Exploring a Time-Based Perceptual Deficit in People who Stutter: Behavioral & Electrophysiological Approaches

By: Matthew Phillips

OVERALL STATEMENT OF INTERESTS

Communication, especially effortless and spontaneous speech, is so ubiquitous that most people take this ability for granted. The power of speech becomes particularly apparent to people who have a speech or language disorder, such as the 1% of people who stutter (PWS) worldwide. As a person who stutters, I am all too familiar with what happens when a breakdown in typical speech occurs. Through my own personal experiences with stuttering, I decided that I wanted to study speech, language, and hearing sciences so I could eventually become a speech-language pathologist (SLP) and help other people with communication disorders, especially stuttering. So much research has been conducted on stuttering, yet little is known about its exact etiology, why some children recover from stuttering while some persist into adulthood, and whether sensory differences exist in PWS. How can clinicians provide the most effective speech therapy to PWS when its etiology is not known, and when most SLPs aren't even comfortable treating such a mysterious disorder (Tellis et al., 2008)? It was through these thought exercises that I decided even though I want to work clinically with PWS, I also want to pursue a PhD researching stuttering.

My University Scholar proposal would serve as my introduction to conducting stuttering research. Specifically, I plan on researching the perceptual rather than the production side of the disorder using behavioral and electrophysiological methods. We know that PWS produce speech differently, but do they also ***perceive*** speech differently? If so, where does this difference occur? The answer to these questions will add to the current body of literature about stuttering, especially perceptual abilities in people who stutter, which is a relatively new line of inquiry.

I believe that my learning to date has prepared me to undertake a project of this scale. As a research assistant in the Language and Brain Lab under Dr. Emily Myers, I have gained a wide range of skills that will be beneficial in completing this experiment. This past summer, I was

awarded a CT Institute for the Brain and Cognitive Sciences Summer Undergraduate Grant to complete an independent research project investigating the effects of musical experience on non-native speech sound learning. Through this experience, I learned how to design experiments on Gorilla Experiment Builder, analyze data using R, and develop the critical thinking skills of a researcher. Additionally, I used Gorilla Experiment Builder to design a study conducted by Dr. Myers and Dr. Erika Skoe this semester. Furthermore, in Spring 2020, I completed an Honors Conversion project for Dr. Gerry Altmann's PSYC 3500 (Psychology of Language) course, in which I wrote a 14-page literature review of stuttering: ranging from stuttering treatment, psychosocial outcomes of stuttering, and the neurobiological etiology of stuttering. This project allowed me to develop a deeper and mechanistic understanding of stuttering through reading primary literature, which reaffirmed to me just how little we know about the disorder.

My learning plan and project plan complement each other in that they focus on expanding my skills as a researcher. My learning plan will increase my knowledge in the field and includes advanced coursework about stuttering, speech science, and electroencephalography (EEG) techniques, which are directly connected to my research plan. Together, my learning plan and research question support my long-term goal of pursuing a PhD in stuttering. The skills learned through this project would benefit the research I will conduct at schools such as Vanderbilt University (Dr. Robin Jones), University of Texas at Austin (Dr. Courtney Byrd and Dr. Zoi Gkalitsiou) and New York University (Dr. Eric Jackson). Through this project I will learn how to conduct research about stuttering, hone my behavioral data analysis skills, and learn a new methodology (EEG), which will be valuable when applying to graduate programs and beyond.

LEARNING PLAN

During my final three semesters at UConn, I plan to modify my plan of study to be more rigorous and specialized to my University Scholar project as well as my professional aspirations. These changes go above and beyond the requirements for my SLHS and PSYC majors without compromising either major's learning objectives (see "Substitutions" document for more detail). My learning objectives for this time encompass two major areas: deepening my understanding in the field of SLHS (**Goal 1**) and diversifying my skills as a researcher (**Goal 2**).

In Spring 2021, I plan on enrolling in SLHS 4251 (Introduction to Articulation, Voice, and Fluency Disorders), an upper-level elective discussing stuttering. I also plan on enrolling in the graduate course SLHS 5335 (Fluency Disorders) in Fall 2021, which will increase my understanding of stuttering beyond what would be covered in the undergraduate course SLHS 4251. While I am quite familiar with stuttering through my personal experiences and readings, these courses will help round out my knowledge of the disorder **(Goal 1)**.

