properties of lutein may offer protection during childhood that prevents the accumulation of oxidative damage in adulthood and beyond. Each of these studies indicate that lutein may promote cognition and brain development in infancy and childhood, but further research is needed in order to draw firm conclusions.

Unlike studies conducted with older populations, studies investigating lutein's role in infants and children focus less on the related actions of zeaxanthin and lutein. Further research is recommended to provide adequate conclusions on the role of zeaxanthin in conjunction with lutein in infants and children.

Conclusion

Lutein has been proven to have a considerable role in the improvement and maintenance of macular and cognitive function throughout the lifetime. At a young age, lutein serves as an antioxidant and anti-inflammatory agent to promote neural and macular growth through the protection of developing tissues. In adult and older adult populations, lutein acts as an antioxidant to improve cognitive function and prevent age-related degeneration, especially the exacerbation of cognitive and macular decline. Its antioxidant properties make lutein a necessary carotenoid for cognitive and macular health. Clinical practice should focus on the importance of adequate lutein intake from birth to ensure sufficient levels are acquired for development and maintained throughout the lifetime.

Future research on the role of carotenoids in cognitive health should aim towards understanding the relationship and distinction between lutein and zeaxanthin. Current research utilizes both, making a distinction between the two difficult for clinical application. Additionally, future research is warranted in younger populations to provide a conclusive understanding of the mechanisms of lutein's actions in infants and children. Finally, future research may benefit from the focus of these carotenoids in other neurodegenerative diseases.

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Sleep Influences Word Comprehension in Preverbal Infants: An EEG Study

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Word comprehension is a complex, dynamic skill that develops rapidly over the first year of life. Despite the importance of this time, research is limited on how these skills emerge (i.e., the mechanisms underlying word comprehension) and the modulating factors affecting its development. The objective of this study was to better understand how potential biological and environmental factors influence early evidence of word comprehension in preverbal infants and, more specifically, to examine whether sleep or parental involvement in learning influenced infants' word comprehension. Infant-parent dyads (N=29) participated in this study at Time 1, ~ six months of age, and Time 2, ~eight months of age. Infants were given novel objects with nonsense labels and learned the object-label associations via parents during at-home play sessions. Infants exhibited word comprehension at both time points, as indicated by N400 amplitudes and latencies. Infants with more sleep exhibited a more negative N400 amplitude at both visits and exhibited slower latencies at Visit 2. A trend indicated more negative N400 amplitudes for infants with parents who utilized more label utterances during at-home training. These findings provide preliminary evidence that biological and environmental factors may support word comprehension, furthering theories of multifactorial influences on language development. This study and further research will improve identification of preverbal infants that could benefit from early intervention.

Introduction

Verbal communication is a monumental milestone for infants and parents all over the globe. Speech provides an alternative pathway for the infant to become an active communicator and allows for exploration and contributions to society [4]. However, a more complete understanding of language development in infants during the preverbal stage (i.e., the time in which children use alternative forms of communication prior to producing verbal language) is limited despite rapid cognitive growth during this period [8,13]. In this paper, the development of word comprehension during the pre-verbal stage was further explored to improve the understanding of how different biological and environmental mechanisms interact and support early language development.

The initial stages of processing and comprehending information via receptive language abilities begin before birth [22]. This development continues during the first year of life, in which the infant strengthens auditory and visual perception aligned with the development of cognitive brain systems [8]. These systems complement language comprehension by aiding an infant's orientation with the environment, as well as the formation of long-term categorization and processing units, also known as schemas [8]. Between four to six months of age, infants' vocal production progresses from sighs and cries to more intentional babbling that slightly resembles frequently-heard phonemes, emphasizing the interconnectedness of expressive and receptive language [11]. Evidence of vocal language abilities emerging in the pre-verbal period is important in understanding the mechanisms of receptive language development as infants attempt to recreate words they have previously processed and stored [15].

It is important to understand how additional factors influence and support this language pathway, by which infants and toddlers effectively utilize word association. Certain cognitive mechanisms support the comprehension process, and recent research suggests that infants in the early to middle pre-verbal stage comprehend novel language more than rote memorization of word characteristics [4]. Bergelson and Swingley found in their study that 80% of infants aged six to nine months were able to correctly orient themselves to a spoken target. This ability to redirect attention indicates an understanding of common labels and general word comprehension skills [4].

Theoretical foundations involving biological and environmental factors provide possible target mechanisms that play a part in the process of word comprehension. Sleep is one biological factor with known effects on cognition and memory [20]. According to Oswald (1980), the main purpose of sleep is to aid in the restoration of the body during a period of inactivity [20]. Sleep allows for the body to take advantage of the calm and immobile state to strengthen pathways, rebalance chemical levels, and repair processes [2]. Additionally, the division of resources during the sleep cycle suggests that rapid eye movement (REM) sleep is responsible for repairing neural connections [2]. The distinction between sleep stages is important when studying infant word comprehension because on average, infant sleep is dominated by the REM cycle [23]. Researchers found that the total time spent in REM decreases to 20% by the fifth year of life [23]. This shift is significant because during the pre-verbal stage, the majority of infants is achieving the greatest amount of cognitively restorative sleep.

The learning environment (including parental involvement) may be a critical factor in word comprehension, considering that cognitive processes work in tandem with the environment to foster learning [3]. Infants are constantly absorbing new sensory information and attempting to process, analyze, and organize information into categories. This is the foundational step in developing receptive language comprehension skills. The learning process begins early in infancy, and specific cognitive abilities (such as word comprehension) mature continuously throughout development into childhood [26]. Often, positive interactions between the learner and others in the social environment increase infants' capability of learning [26]. Specifically, pre-verbal infant learners are supported by their immediate caregivers, who can serve as knowledgeable mentors. For instance, when considering strategies to bolster word comprehension, parents may provide social support in the form of positive feedback to promote word comprehension skills based on their infant's current biological capacities.

The objective of this study was to identify biological and environmental factors that impact developments in word comprehension of preverbal infants. Specifically, the aim was to understand two factors that may support word comprehension: infant sleep and parental involvement. To summarize, biological (e.g., increased sleep) and socio-environmental (e.g., parental involvement) factors may foster language development (e.g., word comprehension). Based on the current literature, developmental changes were expected, as it has been explained that the preverbal stage is a time of rapid and considerable cognitive growth.

This work extends a prior study that utilized electroencephalography (EEG) to measure word comprehension in preverbal infants [11]. EEG records electricity generated by the brain, and an event-related potential (ERP), known as the N400 component, reflects brain responses of ongoing neural processing of expected and unexpected events in the environment [13]. The N400 component is elicited between 400 and 700 milliseconds as a large negative deflection after the stimulus onset. In the current study on infant word comprehension, the N400 was recorded via EEG during video vignettes following a period of at-home training. If an infant successfully learned an object's label, the N400 was more negative in amplitude when observing the correct, matching object (relative to a different, mismatching object) [13]. It was predicted that the difference between N400 response between match and mismatch would become more distinct between Time 1 and Time 2, showcasing a stronger effect of matching. This can be linked to continued cognitive development and better word comprehension abilities as an infant matures [14].

Table 1. Demographic descriptive statistics.

Measurement	Time 1	Time 2
N	29	29
Age in months M ± SD	6.29 ± 0.43	8.24 ±0.48
Age range in months	5.5-7.1	7.4-9.0
Proportion natal sex as % male	52%	52%
Sleep previous week in hours M ± SD	10.58 ±1.8	10.38 ±2.11
Sleep previous week before in hours range	6.0-15.0	5.0-15.0
Sleep night before in hours M ± SD	10.39 ±1.56	10.52 ±1.84
Sleep night before in hours range	7.0-13.0	6.0-15.0
Parent Utterances M ± SD	308.5 ± 119	289.3 ± 132
Duration of Parent Training in hours M ± SD	51.4 ± 11.6	50.5 ± 18

Methods

Participants

Study enrollment at Time 1 included infants around the age of six months. Enrolled infants (N=29, 51% female) were between 5.5-7.5 months (mean age 6.29 months, ± 0.43 months). After eight weeks, infants returned for a second series of research appointments (Time 2). Infants and their parents were recruited primarily through flyers posted around the community and postal letters to caregivers who had previously agreed to be contacted by their local hospital. **Table 1** displays demographic data about the infant participants.

Experimental Procedure

The overall goal of the procedure was to introduce unknown objects to infants, teach them object-label associations, and test the effectiveness of the training using ERP. Infants were given two unique, three-dimensional, wooden, and novel objects at Time 1 and two different objects at Time 2. Object features and non-English bisyllabic labels were given to the object pairs at random (bigu/gigu and bugi/gugi). Phonetic differences were controlled for by utilizing similar consonants at the onset of both labels to reduce the effects of cross-modal correspondence [25].

Implementing a parent-training procedure similar to Molfese et al., parents were instructed on how to teach their infant about the object and its label to build an association with the object-label pairing over the course of three days [16]. Parents recorded 10-minute play sessions in which they showed their child each of the two novel objects for five-minute intervals with a focus on vocalizing the name of the object during play to promote learning association. Additionally, parents were instructed to alternate the order in which the objects were displayed, encouraged to utilize interactive vocalizations and movements, and obscure one object from view to limit distractions. Parents were asked to log additional information about the training sessions such as time of day, infant mood and attention, and total time spent playing. Data from the at-home play sessions was recorded by parents using a portable audio recorder.

After completing at-home training, the infant-parent dyads returned to the lab to complete the ERP word comprehension task (adapted from Hudac's study) involving infant responses to whether the presented audio target matched the visual appearance of the on-screen object [11]. The events featured on the video vignettes were ordered as in **Figure 1**: 1) the on-screen actress asked the infant, "What is it?", 2) a monotone voice off-screen provided context for both the on-screen actress and the infant as to what object was expected to be revealed under the box by saying one of the labels the infant was exposed to during at-home training (i.e., Event 1, "It's a bigu"), 3) the actress redirected her attention to the portion of the screen that held one of the boxes, 4) the box was removed to reveal either a congruent or incongruent object stimulus (Event 2), the target of the study, 5) the actress responded emotionally to the revealed object by repeating the name provided by the off-screen voice with either a happy or confused tone and facial expression (Event 3). Step 5, the final emotion component of the vignette, was not evaluated within the current study.

At each timepoint, infants observed 32 match and 32 mismatch video trials. Here, as the primary outcome, the study examined the peak amplitude and latency of the right frontal N400 taken from 150 to 500 milliseconds after the visual onset of the object in Event 2.

Measurement of Sleep

For the current study, researchers examined responses to the item, "How much did your infant sleep last night?" Responses were recorded in hours and recoded if necessary to standardize. Parents responded to several sleep-related questions in the original study as a means of measuring possible interference from poor sleep on test-retest reliability within this age group (i.e., drastic differences in sleep between Time 1 and Time 2) [7].

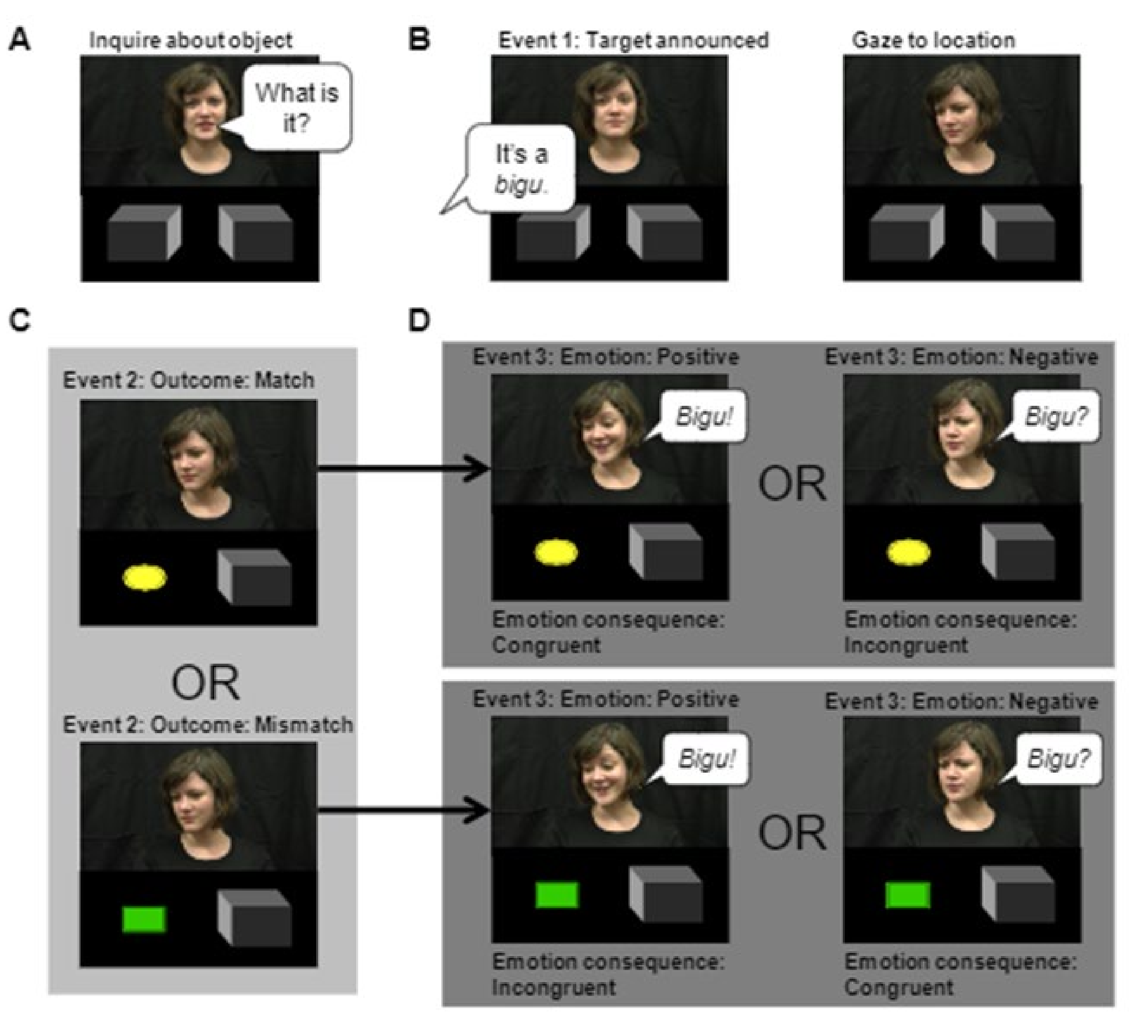


Figure 1. Experimental paradigm in which word comprehension N400 brain responses were time locked to the onset of Event 2. Adapted from Hudac, 2014.
Note: To view this figure in full color, please visit the digital archive at https://joshua.ua.edu/archive.html.

Parent Involvement in Home Environment

Parent involvement was defined as the total number of object label utterances spoken during the recorded at-home training sessions across the three-day training period.

Audio files were transcribed by research assistants within the Brain Research Across Development (B-RAD) lab at the University of Alabama. Transcribers were trained to identify and code parent vocalizations of the target labels as they listened to each 10-minute audio file for both Time 1 and Time 2. Vocalizations were coded to obtain the total number of target labels spoken within a 30-second interval. For each available audio recording, transcribers noted the time of day, the characteristics and labels of objects assigned, and any speakers discernable on the recording (e.g., parent, siblings, researcher/s). The goal of transcription was to total the number of mean utterances of each target word. Transcribers were trained to identify a target word by hearing the "consonant-vowel consonant-vowel" utterance (e.g., bigu). Any discrepancies or issues found within the recording were noted. For example, while the recordings were to be limited to 10-minute play sessions, some audio recordings were longer or shorter.

Data Analysis

A series of analyses of variances (ANOVA) compared mean differences of two independent factors: condition (i.e., whether the visual object matched or mismatched the auditory label target) and time (Time 1, ~six months of age, and eight weeks later at Time 2, ~eight months of age). Models were used to estimate N400 amplitude (Model 1) and N400 latency (Model 2). To test whether biological or environmental factors impacted learning, continuous variables were added to estimate sleep (hours of sleep the previous night) and parental involvement (total number of utterances recorded during training). In this way, models included a full factorial with main effects of condition, visit, and the individual difference factor (Model 1a and 2a: sleep; Model 2b and 2b: utterances) and all possible interactions. An alpha threshold of 0.05 was used to indicate significance ($p<.05$), and Bonferroni correction was used to correct for multiple comparisons.

Results

Word Comprehension

Preliminary models replicated the prior analysis of a subset of data from the experiment conducted by Hudac (2014), indicating that infants successfully differentiated between whether the object matched or mismatched the target auditory label [7]. For the match condition, N400 amplitude was more negative (i.e., more neural processing): $F(1,76)=5.54$, $p=0.036$. N400 latency was slower (i.e., more neural processing): $F(1,78)=4.38$, $p=0.04$. This difference indicates that there is some level of social-cognitive processing and word association amongst participants.