During my senior year, I also plan on enrolling in SLHS 5361and 5362 (Advanced Speech Science I & II). SLHS 5361 and 5362 are related to my research project as they cover both speech production and perception. These courses will provide me greater insight into stuttering, which is a speech production disorder, and into the specific area of my research proposal, which is speech perception. These graduate level courses will prepare me for graduate school as almost all graduate programs require advanced coursework in speech science (**Goal 1**).

I also plan on adding another tool to my research-skills toolbox – EEG – by enrolling in LING 6798 (Special Topics in Linguistics: EEG Methods) during Fall 2021 (**Goal 2**). The second stage of my research project will utilize EEG, specifically a mismatch negativity (MMN) paradigm, to tease out the fine differences in temporal processing among PWS compared to people

who do not stutter (PWNS). This course will provide me the knowledge to successfully conduct my own EEG research. EEG is an appropriate method for this type of study because it is a highly sensitive measure of temporal processing: sometimes neural differences emerge where behavioral differences do not. Additionally, MMN is a pre-attentive measure of sound processing, meaning its response is automatic and less likely to be influenced by task-specific strategies used by participants, which may cloud behavioral data. Two members of my committee (Dr. Skoe and Dr. Landi) are experts in electrophysiological methods and will be able to assist with any gaps in my knowledge that remain after taking LING 6798. Learning EEG methods will be useful for my University Scholar project and will also benefit me as a researcher in graduate school and beyond, where I will enter any program with knowledge of how to design and analyze EEG experiments.

RESEARCH PLAN

1. Literature Review & Research Questions

Developmental stuttering ("stuttering" for brevity) is a multifactorial neurodevelopmental disorder with many affective, behavioral, cognitive, and social consequences (Tichenor & Yaruss, 2019) affecting roughly 1% of the population (Yairi & Ambrose, 2013). While stuttering manifests as a disorder of speech production, there is emerging evidence that people who stutter (PWS) also have disordered auditory perception. Recent studies have found that PWS performed significantly worse than PWNS in a rhythm discrimination task (Wieland et al., 2015) as well as in duration pattern and random gap detection tasks (Prestes et al., 2017), supporting a general temporal auditory processing deficit. The results from Wieland et al. (2015) cannot necessarily support a temporal ***speech*** processing deficit, however, because the researchers utilized musical phrases as stimuli, and temporal changes in music are much less rapid than those occurring in speech.

Frustratingly, the evidence on whether PWS have differences in processing speech, specifically, is mixed. Some research suggests that PWS have deficits in speech, but not non-speech processing which seems to contradict the studies referenced above (Corbera et al., 2005; Gonçalves et al., 2015; Jansson-Verkasalo et al., 2014; Tahaei et al., 2014). Corbera et al. (2005) and Jansson-Verkasalo et al. (2014) used a mismatch negativity (MMN) paradigm to investigate how PWS process speech sounds. Their results indicated that PWS differed from PWNS in processing speech sounds with altered formant frequencies, but the two groups were equivalent for simple changes of pure tone duration or frequency (Corbera et al., 2005) and PWS showed smaller MMN amplitudes than PWNS in response to deviant stimuli differing in phoneme (speech sound) duration (Jansson-Verkasalo et al., 2014). A potential oversight to the Jansson-Verkasalo et al. (2014) study was that the difference between the standard and deviant stimuli was relatively large: 170ms and 100ms, respectively. While these findings allow us to assess gross temporal processing, we are still unable to assess more rapid temporal processing utilized in speech.

There are also conflicting findings surrounding PWS's categorical perception ability. In speech perception, categorical perception is the process that occurs when an individual listens to a phoneme and sorts it into a category. Typically, there is a sharp boundary between perceptual categories (such as between the sounds /b/ and /p/). Some research has found no differences in categorical perception in PWS (Bakhtiar et al., 2019, 2020) while other research has found a significant difference in categorical perception between PWS and PWNS, suggesting less stable phoneme representation in PWS (Neef et al., 2012). While these studies differed in many dimensions, methodological limitations may have prevented Bakhtiar et al. (2020) from finding group differences. Bakhtiar et al. (2020) found no difference in categorical perception between PWS and PWNS along VOT, vowel, Cantonese lexical tone, and pure tone continua. A limitation

to this finding, however, was that all four continua were analyzed together, while the published figures show a possible categorical perception group difference in the VOT condition. This VOT group difference may support a perceptual speech-timing deficit in PWS if analyzed separately.