Effects of Previous Night's Sleep

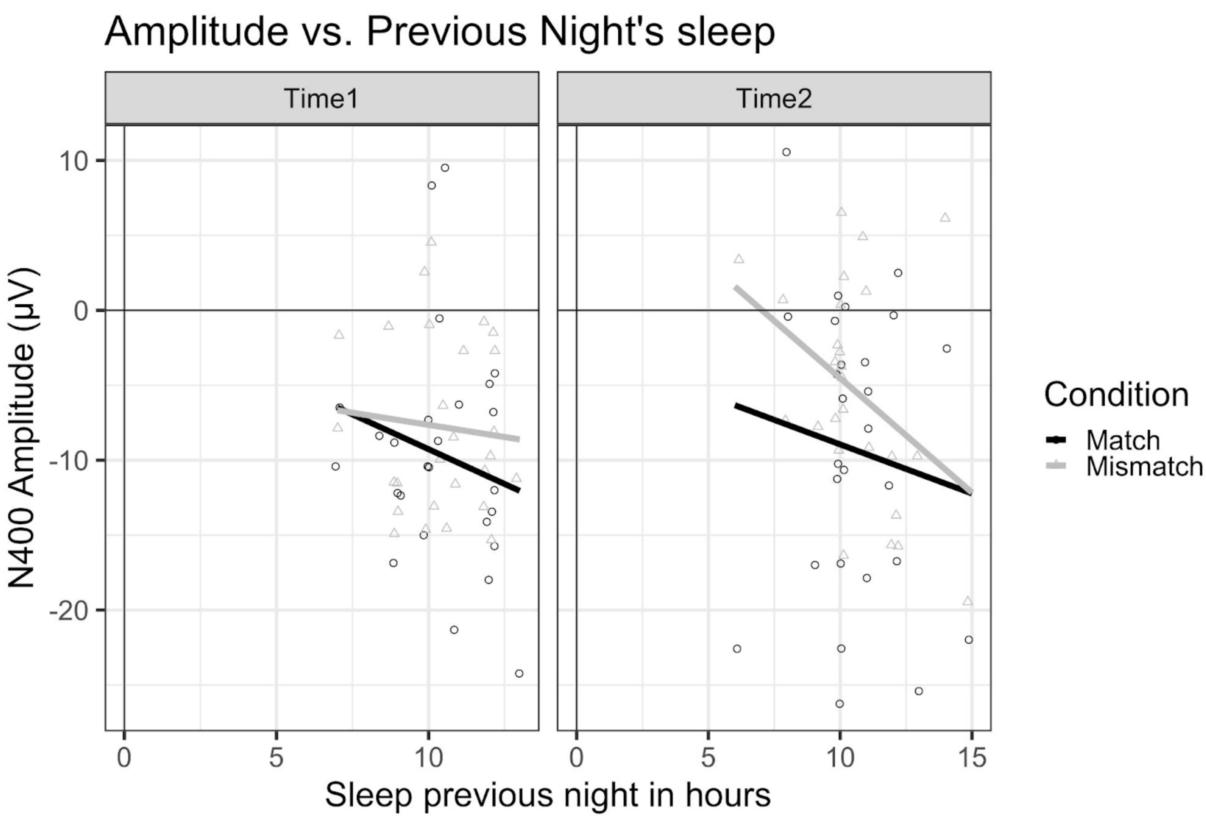
Models 1 and 2 evaluated effects of sleep. For N400 amplitudes, analysis found that a marginal condition effect $F(1,98)=3.79$, $p=0.054$ indicated the match condition was more negative (-9.63 μV) than the mismatch condition (-6.72 μV). An effect of sleep, $F(1,98)=4.05$, $p=0.047$, indicated that infants with more sleep exhibited a more negative N400 amplitude (slope = -0.93). All other effects were nonsignificant (p's > 0.37). **Figure 2** displays the trend in N400 amplitudes.

For N400 latencies, the study found a significant interaction between visit (i.e. Time 1 vs Time 2) and sleep, $(1,100)=8.92$, $p=0.004$. At Time 1 (~six months), match N400 latencies were not related to sleep, but mismatched N400 latencies were faster (i.e., less neural processing) for infants that slept more the night before. In contrast, at Time 2 (~eight months), N400 amplitudes in both conditions were slower (i.e., more neural processing) for infants that slept more the night before. All other effects were nonsignificant (p values >0.11).

Parental Involvement

For N400 amplitudes, infants displayed a marginal effect of parental involvement, $F(1,100)=3.03$, $p=0.85$, indicating that N400 amplitudes were incrementally more negative (i.e., more neural processing) with increased total number of parent utterances. More specifically, infants displayed stronger cognitive processing during the word comprehension task when their parents used the object label more

Figure 2. N400 amplitudes (y-axis in μV) compared to the amount of sleep the night before the word comprehension task (x-axis in hours) at Time 1 and Time 2. Group responses are plotted as a line, and individual infant values are plotted for match (circle) and mismatch (triangle).



during at-home training. All other effects were nonsignificant (p values>0 .08).

Discussion

The ability of infants to consolidate information and categorize ideas into schemas is the foundation of word comprehension [12]. For decades, it has been thought that receptive cognition narrowly precedes expressive vocalizations [4]. However, the present findings align with recent literature suggesting that word acquisition begins far earlier than previously understood [4]. By six to eight months of age, infants have begun to connect word and object associations, as indicated in the current study by differential brain responses in the N400 component.

The general trend of an increased robust word comprehension capacity was expected from six to eight months of age, based on preexisting research [6,8,11,18]. As infants develop in the first year of life, cognitive and physical milestones facilitate development of a receptive vocabulary [12]. It then follows that over time, word comprehension advances to become available for the infant's practical use. Infants are rapidly taking in the world around them while building schemas in which they interpret the world. It is important to understand this maturation and its emergence to provide a sufficient learning environment.

The relationship between sleep patterns and improved cognitive ability was expected, based on data linking infant sleep with cognitive processes critical for language development [2,8,20,23]. As infants sleep, a myriad of biological mechanisms that strengthen neural connections and executive functioning and memory pathways are at work [8]. A longitudinal twin study found similar trends where those who presented with language delays would show less mature sleep cycles earlier in development (i.e., shorter interspersed sleep periods) [8]. These results are meaningful because introducing a consistent sleep routine is an active part caregivers can play in the language development of their infant.

The emerging relationship established by the current findings suggests more engagement from caregivers may influence word comprehension. Despite the caution of over-interpretation of a marginal effect, the data indicated a slightly greater N400 amplitude (i.e., more neural processing) for infants whose parents had more average utterances. In a 2015 study on the relationship between maternal input and linguistic skills, infants at seven months were introduced to words through various communication modes and were given a vocabulary test at two years of age [18]. This 2015 study found that both maternal input and child capabilities predicted expressive and receptive language later in toddlerhood [18]. Taken together with the current study, these results encourage parent involvement in early infant learning.

Measurement of preverbal word comprehension may have broad clinical implications. For instance, neurodevelopmental disorders such as dyslexia and autism spectrum disorder are not diagnosed until the verbal stage of toddlerhood [14]. Additionally, current diagnostic methods rely on the emergence or lack thereof of expressive language in those with language disorders. Therefore, an awareness of how children perceive, encode, and organize information from their surroundings could be a valuable asset to researchers analyzing the receptive language timeline as it relates to later vocalization. Considering the inherent social connectedness obtained through language, delays in language development may hinder interpersonal relationships and social skills. The ability to comprehend language allows for an individual to share attention, respond to questions and instructions, and form emotional bonds with another speaker [9]. This construct can apply to clinical populations and potentially aid in treatment practices such as speech therapy, sleep regulation, and learning techniques. Understanding more about early comprehension abilities may serve to accelerate the diagnostic timeline by means of identifying markers so intervention can begin at an earlier age.

One limitation of this research is that it assumes infants' implicit understanding of the nature of the task. This study's measurement of comprehension is based on the infants' expectation that the narrator will uncover the target object. Although the results indicate that infants differentiate between match and mismatch conditions, it is not possible to assess each infant's understanding of the vignettes. Infants may have in fact successfully learned target words but lacked the social-cognitive development skills to properly interpret the comprehension task.

Another limitation of this study is that the factors of interest, previous nights' sleep and parental utterances, may not be the dominant biological or environmental factors. For the purpose of this research, the data utilized was archival, and it may be the case that more objective and/or reliable measurements would capture more meaningful information. Also, possibly incorporating both audio and visual records of play training could uncover more in-depth information about environmental interactions. Marginal differences in an environment may be a result of several factors. Certain design elements present in similar and stronger environmental findings were not included in the current work. Parents were instructed to be engaging with their infant and utilize the target label but did not receive training specific to child-directed speech and object-movement synchronized play. Additionally, utterances were transcribed manually rather than by computer processing models that may account for discrepancies in parent vocalizations. These elements are common in recent literature linking parent interaction and early language acquisition [18].

Future Recommendations

The results of this study implicate the clear role of sleep in the emergence of infants' word comprehension. Further research on individual sleep patterns in relation to early word association developments over a longer period would provide a more complete understanding of the biological determinants of cognition. Future studies may want to request parents keep a daily log of their infants' habitual sleep patterns. A study that utilizes more concrete parental training along with factors such as incidental learning, and coding technology could be beneficial in strengthening the understanding of the home-learning environment and its effect on receptive language. Another possible direction of infant research would involve twins or infants to compare biological mechanisms within the same environment.

Conclusion

In this pilot study, the authors explored the specific cognitive mechanisms that impact the development of receptive vocabulary in infants during the preverbal stage. It was found that the amount of sleep and parental involvement during learning has a significant effect on the difference in neural responses infants have to the word comprehension task. The findings of the current work could be persuasive in discussions of education and intervention programs for promoting sleep training during the pre-verbal stage.

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A Novel Optical Setup for Simultaneous High-Speed Chemiluminescence Imaging of Multiple Combustion Species by a Single Camera

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Chemiluminescence measurements are commonly used to diagnose reaction zones and flame behavior in combustion processes. For gathering data on the chemiluminescence emissions of two species, either a single camera with a doubler lens or multiple cameras are used to isolate different wavelengths of light. These flame chemiluminescence imaging methods introduce path-length differences and parallax errors, requiring complex post-processing correction techniques which may not be reliable for highly dynamic and/or turbulent flames. In this study, a new optical setup was proposed, wherein a beamsplitter was used to divide the chemiluminescence emissions from the test media (flame) into two separate paths, which were then merged onto a single camera sensor using a knife-edge mirror to mitigate both parallax error and path length differences. A simple Bunsen burner flame was used as a sample test media for simultaneous acquisition of OH and CH* chemiluminescence data; the alignment and data processing techniques are detailed in this study. It was shown that after a relatively straightforward alignment exercise, the optical apparatus was useful for identifying key differences in species behavior.*

Introduction

Combustion research seeks to reduce the environmental impact of fuel-based energy conversion processes. Such research depends on the measurements of properties affecting the structure, composition, and dynamic behavior of the combustion process [5]. Various optical diagnostic techniques exist to study different aspects of the underlying chemical and physical processes in the reacting flows. Particle image velocimetry is used to measure the velocity fields associated with a given combustor [1]. Planar laser-induced fluorescence utilizes a laser to excite minor species in the flame, and then images are captured to obtain quantitative information [12].

Chemiluminescence imaging is a simpler, non-intrusive optical technique used to identify regions where certain minor species are produced; chemiluminescence emissions along the line of sight from these minor species can be detected by a camera depending upon the wavelength of the light emitted by the species [6]. The distribution of specific minor species in the reaction zone can provide important insight to formulate and validate chemical kinetic models and to understand the transient flame processes.

As the chemical bonds break in a reaction between fuel and oxidizer, newly-formed bonds occur as chemical energy is transferred to thermal energy. In the case of chemiluminescence, the unstable molecules or radicals are present for enough time to collide and absorb the kinetic energy, causing the molecules to enter an excited state and, after some time, release energy by emitting a photon [8]. This combustion diagnostic has been used for over half a century to study the chemiluminescence from species such as CO_2*, C_2*, CO*, OH*, and CH* [2]. In prior studies, a different sensor or detector was used to measure each species. This study aimed to overcome this limitation by developing an optical configuration that allowed for simultaneous detection of multiple species using a single detection system.

This study focused on OH* emissions at 308 nm and CH* emissions at 434 nm. The ratio of peak OH* and CH* chemiluminescence can provide insight into heat release rate, temperature distribution, reaction location, and local equivalence ratios in both gaseous and liquid flames [4,7,11]. Multiple methods are available to isolate specific chemiluminescence species. For instance, Guyot et al. performed simultaneous OH* and CH* measurements along a single line of sight in the flame using photomultipliers [3]. The acquired data was used to create a relationship between OH* and CH* intensities.

Vogel et al. studied simultaneous OH* and CH* chemiluminescence by using a camera with an image doubler to acquire data at multiple lines of sight, matching the pixel size of the camera [13]. However, the doubler optic changes the viewing angle for the two species, thereby introducing parallax error. The line of sight for each species would be different with parallax, which can be significant in a flow with turbulent and highly dynamic features. Moreover, the parallax error increases with decreasing distance between the camera lens and test media. Conversely, increasing this distance decreases the parallax error; however, a loss in the signal strength and spatial resolution occurs. Vogel et al. utilized an image correction procedure using a reference target to identify deviations between the two images to make the necessary adjustments [13]. However, the error correction methods in post-processing can be complex and introduce arbitrariness into the data analysis.

Shim et al. acquired OH* and CH* chemiluminescence data by using a single camera to detect one species at a time and changing the ultraviolet (UV) filters between tests [10]. This approach requires multiple experiments to measure multiple species and is susceptible to inconsistencies from test to test, especially in turbulent and highly dynamic flows. Another option is to employ a separate camera for each species, but this option can be expensive for high-speed imaging. In any case, the view angle of each camera will be different, and hence, parallax errors cannot be avoided.

The objective of this study was to present a novel optical configuration that overcomes problems caused by simultaneously imaging multiple chemiluminescence species in turbulent flows. The optical setup can view multiple species along the same line of sight by a single camera without introducing parallax and path length errors. The concept was based on the ideas presented by Reggeti et al. about performing spatially resolved two-color pyrometry in diesel sprays [9]. An equilateral triangular optical path was used to ensure identical view angles and path lengths for light collection at multiple wavelengths. Next, the details of the optical setup and experimental measurements in a Bunsen burner are presented to demonstrate the unique capabilities and potential of the technique.

Methods and Materials

The test media consisted of the flamelets produced by a Bunsen burner (Humbolt H-5550 Accuflame) with a venturi tube for fuel-air mixing as shown in **Figure 1**. Natural gas fuel from the lab supply was fed at the burner inlet where ambient air for combustion was entrained. The flame was stabilized above a stainless-steel mesh with 100 separate openings.

Figure 2 depicts a schematic and a photograph illustrating the optical design of the imaging system created to simultaneously detect two chemical species in the UV range. Light from the test media was split by a 50:50 beamsplitter oriented normal to the camera lens

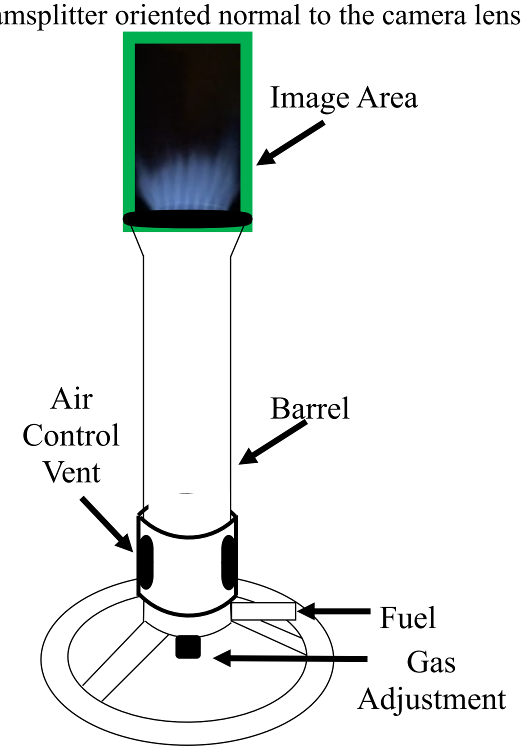

Figure 1. Bunsen burner and test media.