Due to the lack of convergence in the literature, we are unable to conclude where and how the breakdown of temporal auditory processing in PWS occurs. The proposed study seeks to answer this question using a two-phase approach. **Experiment 1** will be a behavioral study investigating **categorical perception** of speech sounds in PWS across two conditions using two stimulus sets per condition to measure both speech and non-speech perception. Temporal processing will be assessed using a **VOT and gap detection task**, while spectral processing will be assessed using a **place of articulation continuum and pitch discrimination task**. Spectral information refers to measures related to pitch and is included in this study to figure out if PWS differ only in time-based perception, or auditory processing as whole (time- and pitch-based), **Experiment 2** will then use the aforementioned contrasts with the most robust differences between PWS and PWNS in a **mismatch negativity paradigm.** This two-phase approach will allow us to distinguish PWS and PWNS in temporal processing at a finer level than has been done before and will clarify where the perceptual breakdown occurs in PWS.

	Methods	**Condition**	**Stimulus**
Experiment 1	Behavioral	Speech vs. non-speech processing	Speech Sound Contrasts, Non-Speech Perception (gap detection, pitch discrimination)
Experiment 2	EEG (MMN)	Temporal vs. spectral processing	Stimuli from Exp1 with most robust group differences

2. Methods

2.1 Participants. The proposed study will test PWS and PWNS groups. For Experiment 1, I aim to recruit 30 participants per group, and for Experiment 2, I aim to recruit 20 participants per group. PWS will be classified as people who self-report being a PWS and score at least a 9 (mild

severity) on the Stuttering Severity Instrument – Fourth Edition (SSI-4, Riley & Bakker, 2009). PWNS will report not being a PWS and score below 9 on the SSI-4. Participants will be recruited from the University of Connecticut community, Prolific (an online participant pool for remote experiments), and the National Stuttering Association, where I hold a leadership position and have connections to thousands of PWS across the country; this will be particularly beneficial for Experiment 1, which will be completed remotely. Participants will be compensated $11 per hour.

2.2 Stimuli & Procedure. The proposed stimuli will utilize two different speech sound continua, differing in VOT (/ka – ga/ syllables) and place of articulation (/ba – da/ syllables) which have been used extensively in the Myers lab, and two non-speech tasks: gap detection and pitch discrimination. Experiment 1 will be designed using Gorilla Experiment Builder, a platform built for remote data collection, which will be instrumental in recruiting participants generally (given current limitations on in-person testing due to the coronavirus pandemic) and in recruiting PWS specifically. For the categorical perception task, participants will listen to syllables one at a time and be asked to sort them into groups (for example, whether a syllable sounds like /ka/ or /ga/, which differs in VOT). This measure has been shown in our lab to be sensitive to individual differences in speech sound perception. (Fuhrmeister & Myers, in prep.)

Experiment 2 will utilize MMN. In MMN, participants wear an EEG cap and listen to a stream of continuously presented syllables differing along one dimension (i.e., temporal structure or pitch). The version of the syllable played most frequently, the "standard," is occasionally replaced with a different version of the syllable, the "deviant." MMN records the electrophysiological dishabituation response when the brain processes the deviant as different from what it has been listening to. Experiment 2 will utilize the stimuli found in Experiment 1 to have the most robust differences between PWS and PWNS (which I expect to be stimuli differing on

the temporal dimension). We will closely follow methods used by Dr. Landi (Hämäläinen et al., 2018) and will utilize an 80:20 standard-to-deviant stimulus ratio, common in MMN research.

3. Data Analysis & Predicted Results

Experiment 1 data will be analyzed using linear mixed effect models using the *lmer* package in R to determine group differences. We will fit a logit function to each participant's categorization responses to measure the slope of the categorization function, with steeper slopes indicating a more categorical perceptual pattern, and shallower slopes indicating a more gradient pattern. I predict PWS will have shallower slopes and shifted phonemic boundaries for the VOT (temporal), but not spectral, continua compared to PWNS, supporting a perceptual deficit in PWS specific to temporal processing. MMN data from Experiment 2 will be analyzed using processing routines described in Hämäläinen et al. (2018). The size of the MMN effect will be compared for speech sounds across participant groups, and we will look for relationships between the MMN size (indicating neural sensitivity to the phonetic difference) and behavioral measures of perception.