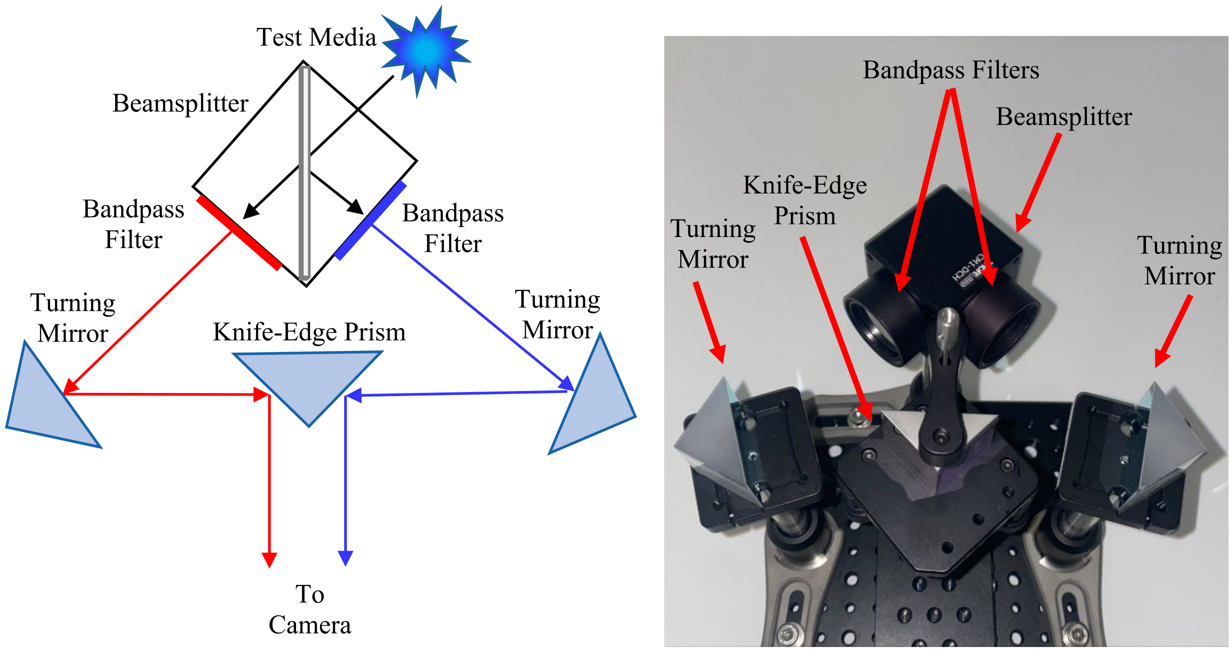

Figure 2. (a) Schematic of the optical setup for OH* and CH* chemiluminescence imaging (b) photograph of the optical setup.

for light collection. This arrangement enabled the two images to be symmetrically divided on the camera lens. Light from the beamsplitter passed through two narrow bandpass filters with central wavelengths of 308 nm for OH* and 434 nm for CH*. Filtered UV light was reflected by the turning mirrors onto a knife-edge prism mirror, which directed the signal to the camera lens of the high-speed camera (Photron SA-5) equipped with a UV intensifier to amplify the collected signal.

The system must be properly aligned to obtain quantifiable results. In this study, a laser-based method was developed and implemented to align the optics as shown in **Figure 3**. A spotting laser mounted on a 3D traverse was used to align different points in the field of view representing the test media. The top diagram in **Fig. 3** shows five different spotting laser points on the beamsplitter, and the bottom diagram shows the corresponding mapped locations on the image plane, i.e., a paper screen at the location of the camera lens. The dark vertical line in the bottom diagram represents the middle of the lens or the reference plane. The calibration ensures that each laser source point (A, B, C, D, and E) is correctly oriented horizontally and vertically with respect to the

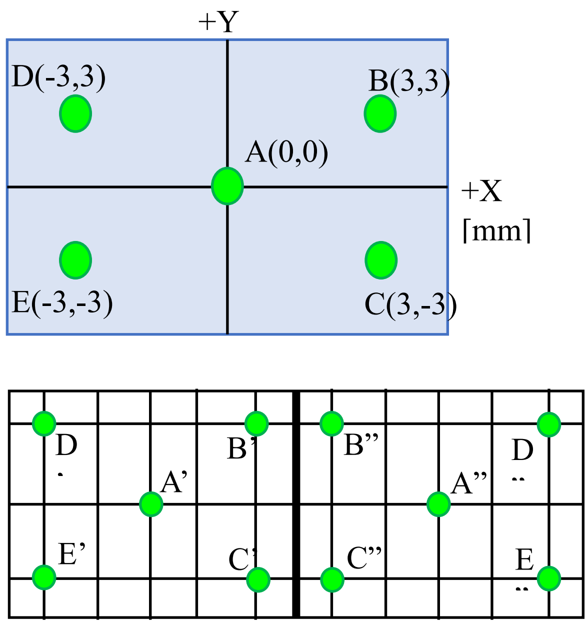

Figure 3. Illustration of laser alignment.

reference plane on the screen. A horizontal shift in the laser is expected to result in a shift in the separation between the beams incident on the screen; a beam disappearing before reaching the edge of the knife-edge mirror implies a misalignment upstream of the laser beam. For vertical alignment, the laser is shifted in that direction; the incident beams on the screen shift the same amount on each side of the reference plane when the optics are properly aligned.

Results and Processing

Prior to acquiring data, a broadband image of a reference target object, i.e., without the band pass filters, was obtained using a Photron SA-5 high-speed camera. The camera image contained two views of the target object mirroring each other about the reference plane if the optics were perfectly aligned. However, it was necessary to determine that the reference plane and any pixel-level deviations in projections of the target onto the two sub-images were mirroring each other. This process was performed iteratively to align the system within the acceptable threshold of one pixel.

The band pass filters were installed after completing the finer alignment procedure discussed above. **Figure 4** shows a typical image acquired by the camera: the OH* signal was acquired by the left sub-image, and the CH* signal was obtained by the right sub-image. Both sub-images shared the same line of sight and path length, and thus, no correction was needed to post-process these sub-images, which was a major advantage of the novel technique. The sub-images show multiple flamelets as expected

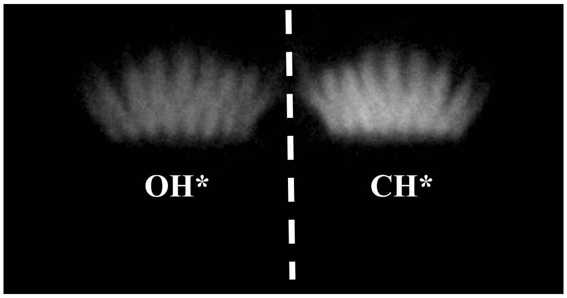

Figure 4. Raw image of the flame acquired by the camera showing two sub-images.

for this burner. In general, the intensity of the OH* signal was less than that of CH*. A careful review also showed that the CH* formed closer to the burner exit as compared to OH*, again confirming the ability of the system to detect minor differences in the species behavior.

Figure 5 shows the result of the post-processing: contour plots of intensity for direct pixel-to-pixel comparison of the sub-images were split and aligned with respect to the reference plane. In each plot, the origin is located at the center of the burner exit. The x-axis represents the transverse (or radial) coordinate, and the y-axis represents the axial coordinate. **Fig. 5** reveals that the flame spanned

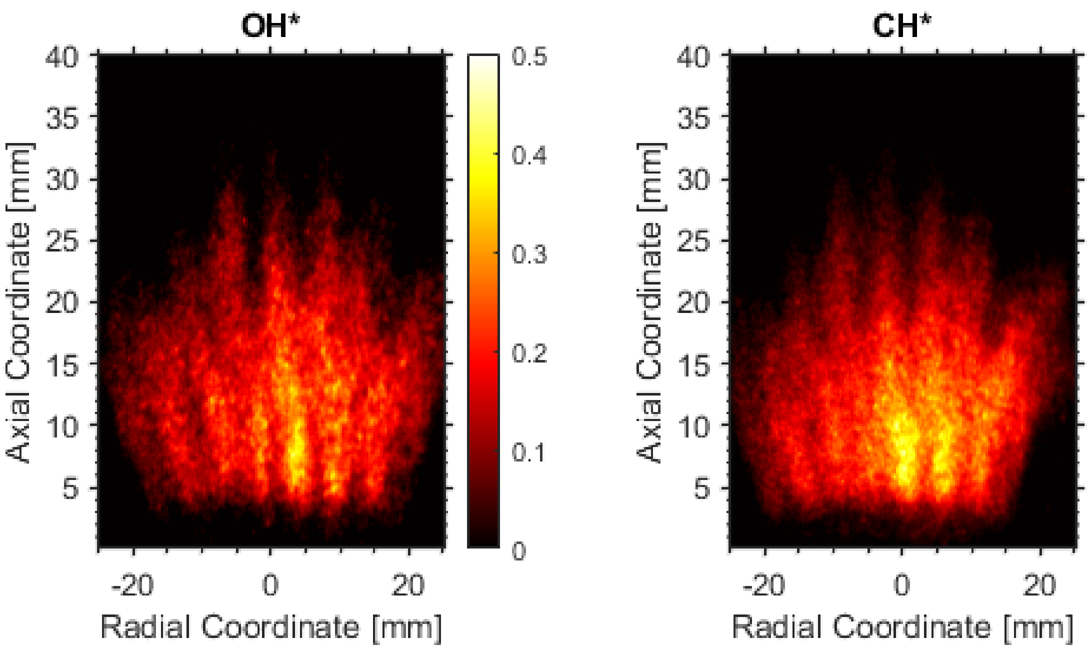

Figure 5. Contour plots that are flipped and aligned from the raw image.
Note: To view this figure in full color, please visit the digital archive at https://joshua.ua.edu/archive.html.

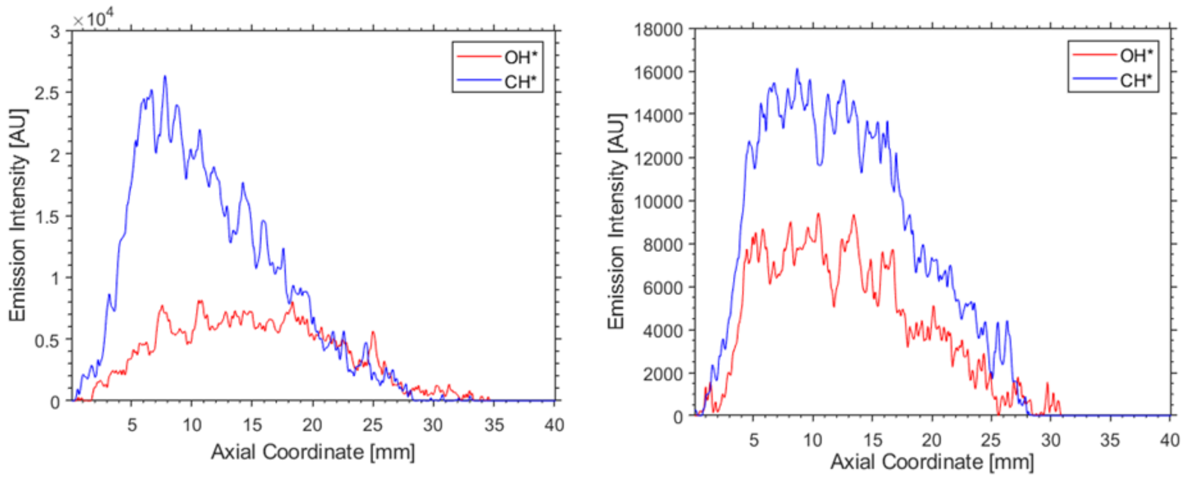

Figure 6. OH* and CH* intensities in the axial direction for y = 0.0 mm (left), 10.0 mm (right).

about 40 mm in the transverse direction and 30 mm in the axial direction. Interestingly, the OH* and CH* intensity contours showed similar overall structural features, but the highest intensity was observed in different regions of the flame. In prior studies, such an observation could not be made accurately because of the significant parallax and path length errors introduced by the optical system.

Axial and transverse profiles of OH* and CH* intensities are compared in **Figure 6** and **Figure 7**, respectively, to identify the local characteristics of the two signals. The intensity of light recorded by the camera was proportional to the quantity of CH* and OH* radicals present along the line of sight for a given pixel. Since the intensities of each radical type were measured simultaneously, the concentrations of each radical species could be evaluated from the intensity profile using a proper calibration procedure. Although an extensive calibration process was not performed, the relative trends of the two signals can still be identified from the intensity profiles.

Fig. 6 shows the axial profiles of OH* and CH* intensities at transverse locations: y = 0.0 mm and y = 10 mm. These results show that CH* existed in higher concentration near the

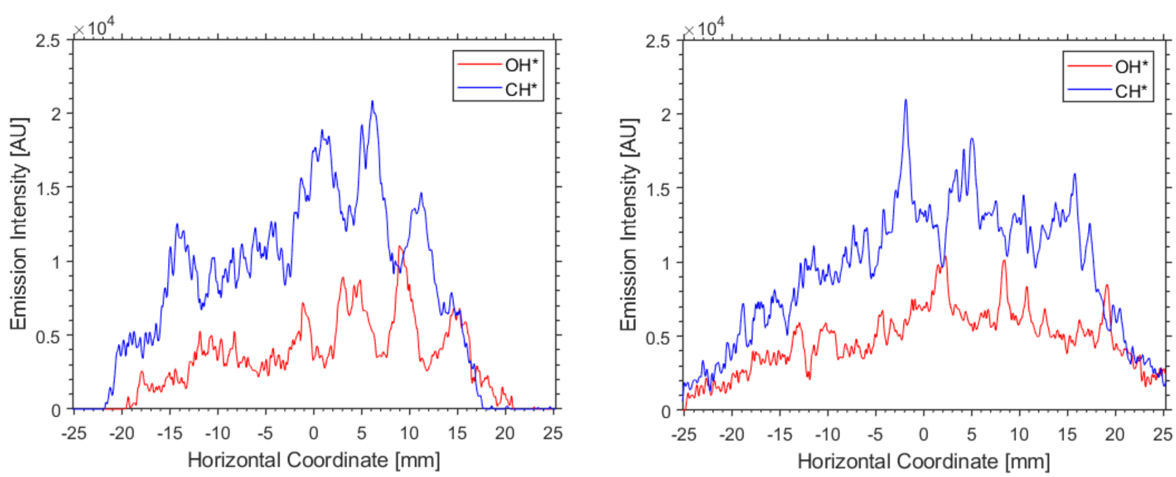

Figure 7. OH* and CH* intensities in the transverse direction for z = 5.0 mm (left), 15.0 mm (right).

burner exit as the fuel molecules are broken down into simpler structures, which confirms the findings of Walsh et al. [14]. Conversely, OH* existed farther downstream to complete the oxidation process. **Fig. 6** shows that the instantaneous spatial variations in CH* and OH* were out of phase with each other at a given location in the flame. This means that a high concentration of CH* resulted in low concentration of OH* and vice versa. The ability of the present system to identify such trends is promising for the study of turbulent flames.

Fig. 7 compares OH* and CH* intensities at two different axial locations in the flame: z = 5.0 mm and z = 15.0 mm. These profiles show that the emission behavior was similar for the two species. The intensity was highest at a location downstream of the burner exit. Again, peak OH* emissions occurred at locations with minimum CH* emissions. Similarly, a phase relationship between the intensity fluctuations could be established with respect to the axial distance from the burner exit.

Conclusion

This study presented a new optical design focused on eliminating parallax and path length differences to allow for high-speed imaging of multiple chemiluminescence species using a single high-speed camera. The optical setup was used to detect CH* and OH* chemiluminescence emissions from a Bunsen burner. Results showed that CH* was formed closer to the burner exit compared to OH*, as shown by previous work mentioned. The intensity of CH* emissions was much greater than those of OH* emissions. Two interesting observations were made in this study: (1) instantaneously, the CH* and OH* emissions were out of phase with each other at a given location in the flame, i.e., higher concentrations of CH* corresponded to lower concentrations of OH*, and (2) at lower axial locations CH* emissions were observed in higher concentrations compared to OH* emissions, indicating shorter time scales associated with fuel decomposition compared to fuel oxidation.

Acknowledgements

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How Racial and General Discrimination Affect the Brain: The Effect of Perceived Discrimination on the Volume of the Hippocampus and Amygdala

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A large body of research has shown that discrimination has negative effects on mental and brain health. Discrimination can stem from a variety of characteristics, including one's race, class, weight, or religion. Those who experience discrimination are treated unfairly or with prejudice in environments such as the workplace, school, and even in various public locations such as stores. The unavoidable impact of racial discrimination on one's mental and brain health is of particular salience given recent historical events. Racial discrimination has been associated with worse cognitive health, including episodic memory. However, few studies have examined the brain mechanisms through which these detrimental effects occur. This study examined how general discrimination and racial discrimination are associated with brain volume using structural MRI. Data were used from the Alabama Brain Study on Risk for Dementia that includes both brain structure and a variety of psychosocial questionnaires from 86 participants. It was hypothesized that greater discrimination would associate with smaller hippocampal volumes and larger amygdala volumes. These areas were highlighted in the study because of their importance in episodic memory and stress responses. The hippocampus is responsible for episodic memory processes, and the amygdala is greatly affected by cortisol released during events of psychosocial stress, such as discrimination. The hypotheses were addressed using linear regression analyses. The regression analysis yielded nonsignificant results for both everyday discrimination and racial discrimination on brain volume.

Introduction

The issue of discrimination in America has been discussed widely in a variety of academic settings throughout history. Psychological and neuroscientific research place a heavy emphasis on ideas such as implicit versus explicit biases or how and why humans discriminate, but in recent years, there has been a shift in focus. Instead of focusing on those who discriminate or the act of discrimination itself, many researchers are beginning to look at the effect that experiencing discrimination can have on one's health. The evidence highly favors the idea that the experience of discrimination, especially because of one's race, has detrimental effects on both physical and mental health, but what has yet to be confirmed is the mechanism through which this damage occurs. This study examined how general discrimination and racial discrimination affect the neural structure of specific brain regions, including the hippocampus and the amygdala. The reason for focusing on these specific areas is because cognitive scientists have made advances in providing evidence that memory and cognition are heavily affected by discrimination, and it is theorized that this is due to the stress caused by discrimination. These areas are highly correlated with memory and emotional regulation, so it would follow that through neuroimaging techniques, it can be seen how discrimination carries out its detrimental effects on memory and cognition.

Chronic Stress and Discrimination

O'Brien (2017) established that racial discrimination is a well-established acute stressor, but the research is lacking in how it functions as a chronic stressor, one that occurs over longer periods of time. He proposed that there is value in exploring discrimination as a chronic stressor as opposed to an isolated event because chronic exposure can eventually lead to changes in neural circuitry [13]. He suggests that the anterior cingulate cortex (ACC) and prefrontal cortex (PFC) are prime areas of interest [13]. The ACC is responsible for emotional regulation and is present in both emotional and cognitive processing. The aspect of the ACC most related to this study is the process of affect regulation. Affect regulation is one of the body's processes of emotional regulation and is the mechanism by which the brain modulates one's emotions, moods, feelings, and expressions to meet the pressures of the environment and maintain emotional homeostasis [16]. The suggestion here is that the constant effort to maintain emotional homeostasis when exposed to long-term psychosocial stress will lead to neural burnout or degradation in these areas.

In a study conducted to gain a deeper understanding of resilience, coping, and stress, the plasticity and connectivity of the ventromedial prefrontal cortex (VmPFC) was examined [14]. As in previous studies, there is a strong correlation between stress and the increase in activity of regions responsible for attention and executive function, such as the VmPFC, left anterior prefrontal cortex, and dorsolateral prefrontal cortex [14]. These are all areas of the prefrontal cortex, which is responsible for executive function and decision-making processes, so these activations can possibly explain how the brain responds to mitigate stress and help guide which areas researchers should focus on examining for differences.

Finally, there has been recent research interest in the correlation between stress and its effect on memory. It is theorized that life event stress has a negative correlation with memory tasks that require higher-order processing, which would suggest that everyday stress correlates with increased age-associated cognitive decline [17]. The study conducted by VonDras does not focus on discrimination as a stressor but does serve as a building block for the idea that stress from life events, like incidents of discrimination, can lead to cognitive decline [17].

Discrimination and Health

Berger delved into the importance of understanding racial discrimination from a multifaceted approach and not relying simply on self-report measures for treatment and assessment [4]. Self-report has often been touted as unreliable because participants may lie or have a different perspective on the topic that the questions concern than the researcher prepared for. For example, it is common for many older Black Americans to not perceive an event as discriminatory while their younger counterparts would because many members of the older generation were raised to not assume those intentions in others. Berger outlined how discrimination becomes disease and, in this explanation, makes clear exactly why self-report cannot be the only measure in which researchers study racism [4]. In his explanation, he details how the hypothalamic-pituitary-adrenal axis is activated by any stressful event, even those that are unconscious to us, and this causes the release of the stress hormone cortisol [4]. An overproduction of cortisol, like in the case of chronic stress from discrimination, can be linked to numerous negative physical and mental health outcomes. This means one's brain can be affected by cortisol even when they are unconscious to the stressful event, making self-report unreliable for determining correlations between prevalence of discrimination and mental health outcomes.

Discrimination and Cognition

The theory of allostatic load is also very important for conclusions made about HPA axis activation. This is an example of the detrimental effects of over-activation that was explained previously, known as allostatic overload. Allostatic overload in the HPA axis due to racial discrimination leads to changes in brain functioning caused by the glucocorticoids and cytokines, both of which are heavily present in the prefrontal cortex, leading to the long-term negative effects seen in the hippocampus and amygdala [4]. This insight is what led to the decision to focus on these two brain regions for the study.

There have been numerous studies on racial discrimination towards people of color, but a study conducted by Coogan et al. with the Alzheimer's Association focused on Black women specifically. This study controlled for socioeconomic status and education to find a potential correlation between race and memory and examined outcomes of both daily and institutional racism [5].

There was increased risk of poor subjective cognitive function among the women who rated themselves as experiencing higher rates of institutional racism, which also seemed to be related to depression and insomnia [5]. There is a recurring theme that racism is correlated not only with these cognitive effects, but with negative mental health outcomes as well, and it would be enlightening to explore the direction or correlation between the cognitive effects and mental health outcomes. Coogan's hypothesis was correct: Black participants had lower memory scores despite only a 2% reported difference in discrimination between black and white participants [5]. This might be caused by the theory proposed earlier in Berger's research that even experiencing discrimination unconsciously can activate stress pathways that lead to cognitive decline [4].

Hypothesis

The goal of this study was to determine potential brain pathways, mechanisms, and explanations for cognitive decline seen in those who experience discrimination. This can be broken down into a two-part hypothesis.

H_0: The experience of perceived racial and general discrimination is not associated with any volume differences in the brain.

H_1: The experience of perceived racial and general discrimination is associated with a decreased volume of the hippocampus.

H_2: The experience of perceived racial and general discrimination is associated with an increased volume of the amygdala.

Methods and Materials

Participants

This study utilized archival data from the Alabama Brain Study on Risk for Dementia (ABSORD) [2]. This includes a sample of 88 participants (57 females, 31 males) from the West Alabama area [2]. The participants reported a wide variety of racial backgrounds including African American, White, Hispanic, Iranian, Multi-Racial, South Asian, and Indigenous [1]. Only 86 participants were able to participate in the structural MRI necessary for the study [1]. Participants engaged in a variety of other memory tests, cognitive tests, neuroimaging, and questionnaires that can be found on the ABSORD website, but only measures relevant to the above hypotheses were included in this study [2]. An a priori power analysis was conducted using an effect size of $\beta=.33$ from the Clark et al. study as a proxy, which indicated that 80% of the time there will be a significant effect between brain size and discrimination in a sample size of minimum 33 [6].

Measures

For this study, only participants that completed the following measures were included in the statistical analyses: Structural MRI scanning, Everyday Discrimination Questionnaire, and the Personal Work and Stress Questionnaire [10,18]. Structural MRI (sMRI) is a neuroimaging technique designed to create images of the brain that represent its anatomy. Since this study was focused on brain size, sMRI was the most compatible form of neuroimaging utilized during the ABSORD research for the goals of this study. fMRI was not used because it measures metabolic activity, which would explain brain activity, while sMRI measures anatomical structure, which correlated better with the study's interest in brain size.

The Everyday Discrimination Questionnaire

The Everyday Discrimination Questionnaire was designed by Williams to assess participants for the experience of discrimination [18]. The questionnaire is scored in three ways: by situation, frequency, and response, with answers coded on a 0 to 2 scale [11]. Kreiger found that the Everyday Discrimination Questionnaire had good internal validity ($\alpha=.74$ or higher), and there were no biases found in responses to questions from any of the racial groups [11].

Personal Work and Stress Questionnaire

The Personal Work and Stress Questionnaire was designed to assess experience of common stressors. This 20-question questionnaire from Holmgren et al. (2019) was originally established to assess work-related stress and personal stress to predict the risk of an individual taking a long-term sick leave [9]. Face validity was confirmed as well as test-retest reliability, which had a percentage agreement (PA) ranging from 55% to 99% and a 77% median [9].

SLUMS Task

The SLUMS task has 11 questions that measure orientation, memory, attention, and executive functioning [15]. The intelligence of the participants was then measured using the Wide Range Achievement Test (WRAT) 4 Word Reading subtest, which is utilized to measure reading skills of participants by gradually increasing the difficulty of words and testing the participant's pronunciation. Pronunciation was chosen for the task because it is widely used as a test for one's cognitive ability, and pronunciation is not as affected as the other skills by aging and or pathological declines in cognition [12].

Procedure

Participants were recruited through the Alabama Brain Study on Risk for Dementia. The exclusion criteria were as follows: "If they had contraindications for MRI, were left-handed, and had a prior diagnosis of any neurological condition, stroke, traumatic brain injury, claustrophobia, or history of substance abuse." [12]. The study excluded the participants without or with faulty sMRI data. Participants were recruited via flyers and online recruitment efforts in the general public of the north Alabama area.

Participants were asked to participate in several tasks. First, they were assessed using SLUMS to measure their global cognitive functioning [15]. The SLUMS task was issued to ensure that participants did not have dementia, which was an exclusionary criterion, and the WRAT was administered to establish baseline cognitive ability and exclude any abnormalities for their age in intelligence [12].

After baseline levels of intelligence and cognition were established among participants, researchers then administered an fMRI task to test memory, which included viewing images for three seconds with an intertrial period of various time intervals (1.72 s to 17.20 s) [12]. The images were a combination of seen and unseen faces and scenery that the participants were required to group into their respective categories. The second of the fMRI tasks was the fMRI checkerboard task, which was used to measure the participant's hemodynamic response function (HRF) in the occipital cortex. Measuring HRF is a method of measuring neural activity [12]. Resting state scans were taken to create a control for the study. Participants closed their eyes for five minutes during this scan but were instructed not to fall asleep. Structural MRI was taken using high-resolution T1-weighted structural MPRAGE scans on a PRISMA scanner located at UAB Civitan International Neuroimaging Laboratory [12].

Analysis

Analysis of these data included the use of Statistical Package for the Social Sciences to conduct a linear regression analysis to find the relationships between amygdala size, hippocampus size, and self-reports of racial discrimination. The analysis was separated into several parts. The first of four analyses examined whether increased incidences of general discrimination measured using the Everyday Discrimination Questionnaire were associated with decreased volume of the hippocampus. The second analysis examined whether increased incidences of discrimination measured using the Everyday Discrimination Questionnaire would predict increased volume of the amygdala. The last two linear regression models were used to analyze if increased reports of experienced racism using the single racism-specific question from the Personal Work and Stress Questionnaire were associated with lowered hippocampus volume and increased amygdala volume. Structural images were analyzed in FreeSurfer using the surface-based processing stream in version 6.0 of the program [8]. This included bias-field correction, intensity normalization, and skull-stripping (removal of extra tissues on the skull) [7]. An exploratory analysis of potential asymmetry between brain regions was conducted by calculation of an asymmetry score for the hippocampus and amygdala, which was then used in a linear regression analysis to determine if discrimination was associated with asymmetries

Table 1. Linear regression analysis: Everyday Discrimination Questionnaire [18] and brain volume and symmetry.

Variable	Estimate	*SE*	95% CI		*p*
			LL	*UL*	
Left Amygdala Volume	5.789	5.933	-6.012	17.589	.332
Total Hippocampal Volume	-.424	10.595	-21.498	20.650	.505
Amygdala Asymmetry	.002	.011	-.001	.004	.164
Hippocampus Asymmetry	.000	.001	-.002	.001	.664

Note. Total Hippocampal Volume = average volume across hemispheres; CI = confidence interval; LL = lower limit; UL = upper limit.

Table 2. Linear regression analysis: Personal Work and Stress Questionnaire [10] and brain volume and symmetry.

Variable	Estimate	*SE*	95% CI		*p*
			LL	*UL*	
Left Amygdala Volume	-10.943	39.229	-88.996	67.111	.781
Total Hippocampal Volume	-.677	10.697	-47.480	25.899	.516
Amygdala Asymmetry	.005	.008	.000	.001	.546
Hippocampus Asymmetry	.010	.005	.000	.019	.053

Note. Total Hippocampal Volume = average volume across hemispheres; CI = confidence interval; LL = lower limit; UL = upper limit.

in the regions of interest. All models were controlled for age, gender, and education with the inclusion of age, sex, and years of education as covariates. All brain regions were normalized using the total intracranial brain volumes for each participant.

Results

Hypotheses were not supported by the analysis. Higher self-reported incidence of discrimination was not associated with decreased hippocampal volume or increased amygdala volume (**Table 1**). Exploratory analysis of the relationship between self-reported incidences of racism and discrimination collected via the Everyday Discrimination Questionnaire and the Personal Work and Stress Questionnaire and brain symmetry also yielded nonsignificant results (**Table 2**). Eight participants were excluded from the analysis due to insufficient structural MRI data.

Discussion

There are a few potential explanations for the lack of significant results in any of the analyses. Participants rated their experiences of discrimination and racism low. As seen in **Table 3**, no participant scored higher than 27 out of 60

Table 3. This table outlines the frequency of scores on the Personal Work and Stress Questionnaire for the single racism question for included participants.

Personal Work and Stress Questionnaire; Single Racism Question Scores

		N	%
1		65	74.7%
2		13	14.9%
3		7	8.0%
4		1	1.1%
Missing	System	1	1.1%

when self-reporting their experience of discrimination on the Everyday Discrimination Questionnaire. 74.7% of participants rated their experience of racism via the Personal Work and Stress Questionnaire as low, a score of 1, and the highest score on the measure was 4 (**Table 3**). The sample was 61.7% White, which was not ideal given this study's aims, but the umbrella of the racial term White can encompass a wide variety of ethnicities and cultural backgrounds not specified in the selection choices [1]. This means the demographic of participants used for the analyses may not have been a good fit for examining this question. There is also a chance that self-report measures were unreliable, as explained by Berger [4]. Participants may have experienced a subtle bias or discriminatory event that was unconsciously processed by their brain's stress response but was not reported in any of the measures.

While standard deviation between brain regions was high, indicating variance from the mean, this could be due to age-related effects instead of those proposed in the hypothesis. The ages of participants included in the study ranged from 20 to 74, but with a lack of middle-aged participants. Sex could also be the cause for brain-related differences, as 60.7% of participants were female. Despite the lack of significant results, future studies in a larger and more diverse sample could prove to be enlightening in understanding how psychosocial stressors affect individuals on a neural level.

Table 4. This table outlines the frequency of scores on the Everyday Discrimination Questionnaire for included participants.

Everyday Discrimination Questionnaire Scores

	N	%
8	13	14.9%
9	2	2.3%
10	10	11.5%
11	6	6.9%
12	9	10.3%
13	7	8.0%
14	7	8.0%
15	4	4.6%
16	10	11.5%
17	6	6.9%
18	2	2.3%
19	4	4.6%
21	1	1.1%
22	3	3.4%
24	2	2.3%
27	1	1.1%

Conclusion

While this sample was not fit for determining the effect of discrimination on the volume of the brain regions of interest, it did provide evidence of detrimental health outcomes from experiencing discrimination as well as providing a solid basis for future studies. If volumetric changes are not the causal factor for the cognitive decline seen in those who report experiences of discrimination, the results of this study could lead research in another direction.

Table 5. This table summarizes the descriptive statistics for the dependent variables in the regression analysis.

Brain Regions of Interest Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Normalized Left-Hempishere Amygdala Volume	87	708.50	1845.86	1242.3471	234.75585
Normalized Total Hippocampus Volume	87	2341.18	4619.11	3290.5282	413.92414
Amygdala Volume Asymmetry Scores	87	-.59	-.36	-.4569	.05000
Hippocampus Volume Asymmetry Scores	87	-.15	.01	-.0659	.03010
Valid N (listwise)	87				

Poor sleep and depression have long been linked to poorer cognition, and this may be the mechanism through which psychosocial stress causes a decline in cognition. Since these results were quite broad, future research should focus on what types of discrimination cause the effects seen on sleep and depression symptomology.

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The Effect of Resistant Starch Consumption on Appetite and Satiety of Prediabetic, Overweight, and Obese Adults

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Resistant starch (RS) in the diet may provide beneficial effects on individuals trying to lose weight. The aim of this review was to collect data from multiple primary research studies to determine if RS can affect appetite and satiety in prediabetic and overweight/obese adults. Multiple randomized crossover studies, randomized intervention studies, and parallel arm trials were examined in this review. Through the research of six studies, results showed inconclusive evidence that RS has significant effects on appetite, hunger, food intake, and satiety biomarkers in either type of individuals. It was concluded that further studies must be completed in order to further evaluate the effect of RS on food intake and possible weight loss.