4. Project Outcomes

While the existing literature supports a speech processing difference in PWS, it does not address what may cause this group difference. The proposed study seeks to address this gap and investigate which features of auditory processing are impaired in PWS and whether auditory processing is abnormal as a whole, or solely regarding speech processing, and has implications for our understanding of behavioral and neural patterns in PWS. This project's results will be shared with the UConn community at the 2022 Frontiers poster presentation and with the broader scientific community at the 2022 American Speech-Language Hearing Association Convention. Additionally, I hope to hone my writing skills and publish the final manuscript in a peer-reviewed journal, such as the Journal of Speech, Language, and Hearing Research.

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Learning and Project Plan

Student Name: Matthew Phillips

Spring 2021

Courses

Dept &Course#	*Course Title*	*Credits*
SLHS 4251	Introduction to Articulation, Voice, and Fluency Disorders	3
SLHS 4249	Introduction to Aural Rehabilitation	3
SLHS 4245	Neuroscience of Cognitive & Communication Disorders	3
PSYC 2700	Social Psychology	3
PSYC 2100WQ	Principles of Research in Psychology	4
SLHS 3299	Independent Study (LAB Lab Research)	3
MUSI 1109	Pep Band	1
		20

Other Learning Opportunities

Opportunity	*Location/Date*
Attend Oxford Dysfluency Conference	Virtual, ***January 2021***
Training on how to use EEG equipment	UConn Cognitive Sciences Shared Electrophysiology Resource Lab (Three 2-3 hour long training sessions ***throughout the semester***)
Apply for American Speech-Language-Hearing Association (ASHA) Students Preparing for Academic-Research Careers (SPARC) Award	Submit application in ***April 2021*** (exact deadline not yet announced)

Project Milestones

Key Tasks
Submit IRB for approval at UConn ***(before Spring 2021 semester begins)***
Apply for UConn SURF Award ***(by February 1, 2021)***
Submit IRB to National Stuttering Association Research Committee for approval to use the NSA mailing list for recruitment ***(by February 15, 2021)***
Create stimuli and design experiment for the behavioral (categorical perception) component of the study (Experiment 1) ***(by May 2021)***
Apply for NSA Research Award ***(by June 15, 2021)***

Summer 2021 (optional)

Courses

Dept &Course#	*Course Title*	*Credits*

Other Learning Opportunities

Opportunity	*Location/Date*
Attend National Stuttering Association Annual Conference	Location: TBD July 7 to 11, 2021
Attend the Joint World Congress on Stuttering and Cluttering (organized by International Fluency Association)	Montreal, Canada July 22 to 25, 2021
Virtual ERP Bootcamp (EEG) training modules by Steven Luck	Virtual Dates: on my own
Read literature relevant to my research project	NA

Project Milestones

Key Tasks
Participant recruitment and data collection (Experiment 1)
Write data analysis script for Experiment 1 using pilot data
Start writing manuscript for Experiment 1 (introduction, hypothesis, methods section)

Fall 2021

Courses

Dept &Course#	*Course Title*	*Credits*
LING 6798	Independent Study (EEG Methods)	3
SLHS 5361	Advanced Speech Science I	3
SLHS 5335	Fluency Disorders	3
SLHS 4296W	Senior Thesis	3
MUSI 1108	Marching Band	1
		13

Other Learning Opportunities

Opportunity	*Location/Date*
Attend ASHA Convention	Washington, D.C. November 18-20, 2021
Read “An Introduction to the Event-Related Potential Technique” by Steven Luck	NA

Project Milestones

Key Tasks
Finish data collection for Experiment 1 (if needed)

Design EEG (mismatch negativity) experiment
Finish writing manuscript for Experiment 1

Winter Intersession 2022 (optional)

Courses

Dept &Course#	*Course Title*	*Credits*

Other Learning Opportunities

Opportunity	*Location/Date*

Project Milestones

Key Tasks
Start recruiting participants and collecting data for Experiment 2
Tie up any loose ends from Experiment 1 (final data analysis, manuscript writing)

Spring 2022

Courses

Dept &Course#	*Course Title*	*Credits*
SLHS 5362	Advanced Speech Science II	3
PSYC 4197W	Senior Thesis	3
PSYC 2400	Developmental Psychology	3
COGS 2201	Foundations of Cognitive Science	3
MUSI 1109	Pep Band	1
		13

Other Learning Opportunities

Opportunity	*Location/Date*

Project Milestones

Key Tasks
Finish recruiting participants and collect data for Experiment 2
Analyze Experiment 2 data
Write manuscript for Experiment 2
Submit manuscript of Experiment 1 and 2 to the *Journal of Speech, Language, and Hearing Research*