Abbreviations: *RS, resistant starch; VAS, visual analog scales; PYY, peptide YY; GLP-1, glucagon-like peptide*

Introduction

According to the Centers for Disease Control and Prevention (CDC), an overweight adult is defined as an individual above 18 years of age who falls within a BMI range of 25-29.9 kg/m^2 [5]. They define an obese adult as an individual over the age of 18 with a BMI of 30 kg/m^2 or above. The number of overweight and obese individuals has been steadily growing not only in the United States, but also throughout the world. Between 1990-2020, obesity rates for adults around the world rose by 27.5%, mainly due to the growing prevalence of sedentary lifestyles and the rise of fast food popularity. Because of this progressing epidemic, scientists and researchers have been trying to focus their attention on stopping the exponential growth of weight gain. This goal is imperative, as overweight and obese individuals have an increased risk of certain comorbidities such as diabetes, hypertension, and cardiac disease. These comorbidities have been tied to factors such as exercise, environmental change, and, most importantly, diet. Epidemiological studies have shown a strong association between consuming inadequate amounts of fiber in the diet and substantial weight gain; therefore, inadequate intake of fiber may contribute to weight gain and the obesity epidemic. Due to this correlation, researchers have been investigating if increasing dietary fiber may help reduce the percentage of obese and overweight adults. Unfortunately, many public research studies have received mixed results on if an increase in fiber is beneficial in lowering obesity rates. One approach that scientists have used has been to narrow down their research to a certain type of fiber, such as resistant starch (RS) [1].

RS is characterized as a type of fermentable fiber, or a portion of starch that is not easily digestible [1]. This starch is not digested by amylase in the intestines and moves onto the colon to be fermented by the gut microbiota. Additionally, RS contains fewer calories than typical starches. These two distinct characteristics of RS suggest that RS consumption may aid in the reduction of obesity rates. Consuming fewer calories by replacing normal starch with RS may lead to a reduced caloric intake and possible weight loss. On the other hand, the gut hormones that impact satiety cues are signaled by the absorption of nutrients in the small intestine. Since RS is not involved in the metabolic processes of the small intestine, it may increase satiety and decrease appetite and hunger.

Current research on the impact of RS on appetite and satiety regulation is controversial, and whether RS is beneficial in fighting the obesity epidemic has been highly debated [1]. Based on this, the central aim of this mini-review analysis was to examine the effects of RS on appetite and satiety in prediabetic and overweight/obese adults. In addition, other parameters related to appetite and satiety, such as gut hormones and the stimulation of insulin post dietary consumption, are also discussed.

Methods

PubMed, Medline, and Web of Science were systematically searched to obtain recent and relevant studies pertaining to RS's influence on appetite and satiety. Articles were included in this study if they were published in English between 2018 and 2021 in peer-reviewed journals. A final list of relevant works was gathered by the authors for further review. To be included in this review, selected studies must have consisted of randomized placebo studies that investigated RS and its influence on one or more of the following outcome measurements: subjective appetite, subjective satiety, energy or dietary intake, and appetite biomarkers such as glucagon-like peptide 1 (GLP-1) or peptide YY (PYY). Further inclusion criteria were studies that were conducted on a minimum of five humans that were at least 18 years of age. Studies were excluded from this review if they met these exclusion criteria: studies focused on dietary fibers other than RS, animal studies, trials that recruited children under 18, and abstracts not posted in peer-reviewed journals. Keywords such as resistant starch, obesity, appetite, and satiety were all included in each research study. The assessment was conducted by authors independently, and different opinions were resolved until reaching group consensus. For each selected article, the authors independently extracted information including study design, number of participants, intervention and dosage, independent and dependent variables, and outcome measurements. As a result of this research, standard deviations and statistical values based on subjective appetite and satiety ratings were pulled from six suitable primary research studies. Results were also organized into **Table 1**.

Results and Discussion

Effects of RS in Prediabetics

Prediabetes is a serious medical condition that has been continuously growing in the American population. This medical condition is the precursor to a condition known as Type 2 diabetes mellitus. According to the CDC, around one in three American adults has been diagnosed with prediabetes [2]. This sudden increase in prediabetic numbers has risen due to the obesity pandemic. To help limit the increase in prediabetic adults, researchers have used RS to try and curb appetite and hunger. Unfortunately, the studies researching this topic report that RS does not increase satiety levels nor decrease appetite, hunger, and fullness in adults with confirmed prediabetes [3,4].

White et al. (2018) tested the influence of RS on prediabetic individuals' appetite and food intake [4]. This study recruited 68 participants aged between 35-75 years old with a diagnosis of prediabetes and a BMI over 27 kg/m^2. Each participant in this randomized intervention study was randomly selected to receive the treatment (45 g/day of RS2) or the placebo (regular starch) for 12 weeks. Food intake and appetite were measured through food intake tests, photography of meals before and after, and visual analog scales (VAS). It was noted after the end of the 12 weeks that there was no significant effect on either food intake or VAS values. Within the VAS values, hunger ($p=0.25$) and fullness ($p=0.86$) were not significantly changed compared to the control group. It was concluded that RS did not affect appetite or food intake in prediabetic adults.

A similar study was conducted by Marlatt et al. (2020), where the role of RS on risk factors associated with diabetes in prediabetic patients was examined [3]. The researchers recruited 59 prediabetic patients between 35-75 years old with a BMI over 27 kg/m^2. This 12-week study conducted measurements on appetite, fullness, hunger, food intake, and disinhibition in participants using both the VAS and intake photography. To test

Table 1. Studies investigating the effects of RS in prediabetic or overweight/obese adults.

Authors	Study Design	Intervention		Study Participants			Outcome Measurements		
		RS source & amount	Duration	Sample Size	Gender	Age Range	Energy Intake	Hormones	Subjective appetite of Satiety (VAS)
White et al. (2018)	Randomized Intervention	RS2 (45g)	12 weeks	N=68	M-34 F- 34 Prediabetic	35-75 y	No sig. difference	N/A	No sig. difference
Marlatt et al. (2020)	Randomized Parallel Arm	RS2 (45g)	12 weeks	N=59	M-30 F- 29 Prediabetic	35-75 y	No sig. difference	No sig. difference	No sig. difference
García-Vázquez et al. (2019)	Single Blind Randomized Crossover	Banana Starch (20g) HAMS (33.3g)	3 separate days	N=14	M-7 F- 7 Overweight /Obese Subjects	18-30 y	N/A	N/A	Banana Starch: Appetite ↓ ($p=0.006$) Satiety ↑ ($p<0.05$) HAMS: Appetite ↓ ($p=0.006$) Satiety ↑ ($p=0.036$)
Sanders et al. (2020)	Randomized Crossover	Yukon Gold Potatoes (19g)	2 separate days	N=19	M-9 F- 10 Overweight /Obese	18-74 y	No sig. effect	N/A	No sig. effect on hunger, desire to eat, and prospective food intake Satiety ↑ ($p=0.02$)
Vetrani et al. (2018)	Randomized Crossover	High Amylose Wheat Flour (7g)	2 separate days N=10	N=10	M-5 F- 5 Overweight /Obese	34-58 y	No sig. effect	N/A	Desire to eat ↓ ($p<0.05$) No sig. effect on hunger, satiety, or prospective food intake
Al-Mana et al. (2018)	Randomized Crossover	RS2	2 separate days	N=10	M-10 F- 0 Overweight /Obese	18-32 y	Intake ↓ at dinner ($p=0.017$)	No significant effect	No sig. effect

the effects of RS, Marlatt provided half of the participants 45 g of RS (amylose) per day. The other half of the participants received solely 45 g of amylopectin per day (control). After 12 weeks, the study concluded that RS did not have a significant effect on hunger and satiety in prediabetic participants. Additionally, measures such as hunger (p=0.45), satiety (p=0.33), food intake (p=0.30), and appetite-related hormones such as Ghrelin (p=0.47) were not significantly changed in the RS group compared to the control group. However, it was found that disinhibition had a statistically significant increase (p=0.03) in female prediabetic patients who were given the RS treatment.

These two studies both concluded that replacing regular dietary starch with RS in prediabetic patients had no effect on appetite, hunger, and satiety. Researchers also found that with some patient populations, mainly female, disinhibition rose as participants often complained of wanting to overeat more when given the RS treatment. This may be due to the fact that some RS bypasses the small intestine without digestion, which may reduce the influence of satiety cues in one's gut. Furthermore, both studies recruited participants with the same age range (35-75 years old) and gave the same amount of RS treatment (45 g/day for 12 weeks). Therefore, further studies with different treatment variables and time frames are warranted to determine whether RS could affect appetite and satiety in prediabetics. Additionally, further research should be conducted to investigate which type of RS presents better regulatory effects on appetite and satiety in prediabetics, as amylose RS saw greater disinhibition effects compared to the RS2 in the White study. This distinction might help to narrow down research and provide stronger recommendations for the public.

Effects of RS in Overweight/Obese Adults

Researchers have investigated if adding RS into an obese or overweight person's diet will help to decrease weight gain or even help to increase weight loss. In a study conducted by García-Vázquez et al. (2019), the researchers conducted a single-blind, randomized cross-over study on 14 obese/overweight volunteers aged between 18-30 years old and with a BMI over 25 kg/m^2 [6]. Volunteers were randomly selected to receive each of the three different clinical treatments: 20 g/day of native banana starch (NBS), 33.3 g of high amylose maize starch (HAMS), and 0 g of RS in digestible maize starch. Each treatment period was conducted over 24 hours and was followed by a one-week washout period before the next treatment date. Appetite was assessed using a VAS scale at the end of every study period.

Through the data analysis of the VAS answers, García-Vázquez determined that there was no significant effect on appetite with either the NBS or the HAMS intervention. Hunger sensations and appetite were significantly lower 60 minutes after the HAMS treatment compared to the NBS and the DMS treatment group (p=0.006). Additionally, satiety sensations were significantly higher in the HAMS treatment compared to the other two intervention groups (p=0.036). Comparatively, there was no significant difference in the fullness of the participants for any treatment group (p>0.05). Overall, participant hunger, appetite, and satiety were significantly higher in all treatment cases (p<0.0001). It was concluded that RS, specifically HAMS, did affect appetite in obese/overweight adults and should be further examined for weight loss.

Most other studies on this topic, however, found either inconclusive evidence or results indicating that RS did not help to decrease appetite or increase satiety in their overweight/obese adult volunteers. One of those studies, conducted by Sanders et al. (2020), examined the influence of RS on insulin sensitivity, metabolic markers, and appetite ratings [7]. Sanders conducted this pilot randomized cross-over trial in overweight/obese individuals who were at risk for diabetes due to their weight. Nineteen adults between the ages of 18-74 who had a BMI of 27-39.9 kg/m^2 with a waist circumference >89 cm for women and >102 cm for men participated in this study. Each participant was randomly provided one intervention each week during the two-period study with a 1-week washout period in between. Both treatment weeks consisted of breakfast meals with no RS added. The two interventions consisted of a lunch and dinner meal of 300 g of Yukon Gold potatoes a day (19 g RS) and a similar energy concentration, carbohydrate-based meals for the control (1 g RS). VAS was used to score appetite, satiety, hunger, desire to eat, and prospective food consumption. VAS scores were taken five minutes pre-intervention and at 30-minute intervals from 30-300 minutes post-breakfast on the day after the intervention. Energy intake was logged through meal journals and calorie counting.

Through VAS assessments, it was discovered that hunger ($p=0.150$), prospective energy consumption ($p=0.064$), and desire to eat ($p=0.221$) were not significantly lower in the RS group compared to the control element. Despite this, satiety levels were significantly decreased in the control compared to the RS intervention ($p=0.002$). Energy intake from the three-day food diary concluded that there was no significant difference between the RS intervention and the control ($p=0.392$). Due to these results, Sanders deduced that limited significant effects from RS were seen for appetite and satiety. Despite these results, further tests are necessary due to this research being a pilot study on Yukon potato RS.

Similar to this study, Vetrani et al. (2018) also tested for the influences of RS on appetite and food intake suppression in overweight adults [8]. Ten non-diabetic yet overweight/obese adults were recruited for this study. The individuals that were included were 34-58 years old with a BMI mean of 30+ kg/m^2, fasting glucose under 100 mg/dl, cholesterol under 172 mg/dL, and triglycerides under 77 mg/dL. They were studied on two separate occasions at least 1 week apart. Participants were divided into two groups where they either consumed a 130 g meal with 7 g of amylose-rich wheat flour or one 117 g control meal with only conventional wheat flour. Appetite ratings through VAS logs were taken at 30-minute intervals between 30-240 minutes after the intervention. Dietary 24-hour recall was used to test food intake. During these tests, the researchers discovered inconclusive evidence. During the VAS postprandial questionnaires, individuals showed a significant decrease in the desire to eat after four hours of the meal ($p<0.05$). Comparatively, there was no significant difference between the two groups for hunger, satiety, or prospective food intake ($p>0.05$ for all). It was concluded that the use of RS may be useful in reducing the desire to eat, but overall may not help obese individuals.

To further test the acute effects of RS on food intake, appetite, and satiety, another crossover study was completed by Al-Mana et al. (2018) with 10 obese/overweight males [9]. The individuals that were included were 18- to 32-year-old males with a BMI within 28-37 kg/m^2, fasting glucose under 6 mmol/L, hemoglobin over 13 g/dL, no history with gastrointestinal disorders or endocrine disorders, and had a stable weight for three months prior to the study. Individuals were studied on two separate occasions with at least 1 week apart. Participants were divided into two groups where they either consumed 80 g of RS or 32 g of the placebo that was incorporated throughout breakfast and lunch meals for each test day. Blood samples of GLP-1 were taken 15 minutes before breakfast and right before breakfast at time 0. Lunch was served at 180 minutes. At 420 minutes, a large ad libitum meal was provided to test for food intake post-intervention. Appetite ratings through VAS logs were taken at 30-minute intervals between 30-240 minutes after the intervention. Dietary 24-hour recall was used to test food intake. Statistical analysis was completed through AUC tests for GLP-1 and through ANOVA and paired t-tests for VAS scores. During these tests, the researchers saw no evidence that RS affects appetite. Energy intake in the RS group did not show a significant difference compared to the placebo ($p=0.508$). Additionally, VAS scores did not show any significant differences in appetite, satiety, prospective food consumption, and hunger ($p>0.05$ for all) between the RS and control groups. Due to these conclusive data points, Al-Mana concluded that RS may have short-term benefits on appetite, but it did not change blood biomarkers for appetite nor satiety significantly. Trends would need to be further analyzed over time.

These four studies, when combined and analyzed together, have run inconclusive results on whether RS should be used to help decrease appetite and increase satiety and fullness in overweight/obese individuals. Each intervention study provided participants with different amounts and types of RS for different durations of time. The three-session-long study, such as the one conducted by García-Vázquez, concluded that over time, RS was helpful with decreasing appetite [6]. Comparatively, the shorter two-period-long studies of Sanders, Vetrani, and Al-Mana resulted in the conclusion that RS had little to no effect on overweight/obese adults' appetite or hunger [7,8,9]. This pattern must be investigated in future studies. Longer studies, even by just one study period, seem to show more effects of RS in regulating appetite, satiety, and energy intake compared to the shorter studies. Researchers should attempt to conduct longitudinal studies in the future to truly compare RS interventions and their effects on appetite.

Conclusion

This mini-review was designed to determine the effects of RS on appetite and satiety in prediabetic and overweight/obese adults. Evaluations of VAS, which depicted subjective appetite, desire to eat, hunger, and fullness, along with satiety blood markers of GLP-1 and PYY hormones, were used in adult participants. Assessments of these values suggest that RS may help to slightly lower appetite in healthy adults. However, there is mainly inconclusive evidence that describes whether RS significantly affects subjective appetite and satiety in both prediabetic and overweight/obese adults. Results throughout the studies often contradicted each other, and there is not enough evidence to support the use of RS in overweight/obese and prediabetic adults. Mechanisms of the amount of RS needed to elicit a response and its specific metabolic response remain undetermined. Further investigations regarding the source, amount, and duration of the RS intervention to cause a clinically-significant effect are warranted. With the expected rise of the obesity epidemic and subsequent experimental studies on RS and its effect on appetite and satiety, it is imperative to consider the way the nutrient is delivered and for how long. Additionally, further research using a longitudinal study design may improve results and provide more conclusive and definitive answers than two-day crossover trials.

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How Well Do Mothers' Judgments About Their Smartphone Use Correspond to Their Actual Use?

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The typical mother's cell phone use is high and trending upward, leading to the potential for a myriad of adverse effects. This study explored how closely a mother's judgments of her own smartphone use corresponded to real usage patterns. A demographic survey and a technology questionnaire were used to gather information from a sample of 96 mothers with two- to four-year-old children. Real-time usage statistics were taken from an application on each mother's smartphone designed to monitor usage activity. Results indicated that mothers who judged their phone use to be high did not actually log more daily screen time compared to other mothers. However, they did pick up their smartphones more, receive more notifications, and were more likely to have mother-child interactions interrupted. Overall, it was found that mothers' judgments of their smartphone use sometimes, but not always, corresponded to their actual usage patterns.

Introduction

Smartphones have become increasingly integrated into everyday activities. This integration has introduced tremendous benefits to individuals in terms of information access, health monitoring, social and professional communication, and entertainment. However, smartphone overuse, particularly social media overuse, has been shown to pose a significant risk to the physical and mental health of both adolescents and adults (e.g., heightened rates of suicide; anxiety; depression; sleep deprivation; low self-esteem; loss of identity; eye strain; cyberbullying; addiction; neck, back, and hand pain; car accidents; etc.) [2,5,6,7,20,24,26,28]. Due to these risks, it is important for individuals to understand their own patterns of smartphone use and whether they might be prone to overuse. The research community is working to identify the best tools for assessing smartphone use and the best indicators of overuse (i.e., excessive or "problematic" smartphone use) [9,27]. However, even in the absence of these tools, individual users make personal judgments about how much they use their smartphones and whether they may be overusers. For example, in one survey, about half of respondents (47%) considered themselves "addicted" to their smartphones, and an even higher percentage (56%) reported that they overuse technology [29]. The primary question in the current study was how closely an individual's actual patterns of smartphone use matched subjective judgments of their use. Mothers of young children were chosen as the study's target population because their overuse has the potential to negatively affect both themselves and their children [14,15].

Technology is prevalent in our everyday lives—the average family has five internet-connected devices in their home [1]. Further, 95% of U.S. adults between the ages of 18 and 49 own a smartphone [16]. Technology use, including smartphone use, is also pervasive—the average American adult spends 8-10 hours a day using digital media and touches their smartphone more than 2,600 times per day on average [25,30]. Adults, on average, are estimated to spend between four and five hours each day on their phones. This not only represents an increase from previous years, but it leads to the expectation that this trend will grow in the coming years [31]. Rather than occurring all at once or in a few extended episodes, smartphone use tends to be spread out across the day with 70% of episodes lasting less than two minutes and only 5% lasting more than 10 minutes [32]. This pattern is also reflected in the sheer number of times that adults check their smartphones: nearly 100 times/day, with young adults aged 18 to 24 approaching twice that number [3]. In fact, research suggests that we interact with our smartphones about once every 5 minutes [10]. Notifications can be one cause for adults picking up or unlocking their smartphones; adults receive between 45 and 80 notifications per day [8]. However, research suggests that 89% of pickups are initiated by the user and not by a notification [10]. This data suggests that we spend significant amounts of time on our smartphones and that they can be an ongoing source of distraction or interruption throughout the day [4,11].

Smartphone use, especially overuse, is associated with physical and mental health problems. In terms of physical health, increased smartphone use in adults corresponds to more headaches, restlessness, tinnitus, and neck and back pain [23]. It can also lead to increased blue light exposure, which is associated with sleep problems as well as short-term eye pain and long-term eye problems [5]. Overuse has also been linked to a myriad of mental health issues such as depression, anxiety, and low self-esteem [13,28]. Many of these share an especially strong link with increased social media usage and the social isolation which can accompany it. For example, using TikTok and Snapchat is associated with an increased risk of developing depression for adults over 35. In contrast, using Facebook is associated with an increased risk among adults under 35 [17]. These general adult patterns play out in subsets of adults, too. For example, mothers who exhibit higher levels of smartphone use also report higher levels of depression and stress, and mothers who report increased social media use (e.g., Facebook, Instagram, etc.) are vulnerable to the same mental health risks as the rest of the population [12,13,17].

However, one unique aspect of a mother's smartphone use is that it has the potential to negatively affect both her health and the health of her young children. For example, mother-child interactions are less frequent, of lower quality, and shorter when interrupted by technology use, something researchers have dubbed "technoference" [14,19]. Due to the accessibility of smartphones, interruptions can happen anywhere at any time, and they can be initiated by either the parent or the device. This poses a constant threat to the quality of mother-child interactions. For example, parents can spend as much as about half of their time at family dinners on their smartphones and are often "absorbed" in their devices [18]. Furthermore, absorbed parents often react harshly when the child tries to engage the parent. Perhaps then it is not surprising that parents who perceived their phone use as too much or who reported higher incidence of interruptions from their smartphone use also reported more problem behaviors (e.g., tantrums) from their three-year-olds [15].

The main research question in this study focused on how well mothers understand their smartphone use, given the risks associated with smartphone overuse on the mother and the child. The study examined whether mothers' subjective judgments about their smartphone use corresponded to their actual patterns of use. There is reason to believe they might not. For example, among adults who averaged more than five hours of smartphone use per day, 80% believed they were below the national average, suggesting that many adults do not have accurate perceptions of their use or do not understand how much the average adult uses their smartphone [22]. In either case, smartphone use in the average adult far exceeds the recommended amount of less than 2 hours of screen time per day (outside of work), and this discrepancy needs to be better understood [21].

Methods

Participants

96 adult women participated in this study. Each was the mother of a child between the ages of two and four years old. Mothers were recruited from the Tuscaloosa, AL and Birmingham, AL areas. 78 (81%) were married, 5 (5%) were divorced, and 13 (14%) had never been married. 82 (85%) were part of a two-parent home, whereas 14 (15%) were part of a single-parent home. In terms of race, 67 mothers (70%) identified as White, 18 (19%) identified as Black, and 11 (11%) identified as Asian,

Demographics	N	Percent
Marital Status		
Married	78	81%
Divorced	5	5%
Never Married	13	14%
Household		
Two-Parent Home	82	85%
Single-Parent Home	14	15%
Race		
White	67	70%
Black	18	19%
Other	11	11%
Education		
Masters (or Higher)	30	31%
College Degree	30	31%
High School/GED	34	34%
Some High School	2	2%
Household Income		
$100,000+	32	33%
$50,000-$100,000	36	38%
$25,000-$50,000	15	15%
>$25,000	13	14%

Figure 1. Summary of the participants' demographics.

Hispanic, American Indian, or other. In terms of education, 30 mothers (31%) earned a master's degree or more as their highest degree, 30 (31%) earned a college degree as their highest degree, and 34 (35%) earned a high school degree or GED as their highest degree. Two mothers did not finish high school. In terms of income, 32 mothers (33%) reported household incomes of $100,000 per year or higher, 36 mothers (38%) reported household incomes between $50,000 and $100,000 per year, and 28 mothers (29%) reported household incomes of less than $50,000 per year. Within this latter group, 13 mothers (14%) reported household incomes of less than $25,000 per year, placing their family below the poverty line. The median income range was $60,000-$70,000.

Measures

Demographic Survey

Mothers answered questions about themselves and their households, including their marital status, family structure, race, education level, and household income. For marital status, mothers were asked: "What is your marital status," with never married, married, widowed, or divorced as options. For family structure, mothers were asked: "What is your family structure," with two parents at home, single parent at home, or non-parent adult at home as options. For race, mothers were asked to report their "race/ethnicity" from 13 different options including "other." For education level, mothers were asked to report their "highest level of education obtained," with seven options ranging from less than high school (lowest option) to graduate/professional degree (highest option). For household income, mothers were asked to report their family's "average yearly income, before taxes," with 12 options ranging from below $15,000 per year to over $100,000 per year, with each option increasing by $5,000 or $10,000 over the previous option (e.g., $30,000-$39,999/year, $40,000-$49,999/year, etc.). **Figure 1** summarizes the demographics of the participants.

Technology Questionnaire

Mothers answered questions about their technology use, with an emphasis on smartphone use. Questions focused on mothers' perceptions of their smartphone use and actual usage statistics. In terms of perceptions of use, the study focused on four critical items from the questionnaire. For the first three items, mothers were asked to report their level of agreement, ranging from strongly disagree to strongly agree on a 5-point scale, with different statements probing their smartphone use. Those statements were: "I feel like I use my mobile phone too much," "When my mobile phone alerts me to indicate new messages, I cannot resist checking them," and "I often think about calls or messages I might receive on my mobile phone." For the fourth item, mothers were asked to estimate how often their mother-child interactions were interrupted by their smartphone: "On a typical day, about how many times does your smartphone interrupt a conversation or activity you are engaged in with your child?" In terms of actual use, an app (Screen Time for iOS phones and Digital Wellbeing for Android phones) was used for the acquisition of daily usage statistics (e.g., pickups, notifications, daily minutes, minutes per app, etc.) For iOS users, "pickups" indicate how many times the smartphone is picked up throughout the day. For Android users, the corresponding measure is called "unlocks." Users of both operating systems can also view the number of daily notifications they receive. Notifications include text messages, emails, and alerts. Both systems also track total daily minutes of device usage. This total can be further broken down by individual apps (e.g., using Instagram for 90 minutes and Twitter for 30 minutes on Monday).

Procedure

Mothers and their two- to four-year-old children were recruited to participate in a larger study examining mother-child interactions. Mother-child dyads visited the study's research facility in Tuscaloosa or the testing location in Birmingham, completed a series of measures and tasks, and engaged in a 10-minute free play session. As part of the study, mothers completed both the Demographic Survey and the Technology Questionnaire. These measures were administered via Qualtrics, an online survey tool. In most cases, mothers completed these two measures along with the other survey-based measures on an iPad in a quiet waiting area. In some cases, particularly during COVID testing protocols, mothers were sent a link to the full survey and completed the two measures on their own device (i.e., smartphone, computer, etc.) in their free time before arriving at the testing site. When the full testing session was finished, mothers were given a $25 gift card for their participation. Because some of the data collection occurred during the COVID pandemic, experimenters and participants wore masks when in close proximity to each other. Additionally, all study spaces and materials (i.e., iPads, etc.) were sterilized upon session completion.

Results

The primary questions in this study were related to how well mothers' judgments about their smartphone use matched their actual patterns of use. These questions were addressed by examining three specific items from the Technology Use Survey and data from screen time apps on the mothers' smartphones. The results included some basic descriptive statistics about mothers' smartphone use from the survey and data from the actual research questions.

Descriptive Statistics

On average, mothers spent more than four hours a day on their phones. Their four most frequently used apps totaled an average of 223 minutes a day (3 hours and 45 minutes). The most common app, Facebook, accounted for 90 minutes per day. On average, mothers picked up their phones 82 times per day (once every 12 minutes while they were awake), and they received 107 notifications per day (or approximately one every 13 minutes throughout a 24-hour period). Furthermore, 68 of the 96 mothers (71%) agreed that it was hard to resist checking their smartphone, which is 3.5 times the number of those that agreed they could resist checking their smartphone. Half of mothers also said they thought about calls or messages that they might receive. Perhaps most significantly, 79 of the 96 mothers (82%) said they used their phone too much. Nearly all mothers (95%) said that conversations or activities with their child are interrupted every day by their smartphones. In fact, 6 in 10 said they were interrupted more than 5 times per day, and 1 in 4 reported they were interrupted more than 10 times per day.

Research Questions

First, it was examined whether mothers who agreed with the statement that they used their smartphones "too much" would display more overall phone use compared to those who disagreed with the statement as indicated by their daily pickups, notifications, total minutes, and social media minutes. For each outcome, an independent sample t-test was conducted comparing mothers who agreed with the statement to mothers who did not. For pickups, mothers who agreed ($M=76$) averaged 31 more daily pickups than mothers who disagreed ($M=45$), a difference that was statistically significant, $t(91)=2.18$, $p=.032$ (see **Figure 2**). For notifications, mothers who agreed ($M=101$) averaged 42 more daily notifications than mothers who disagreed ($M=59$), a difference that was marginally significant, $t(92)=1.71$, $p=.09$ (see **Fig. 2**). For total daily minutes, mothers who agreed ($M=208$) averaged 99 fewer total minutes per day than mothers who

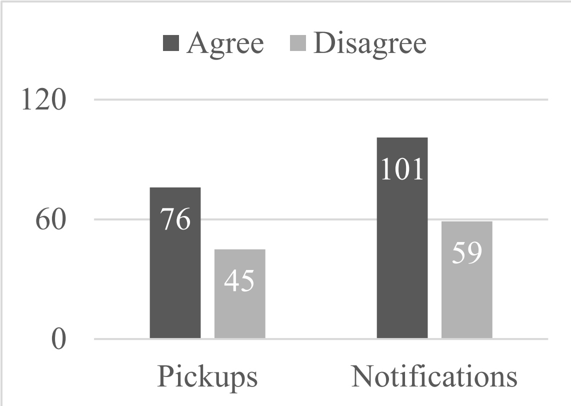

Figure 2. Daily pickups and notifications for mothers who agreed or disagreed that they use their smartphone "too much."

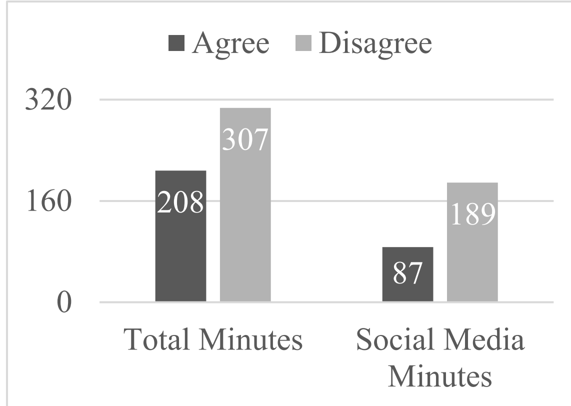

Figure 3. Daily total minutes and social media minutes for mothers who agreed or disagreed that they use their smartphone "too much."

disagreed (M=307), a difference that was marginally significant, t(84)=1.78, p=.078 (see **Figure 3**). For daily social media minutes, mothers who agreed (M=87) averaged 102 fewer minutes per day than mothers who disagreed (M=189), a difference that was statistically significant, t(76)=3.28, p=.002 (see **Fig. 3**). Overall, these results suggest that mothers' opinions about whether they use their smartphones "too much" are supported by the number of times they pick up their smartphones each day and the number of daily notifications they receive. However, their opinions are not consistent with their overall daily use and social media use. In fact, mothers who agree that they use their smartphones too much actually use them far less, on average, than mothers who do not agree. However, when social media minutes were removed from the overall daily minute totals, mothers who agreed with the statement (M=107) did not differ from mothers who disagreed (M=122), p=.882, suggesting that differences in daily social media use account for the overall difference in total usage.

Second, the study examined whether mothers who agreed with the statement that it is hard to resist checking their smartphones would display more checking behavior in the form of pickups and notifications. Again, an independent samples t-test comparing mothers who agreed with the statement to mothers who did not was used. For pickups, mothers who agreed (M=78) averaged 26 more daily pickups than mothers who disagreed (M=52), a difference that was statistically significant, t(91)=2.14, p=.035 (see **Figure 4**). For notifications, mothers who agreed (M=101) averaged 28 more daily notifications than mothers who disagreed (M=73), a difference that was not significant, p=.185 (see **Fig. 4**). These results suggest that mothers' opinions about whether they can resist their smartphones are supported by the number of times they pick up their smartphones each day. Notification data provides a murkier picture. There was an obvious magnitude difference between the number of notifications received by mothers who agreed with the statement and the amount received by mothers who did not, but this difference was not statistically reliable.

Third, it was examined whether mothers who agreed that they think about calls or messages they might receive display an increased checking behavior, in the form of pickups and notifications. Again, an independent samples t-test comparing mothers who agreed with the statement to mothers who did not was used. For pickups, mothers who agreed (M=68) averaged 5 fewer daily pickups than mothers who disagreed (M=73), a difference that was not significant, p=.644 (see **Figure 5**). For notifications, mothers who agreed (M=89) averaged 8 fewer daily notifications than mothers who disagreed (M=97), a difference that was also not significant, p=.688 (see **Fig. 5**). These results suggest that mothers' opinions about whether they think about calls or messages

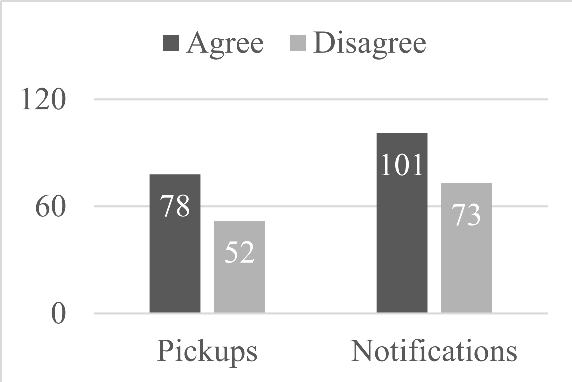

Figure 4. Daily pickups and notifications for mothers who agreed or disagreed that "it was hard to resist checking their smartphone."

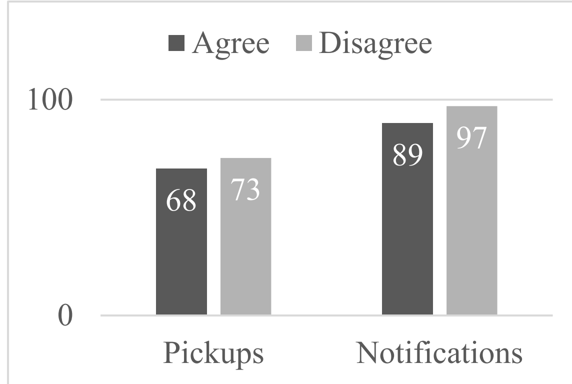

Figure 5. Daily pickups and notifications for mothers who agreed or disagreed that "they think about calls and messages they might receive."

they might receive have no bearing on whether they pick up the phone more frequently or on whether they receive more notifications.

Finally, the study also asked a secondary question in this study about whether mothers' opinions about their smartphone use might affect quality interactions with their children. This question was addressed by examining the same three items from the Technology Use Survey and their relationship with a fourth item, on which mothers answered the secondary question by estimating how often their smartphone use interrupted activities with their child. Independent samples t-tests were used to compare mothers who agreed with the statements to mothers who did not. Regarding using the smartphone "too much," mothers who agreed ($M=5.5$) averaged over 3 more daily interruptions than mothers who disagreed ($M=2.4$), a difference that was statistically significant, $t(94)=4.11$, $p<.001$. Regarding the difficulty "resisting" checking their smartphones, mothers who agreed ($M=5.4$) averaged over 1.5 more daily interruptions than mothers who disagreed ($M=3.7$), a difference that was statistically significant, $t(94)=2.63$, $p=.01$. Regarding "thinking" about calls and messages they might receive, mothers who agreed ($M=5.9$) averaged over 1 more daily interruptions than mothers who disagreed ($M=4.2$), a difference that was statistically significant, $t(94)=2.85$, $p=.005$.

Discussion

Overall, the participants in the study, like most American adults, spend significant parts of each day using their smartphones. Mothers averaged approximately four hours per day of smartphone use, with over half of this time accounted for on social media apps like Instagram and Facebook. They also picked up their phones an average of 82 times per day, and they received on average more than 100 notifications per day. Each of these statistics falls near or above the corresponding national average. This level of use can be problematic, both for the mother and potentially for the child. There was some evidence of this: 71% of mothers reported having trouble resisting the urge to check their smartphones, and 82% agreed that they use their smartphone too much. According to these subjective judgments, mothers in this study communicated clearly that they felt susceptible to overusing their smartphones. However, these judgments only sometimes matched their actual patterns of phone use.

First, it was determined that mothers who judged that they use their phone "too much" picked up their smartphones more throughout the day (+31) and received more notifications (+42) compared to those who did not judge they use their phone "too much." However, mothers who agreed with this statement spent, on average, less time on their smartphones each day than mothers who disagreed (-99 minutes). Notably, the main difference between agreeing and disagreeing mothers in terms of total minutes related specifically to social media use. Mothers who agreed that they used their smartphone “too much” logged less time on social media platforms than those who disagreed (-102 minutes), accounting for the entire difference seen earlier in total minutes. Here there is a disconnect between mothers’ perceptions of their smartphone use and their actual use, particularly from mothers who disagreed. This disconnect could be driven by social media use. Second, the study also found that mothers who agreed it was hard to resist checking their smartphones picked up their smartphones more throughout the day (+26) compared to those who did not agree that it was hard to resist checking their smartphone. Although the number of notifications received by mothers who agreed was not statistically higher than those who did not, this group did receive more overall daily notifications (+28). Third, there were no differences in smartphone use between mothers who said they often thought about calls and messages they might receive and those who did not. Finally, there was evidence that mothers’ judgments about their smartphone use relates to interactions with their young children. Mothers who agreed they used their smartphones too much, agreed that it was hard to resist using them, or agreed that they thought about calls and messages they might receive reported experiencing more interruptions during activities with their child due to their smartphone. In fact, every mother in the study said that their smartphone interrupts interactions with their child multiple times a day, and nearly 60% said they are interrupted more than five times per day. Past research has shown that such interruptions can lead to lower-quality mother-child interactions and negatively affect children’s social and cognitive development [14,19].

Together, it was determined that mothers’ judgments of their smartphone use sometimes, but not always, match their actual use. When they do not, mothers can either be over- or underestimating their use. Both could potentially be problematic. For those who underestimate, they might minimize the potential for their use to have negative effects on their own health and/or the health of their child. For those who overestimate, they may unnecessarily experience anxiety or other mental health problems as seen in the correlation between social media usage and depression that was displayed when TikTok and Snapchat users were studied by an outside source [13,17]. One direction for future research might be to explore if increased worry (e.g., mothers who think they use their smartphone too much even when they do not) might unintentionally limit or buffer actual smartphone usage. There was some support for this possibility in that mothers who agreed that they used their smartphones too much spent less time on average on them than mothers who disagreed. Determining if worry serves to limit smartphone usage because of users’ hyper-awareness could explain the disconnect between perceived use and actual use noted in the study.

There were several limitations in this study that could also be addressed in future research. Phone usage statistics shown in screen time monitoring applications are imperfect, and their counting algorithms are not fully understood. It can be unclear exactly what counts as a pickup and which activities count towards screen time. Since these were used in this study, it cannot be certain how accurately the mothers’ actual use patterns are represented. Also, any calculation differences across apps could skew the results. Additionally, some smartphone actions like using the calculator, checking the time, or receiving a notification about a doctor’s appointment seem qualitatively different from actions like scrolling through Facebook and receiving an alert from a YouTube channel. The counting statistics in the app do not always distinguish these. It is possible that the idea that purposeful or functional daily smartphone uses such as navigation, calculators, or playing background music might differ from uses related to boredom or entertainment should be explored in future studies. In addition to the generic judgments the mothers made (e.g., whether their smartphone use was “too much”), it might also be interesting to have participants provide exact estimates of their perceived use (e.g., “estimate the number of minutes you spend on your smartphone each day"). This would make it possible to quantify the difference between their perceived and actual use. Further, since both actual use and perceived use could potentially impact mental health, assessing and analyzing both could provide new insights into how each contributes to the mental health risks associated with overuse (e.g., "is overuse less problematic if you don't think you overuse?"). Regarding the participants, this study focused specifically on mothers with young children in Alabama, which meant that the sample was regionally bound, exclusively female, and consisted predominantly of young adults (with children). Consequently, there could be regional, gender, or age-related findings in this sample that would not generalize to the wider public. And while the sample was racially and economically diverse, future studies could diversify the sample even more.

One theme that emerged in the study was that mothers often worry about their smartphone use. Therefore, it might be helpful to suggest some simple ways for mothers to reduce it. These could include: making notifications less invasive by placing the phone screen down so that touching it is less tempting, designating a permanent location for the phone like a charging station (rather than carrying it around), developing a reward system where phone use is earned after reading a book or walking outside, putting a reminder image on the lock screen, placing a sticker on the back as a reminder, or assigning designated times to check notifications, texts, etc. It might also be helpful to educate mothers on some of the basic features, functions, or apps available on their smartphones that could help to limit screen time. These could include: how to track smartphone use with a built-in or downloaded app (e.g., RescueTime, Apple's Screen Time, Google Digital Wellbeing, etc.), how to schedule periods of downtime using something like a do not disturb function, how to set screen limits for a maximum amount of use overall or for certain apps, how to turn off notifications on some or all apps, how to set the phone's color to grayscale, and how to silence the smartphone or simply turn it off. Utilizing the tips mentioned above could serve to limit smartphone usage and reduce the negative impacts that heightened usage patterns have on mothers as well as their children.

Conclusion

This study sought to identify how closely a mother's judgments of her own smartphone use correlated to real usage patterns. The goal was to determine if there was a disconnect present between perception and reality of smartphone usage and if this disconnect had any negative effects. It was found that mothers' judgments of their usage patterns are shown to be higher than their actual usage, potentially due to increased worry that could be buffered through the tips stated above. This could allow for an accurate connection between perception and reality to be made in order to remove the negative effects of smartphones from daily living.

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Analysis of the Argument for Battery Electric Vehicles (BEV) and Examination of Energy Alternatives

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Global warming, climate crisis, atmospheric fluctuations: whatever it may be called, the facts are undeniable. The world is heating up, sea levels are rising, habitats are shrinking, and extreme weather events are becoming increasingly common [9]. Human interactions with the environment, such as farming, fossil fuel consumption, and deforestation, contribute largely to the atmospheric gasses that cause global warming [9]. With the plethora of increasing consequences, it is time for a change: individuals must reduce their carbon emissions globally. Transportation comprises 30% of global greenhouse gas emissions, leading many experts in the science community to call for the electrification of vehicles [6]. A complete switch to electrified transportation by 2035 may allow us to keep global warming under a 2 °C change [3]. However, while many argue that these electric cars are much more efficient than gas-powered vehicles in the long run, the catastrophically negative effects of lithium mining beg the question: Are electric vehicles really the solution?

Theory

Lithium batteries, when compared to gas-powered engines, are advantageous due to their high energy density and are low-weight, low-maintenance, and fast-charging [7]. Battery electric vehicles (BEV), when charged at specific times, can aid in stabilizing busy power grids as well as by reducing demand during variable peaks in energy consumption [9]. With petroleum deposits being exhausted and other sources such as solar, wind, and tidal electricity becoming scarce, the addition of BEVs can compensate for these gaps in resources. Environmentally speaking, BEVs produce less greenhouse gasses and consume fewer metals than traditional gas-powered vehicles [10]. Healthwise, they are notably better than gasoline- or diesel-burning vehicles, as BEVs give off almost ten times less ionizing radiation than their gas counterparts [10]. In order to further improve the efficiency and usability of BEVs, the Institute of Electrical and Electronics Engineers analyzed 212 studies submitted by various researchers. One major area of growth has been focused on optimizing the charging and the longevity of lithium batteries and trying to engineer more efficient battery packs [3]. These breakthroughs have improved and encouraged the usage of lithium batteries in BEV. The increasing lithium battery demand has created an increased need for lithium resources, which are currently mined in only nine countries, and has brought forth a rapid expansion of lithium mining in these areas—leading to detrimental environmental changes surrounding the mining areas [7,8,12].

Methodology

This paper aimed to analyze the arguments for BEVs, examine multiple alternatives, and suggest the most ecologically-friendly alternative to traditional gas-powered engines in vehicles. This was done through a formal review of several published manuscripts on the BEV and alternative energy sources, ranging from the years 2011-2021. The literature was synthesized to discuss the advantages and disadvantages of alternative energy sources, and suggestions were presented for vehicle power-system development.

History of the BEV

Contrary to the widespread belief that BEVs are a recent technological advancement, the first BEV was debuted in 1834 [1]. This new form of short-distance travel quickly gained popularity and increased in number until internal combustion engine vehicles (ICEVs), with their long-distance drive capability, were introduced to the public and took over the market [1]. Following this, rechargeable lithium-ion batteries were invented (1991), and their utilization in laptops began. The technology was quickly adapted to power vehicles, and the Prius was released by Toyota in 1997. The industry was then spearheaded by the Tesla Motors company, who gained a majority of the BEV market and helped BEVs establish their place in today's world [1].

BEV Analysis

A continual problem with any source of energy is the energy lost to friction. In a gas-fueled vehicle, 79% of the gas is lost in the process, meaning only 21% goes towards powering the vehicle [6]. Thus, gas-powered engines need to consume a significant amount of fuel to power a vehicle. Alternatively, BEVs optimize the energy usage via lithium batteries, effectively putting 77% of the electricity to work [6]. Because energy loss due to friction is directly tied to the amount of energy needed to power a vehicle, reduction of this energy loss creates a more efficient and environmentally-friendly vehicle. If all gas-powered vehicles were switched to BEVs in just the UK, a 61% friction reduction would be seen in the next 15-25 years, corresponding to 117,000 liters of fuel saved [6]. Reduction of fuel consumption and demand will reduce fossil fuel emissions. BEVs, when powered by electricity from a renewable energy source, produce 4.5 times less CO_2 emissions and use ¼ of the energy compared to gas-powered vehicles [6]. On a global scale, implementation of technology such as lithium batteries used in BEVs would result in worldwide energy savings of almost 9% [6].

The transition from ICEV to BEV is projected to have positive impacts on human and ecosystem health worldwide. In a comparison between BEV and ICEV (both gas and diesel), BEVs were shown to have significantly lower overall toxicity to humans, lower radiation emissions, and reduced resource depletion (both metal and fossil) [10]. The usage of lithium batteries in these vehicles is projected to reduce CO_2 emissions by 64% and fossil fuel usage by 73% before the year 2050 [10]. Projections show that BEVs are better for biodiversity; they have 42% and 57% less impact on natural ecosystems compared to ICEV-diesel and ICEV-gas, respectively [10]. Thus, the overall environmental damage (encompassing biodiversity, CO_2 emissions, and global warming) of BEVs is 70-80% lower compared to the impact of ICEVs [10]. BEVs will have beneficial impacts to the global environment as they create less poisonous gasses, elicit less heating of the Earth and less fossil fuel depletion, and have fewer negative effects on biodiversity. However, BEVs may have localized negative impacts, especially around areas of lithium mining.

While the advantages of implementing BEVs are undeniable, the negative aspects are often downplayed until they accumulate into a more immediate threat [7]. Early warning signs of environmental damage have been ignored in the past—for instance, usage of chlorofluorocarbons and the subsequent damage to the ozone layer, an increase in atmospheric greenhouse gas emissions, and global warming. Because lithium battery production has similar parallels to ICEV emissions in the climate change crisis, it is important to conduct research on both the pros and cons of BEVs and the lithium batteries that comprise them [7].

Lithium stores exist in concentrated locations around the world. One of the largest deposits of lithium exists in the South American countries of Chile, Argentina, and Bolivia, which make up the "Lithium Triangle" [7]. About half of the global supply of lithium reserves is found in the Lithium Triangle, making up the majority of industrial lithium [7]. While lithium is present in trace amounts in both salt and freshwater systems, minable lithium resources are located in soil and salt brines. Currently, about half of lithium sourcing is from salt brines, and 40% comes from mineral mining, while a scarce 10% comes from other sources [7]. Lithium demand doubled in the United States from 2005 to 2010 and is predicted to increase by at least 8-11% annually [7]. By 2024, lithium batteries in BEVs are predicted to account for almost 70% of lithium consumption [7]. With this increasing demand, it is imperative to recognize the drawbacks of lithium mining and enact policy that will keep both ecosystems and humanity safe.

In the Atacama Desert in Chile, one of the largest natural sources of lithium, indigenous Atacameño people use the same water source that is used for mining practices [2]. For the Atacameño, they value water as “a being”; it provides the “essence of life and livelihood” and is used to perform sacred rituals. These practices may experience considerable losses if mining practices impact the quality and quantity of the water supply [2]. Using lithium resources, as well as many other rare elements, for market purposes presents an ethical dilemma, especially when the wealthy countries vying for lithium (the United States, UK, and northern European countries) have a rich history of indigenous exploitation [2]. Advocates for the Atacameño argue that the native waters are an extension of the people and their beliefs, while mining companies cite the Water Code of 1981 that denotes water can be sold or traded [2]. Legally, the usage of the water and brine is at best negotiable, but ethically, the exploitation of this source is morally reprehensible. If mining companies are to pursue the extraction of lithium here, they must navigate the exceedingly difficult rulings involving the Atacameño people’s resources, and if not, they may struggle to find readily available sources of lithium [2]. In addition to some of the moral and ethical considerations to lithium mining in this area, other logistic obstacles also pose many challenges to accessing lithium reserves.

Most lithium reserves exist in the arid climates of South America. In these naturally dry locations, water is scarce, and 95% of water used in the extraction process evaporates, further aggravating the problem [8]. This depletion of water has adverse effects on ecosystem and hydric balance as well as in the aquifers that exist there. Over the last 25 years, lithium mining in South American desert areas has led to a significant reduction in vegetation at a rate two times faster than the global vegetation depletion by humans [8]. Daytime temperature in the mining areas has increased by 0.13 °C to 0.46 °C from 1997 to 2017 [8]. Additionally, Liu and colleagues observed a significant decrease in soil moisture, which is significant given many of the locals around the mining areas make their livelihood via farming [8]. The drying of soil and loss of vegetation is projected to have massive impacts on the wildlife in this area. While these consequences are in their preliminary stages, the projected rapid increase in lithium demand implies an uncertain future for the ecosystems and communities surrounding lithium mines.

The largest lithium deposits are found in countries such as Argentina and Bolivia, who demand that mining of the element adhere to local regulations. According to the Mining Institute of Spain, this can be difficult, as lithium brines in Argentina are legally defined as water [12]. The complexity of permits and regulations create severe obstacles for companies and individuals attempting to develop lithium mines in Argentina [12]. This in turn creates legal difficulties for those wishing to pursue mining here, as they must either wait until legislation has been amended or run the risk of legal repercussions in the near future.

The projected rate of lithium battery consumption (including phones, laptops, etc. as well as ICEV) is greatly outpacing the discovery and reserves of lithium supplies. Research shows that current lithium reserves will be completely exploited by 2025 [14]. While this projection can objectively be deemed aggressive, it should be noted that consumption has not continued increasing at this rate since mining began. Lithium is a non-renewable resource, and therefore supplies will not last forever. While recycling lithium is possible, the return on the process is not effective enough to encourage it, and the understanding and developing of technology to recycle lithium batteries is in its very early stages [3]. Currently, the primary recovery methods in this industry focus on saving metals such as Li, Co, Ni, and Mn, but challenges arise due to the lack of mature technology and effective recovery as the battery components change over time [5]. Therefore, the resource will eventually be drained. When a major reason for the switching of ICEVs to BEVs is the exhaustibility of fossil fuels, converting to lithium batteries risks the depletion of another non-renewable resource. A better long-term future may be aimed at developing technology with resources that are renewable.

While BEVs produce less emissions overall, create less friction in their usage, have less human health impacts, and better support biodiversity of ecosystems compared to ICEVs, the mining of lithium for the batteries creates a dilemma for the informed individual. Yes, BEVs are better for the environment and produce less atmospheric emissions, but are they good enough? Should the localized consequences of lithium mining in the ecosystems surrounding mining sites be ignored in order to support them? While BEVs are a great short-term solution, the research and funding of alternatives, especially renewable energy, needs to be pursued.

Alternative Examination

The potential for a technological breakthrough in the transportation industry lies in a variety of areas, including metal-air batteries, lithium metal polymer (LMP) batteries, and fuel cell electric vehicles (FCEV). Metal-air batteries, which are made up of metal anodes and cathodes, have an increased density and efficiency compared to lithium batteries and are therefore a promising alternative. However, the market does not yet have the framework to support their adoption [14]. LMP batteries use the reaction of a metal oxide intercalation compound with a lithium metal and are significantly better for the ozone layer, as they require less energy from coal-produced energy when compared to lithium-ion batteries [13]. It is important to note that even though LMP batteries support the slowing of global warming compared to ICEV, they invoke moral dilemmas similar to those presented by lithium mining. Additionally, LMP batteries contribute to eutrophication of aquatic environments, which if implemented large-scale, will result in a reduction of aquatic biodiversity [13]. FCEVs, powered through electrochemical reactions between hydrogen and oxygen, although less efficient than BEV, produce virtually no emissions, and charging of these cars can be done much faster than BEV [14]. Potential blockages in the widespread development of this technology include the necessity of electricity (which produces hydrogen) and the relative expense for consumers [14]. Romejko and Masaru emphasized the potential of FCEV, suggesting that a government subsidy program to provide consumer incentive may facilitate quick development of the FCEV industry [11]. Governmental subsidies could potentially be adapted to cover vehicles powered by metal-air or LMP batteries as well, aiding the rate at which the alternative vehicles are brought into the consumer-markets and accelerating the transition away from fossil fuels.

Perhaps the most promising, if not the most complicated future prospect, is the decarbonized integrated electricity gas system (IEGS) [4]. By mathematically modeling emissions and framework in the categories of power-to-gas (P2G), carbon capture system (CCS), and BEV, researchers were able to optimize energy utilization for the benefit of the environment. Their strategy employs P2G to convert excess electricity to natural gas and combines it with CCS to reduce the creation of CO_2 during usage. BEVs are also utilized in this system as tools to help save total energy cost. The implementation of their system alone reduces operation costs by 17.4% [4]. The potential of wind energy to be adapted into their system is also recognized; they believe this would reduce the system operating costs by a total of 20% [4]. This system, when compared by total energy cost savings to other possible solutions, stands apart as a bright prospect for the future.

Conclusion

BEV, with its starkly superior efficiency as opposed to ICEV (it is 56% more efficient) and general goodwill in the area of biodiversity, is hailed by many as a viable alternative to traditional vehicles [4,6]. While BEV are unmistakably better for the environment than the more traditional ICEV, the ethical dilemmas of expanding this technology require further examination. Impacts on indigenous tribes, causal drought, and reduction in both plant and eventually animal biodiversity are potential implications of the future of this technology. Flaws in this and similar methods fuel research into other plausible solutions to the rapid addition of CO_2 to the atmosphere. With the potential advancements of metal-air and LMP batteries, FCEV, and the IEGS, future prospects are looking optimistic. These technological advancements pave the way for efficient, ethical, and hopefully renewable sources of energy that can be deployed across the globe.

While there is no perfect solution to the emissions created by vehicles and man, developments in this area provide hope in the fight against climate change. In a time where each current form of vehicular technology has ecological, political, and/or moral drawbacks, a crossroads is approached. New technology is waiting to be discovered, but there is no guarantee that this new form of vehicular power will be more efficient or environmentally safe. As a society, pursuing a combination of current technologies, as presented by IEGS, may be the most effective way to create efficient energy that softens the negative environmental impact, remains conflict-free, and can be adapted to utilize any newly-discovered power technology. The IEGS and others like it should be further researched in an effort to find a viable and truly effective vehicle-power system.

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Interview with Dr. Rajesh K. Kana

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JOSHUA Staff: *Regarding your background, what eventually led you to become a professor at the University of Alabama? Where are you from? Where did you go to college? And what did you do prior to taking on this role?*

Dr. Kana: I did my PhD in India, and it was a long journey from then onwards. I came to this country, probably 20 years ago, on a Fulbright Fellowship to UCLA, and I was there for six months. My PhD work was on autism, but it was mostly on linguistic and behavioral studies, and I always had an interest in learning more about brain imaging. The time I spent at UCLA helped me to get engaged in neural imaging research in the basic courses that I did there. I returned to the U.S. in the end of 2002 as a postdoctoral fellow at Carnegie-Mellon University in Pittsburgh. I was there for about four years doing in-depth research in autism spectrum disorders using different types of neural imaging techniques. Then I joined the UAB faculty in 2007, and I was at UAB from 2007 to 2019. In 2019, I moved to UA, where I have been since. The transition from UAB to UA was mostly related to wanting to do something more challenging related to autism and neural science. We do have a good collection of autism faculty, not just researchers, but also those who do clinical work and services at UA. We thought it was a good idea with all these people together to build a center for autism, and that is exactly what we have done. We built the center called the Center for Innovative Research in Autism in 2020.

JS: *We understand that your current research involves projects that revolve around using brain imaging techniques to understand the functional and anatomical organization of the brain in autism. What led you to this field specifically, and did you have any personal or professional experiences that drew you to this specific career path?*

K: Not much personal experience, but I always wanted to do something in a special education related field. The trick there for autism was reading this book called *An Anthropologist on Mars* by Oliver Sacks. Oliver Sacks was a famous neurologist, and he writes very interesting books where he talks about different cases, such as a case of schizophrenia or autism. In this book, *An Anthropologist on Mars*, there is a chapter on Temple Grandin, an autistic person. She's a faculty in one of the universities in the U.S. She is autistic, but at the same time she has written books, and she teaches, and she also talks about autism. At that time when I read the book, it was so fascinating to hear from a person who's autistic talking about her own experience, her own personal, first-hand perspective. That was the trigger to get me into autism research, basically prompting me to think that this is maybe a field to get into. Again, this was in the year 2000 or 2001, so you can imagine that the autism research itself is 20 years back at this point as well. In addition, the brain is fascinating, and we wanted to know more and more about autism and neuroscience. When I was at UCLA, I also got to work with some of the non-neuroscientists there, and that also acted as a catalyst to get into that field.

JS: *With regard specifically to your research, what do you consider to be some of the most exciting and impactful advancements over the course of your career? What have been some of your most exciting advancements in research in your time at UA, specifically?*

K: There are a bunch of things I could say. I always say that the students are the ones which make up the lab. I always think that. If you have good students, you will have a good lab. One way or the other, I've had lots of really good students, be it undergrad students or grad students. Right now, we have about six or seven undergrad students working in the lab, and we just realized that we submitted around five abstracts and posters for the URCA conference at UA. [...] Looking back once we did it, there was a very good feeling of accomplishment. This is not like a computer testing somebody does with a participant; these are neural imaging studies, which are heavy-duty. As an undergrad, to come and learn in a shorter time and then to get that product out is a difficult thing to do. Definitely, the publication and the product aspect of [research], especially when that is the student's accomplishment, gives a sense of accomplishment for any faculty. Fortunately, we got a grant to study reading intervention in autism and the brain, so that was one of my highlights. Of course, you know the stories when somebody writes from somewhere saying, "Hey, I read your paper, and we really like the kind of research you do." Getting that could be one. Or somebody who participated in research, and their family from New Jersey or Miami or somebody writes to us saying, "We had a wonderful experience visiting your lab and going through the experiments." It's very difficult to pinpoint specific things, but there are these phases that you feel very happy about. There could be phases where you feel depressed too.

JS: *What unique opportunities has being affiliated with the University of Alabama, specifically the Center for Innovative Research in Autism, brought to your research? What kind of research does the Center for Innovative Research in Autism do specifically?*

K: One of the fascinating aspects of the center is that it's part of the College of Arts and Sciences, but at the same time, it's very interdisciplinary. For example, there are about 15-20 faculty at UA working on different aspects of autism, and there are a bunch of them in psychology, a couple in communicative disorders, some in education, and one in biology. It's a great mix of these people who are all thinking in different directions, but at the same time studying the same topic from different angles. One of the most exciting aspects of CIRA is to have these faculty together and create some projects collaboratively, so I have my own collaborations with the different faculty. I have one with the faculty in education and a few with some of the other departments and so forth. I think that the collaborative interdisciplinary nature of the center helps us really build very exciting projects. One grant application that we submitted recently involves about four to five different faculty, MRI imaging, neural imaging, electro-encephalopathy EEG, eye tracking, and behavioral testing as well. All of these combinations of things are difficult to do if you are sitting in your own silo and then operating. I think that is a really exciting part, the collaborative interdisciplinary nature [of CIRA].

JS: *What does a typical day in your lab look like?*

K: The typical day in my lab can differ actually. [...] A conference room and testing room: that's what the lab is, with people visiting and working in front of a computer. Why it varies is that sometimes we have a busy day when all the students and I are there, and we're all talking about a lab meeting or projects. When we are collecting data, the testing room is heavily used, the participant is coming in, their families are waiting, and so on and so forth. Some days, we all go to UAB, actually, and then collect our data from the MRI center there. We don't have a scanner at UA, yet, and it's coming in August. We have testing sessions also sometimes at UAB if it's long. We have a three-hour testing for one of the projects and an hour-and-a-half scan, so [a day at the lab] can vary in certain weeks and certain days depending on when we are collecting data and when we are analyzing data.

JS: *What do you look for in undergraduates interested in researching for your lab? Do you have any advice for students also interested in earning a PhD and maybe conduct research themselves in the future?*

K: I always tell undergrad students that it's perfectly okay if you don't have an imaging background or a research background. All those things you can learn by doing. The first and foremost thing to have is your interest and motivation. If you don't have that, you can be miserable in the lab. The lab can be extremely productive, but you will be just sitting and watching it from the side. [...] But if you are motivated and interested and ready to put in a certain number of hours, I think you should be fine and productive. I always tell students that the motivation factor and the interest factor is the critical thing in being successful in the lab. For the second question related to going to higher education, grad school or med school or anything like that, I would say research is extremely important. [...] If I'm looking at a grad student application who's coming to any program for example, one of the first things that I look at is whether you have any research exposure at all. It doesn't have to be on the exact same subject, as long as you went through the process of research and have some product to show. If you have a poster, that's great. If you have a paper and a poster, that's absolutely wonderful. It tells you a lot of things as a reviewer: you did spend time in research, you understand the process of research, you also are not bad at working in a team. I would absolutely encourage students to get into research as early as possible, probably from sophomore year, and stick to one lab. You would probably produce a lot—of course, if it fits with your interest—by the time you graduate. And I've seen in my own students, even if they go to non-research schools like medical school, it was very helpful, even in the interview process. A student who went through a research lab for two years will have many more things to talk about in any interview as opposed to somebody who just finished a bunch of courses.

JS: *What advice would you give students looking to pursue their own research within the field of neuroscience?*

K: It is always a "kid in the candy store" kind of feeling when you are interested in research. Everything looks pretty cool and interesting, and it is a good problem to have. Sometimes when you ask students, they will say, for example, "I am interested in social cognition." That's such a huge topic area, a field of research itself, and so it's a fascinating journey narrowing down that [interest] and how you can get from that bigger field to specific questions to finally get to that one specific question and then how to test those questions. This applies to not only students but for faculty too. 95% of grant applications faculty apply to don't get funding. The funding is very minimal, so why are not all faculty successful in grant applications? It is because the ideas are crude many times, or the ideas are not testable or feasible. This refining process is kind of like picking up a stone from the street and polishing, polishing, polishing until it turns into diamond. Not many people can be successful in that, but that process is important, and that's what students need to learn: how to come to that specific question or questions.

JS: *You mentioned earlier that a scanner is potentially coming to UA, so could you talk a little bit more about that and about some of the new projects that you have coming up or grants that you are going to be taking on in the future?*

K: The scanner is a big, big event for UA. This whole thing started when I joined UA [and worked with] another faculty member, Sharlene Newman, the director of the Alabama Life Research Institute (ALRI). Sharlene and I decided that we would write a grant because it's very difficult to ask the university, "Hey, can you give us $6 million to buy a magnet?" The answer will most likely be no. NIH and NSF have this grant called the major instrumentation grant or the major research institute grant, and Sharlene and I wrote the grant saying that we have a bunch of neuroscientists here, we have a neuroscience minor, we have an educational neuroscience program, there are many people interested in working in the field of neurosciences, and that this is a good time for us to get a scanner. Finally, that NSF proposal got funded, so we got about $2.8 million for that grant, and then we went to UA, saying we need a little bit more money to be put in there so that we could purchase the scanner. It's [now] a reality, the purchase is complete, and it is going to be a Siemens 3 Tesla MRI Scanner. The scanner will be delivered sometime in mid-July of this year [2022], and it will be in the back of the University Medical Center. There is a huge MRI suite being renovated at this point, where it is going to be placed. Sometime this fall, probably mid-fall semester, it will be open for business for faculty to use it for scanning. This is going to be a landmark in the history of UA because this is the face where neuroscience is going to take the next leap to the higher level. As I was telling you, there are a bunch of faculty in different departments—psychology, engineering, philosophy, anthropology, education, etc.—all involved in or interested in neuroimaging work. This will provide them a chance to launch their projects to get into. We ourselves have a bunch of projects we have been working on. I have a project where we are planning on looking at emotion regulation issues in adults with autism. Once the scanner comes in, I think we will be able to collect some data on that one. We have a study on social intervention in adults and adolescents with autism that will get data collection here. Also, once the scanner comes, you will see many projects coming up. We also have been working on a neuroscience major proposal, so that is in the works, and at some point, that will go out for review externally. If it gets approved, UA will have a neuroscience major starting in fall of 2023. It is going to be a very interesting time in terms of new students coming in, and it will make faculty recruitment much easier.

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We accept articles from current undergraduate students at accredited universities. If you are a graduate student or recent alumnus of UA, we will consider your article if the majority of your work was conducted while you were an undergraduate at UA. Undergraduate students from other institutions may submit; however, priority will be given to those who conducted their research at UA.

1. Your name, email address, and phone number must be included.
2. Your submission must relate to science or health.
3. Your work must be sponsored by a faculty member.
4. The length of your submission must be between 2000 and 4500 words. We will accept longer submissions if the author can limit the submission to the required length for the publication, and any extra material is able to be published online.
5. Figures, charts, and graphs are allowed but not required. (Note: The color will be mostly black and white.)
6. Your paper must contain an abstract.
7. Your citations must follow the guidelines listed on our website at: https://joshua.ua.edu/submissions-and-guidelines.html.
8. The deadline for submission is February 28, 2023.
9. Email submissions to joshua.alabama@gmail.com.

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