Investigating the Psychological Aspects of Voice and Communication via Contemporary Personality Psychology

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Submitted to the Graduate Faculty of the

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2024

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

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Voice-specialized speech-language pathologists regularly navigate the psychosocial aspects of voice and communication with their patients during voice therapy. Although some clinicians may feel comfortable navigating the psychological aspects of voice and communication, many do not, as very little empirical data exist to understand these relationships. The present manuscript examines two components of the psycho-social-vocal relationship: 1) how one's voice and communication influence their well-being and 2) how individual psychological differences (i.e., personality) may relate to the pathogenesis of certain voice disorders.

The first two studies address *communicative congruence,* or the extent to which an individual feels that their voice and communication are aligned with their sense of self or identity, and how communicative congruence maps onto depression. Across two separate samples, these studies find robust evidence that experiencing incongruence is associated with dysphoria, or significant emotional unease or distress. Additionally, these studies demonstrate that dysphoria mediates the relationship between congruence and depression. Together, these studies provide an unprecedented examination of communicative congruence.

The third study revisits the *Trait Theory of Voice Disorders*, which posits that certain personality traits may predispose an individual to developing and maintaining certain voice disorders. By integrating advances from rigorous personality science, the results of this study replicate prior findings and document novel relationships previously uninvestigated. Additionally, this study addresses gaps in the extant literature and identifies meaningful, tangible steps forward to further advance this area of research.

Neither the notion of “congruence” or personality as a precipitating factor for voice disorders are new. The current investigations advance these areas of research by integrating contemporary theories and analytic frameworks from Psychology. As a result, these studies yield meaningful contributions to the relatively sparse empirical evidence in the existing literature into these topics. Collectively, the findings from these studies provide further insight into the ways in which communication behaviors may influence a person’s well-being, as well as how psychological processes like personality may serve as a risk factor for developing certain vocal pathologies. Although more work is necessary, the current studies provide a solid foundation for future, more rigorous work into these relationships.

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Preface

Sir Isaac Newton once wrote, “If I have seen further, it is by standing on the shoulders of giants.” This quote feels particularly apropos given the focus of my dissertation. The interactions between one’s psyche and voice/communication have been discussed and studied by many over the years. This dissertation is only possible because of the work of so many people before me. I also truly believes that it takes a village, and I have climbed atop these giants’ shoulders with the help of an amazing community of family, friends, colleagues, and mentors.

First and foremost, a tremendous thank-you and to my family for their unwavering love and support over the years. From driving me to and from practices, competitions, care packages, and for helping with so, so many moves throughout my academic career. I would not be who I am today without such a loving and caring family who have supported me through it all. Y’all have helped guide me throughout my life and helped me achieve all that I have been able to achieve. Alfredo, thank you from the bottom of my heart for all your love and support, even if from a physical distance at times. I know that you still don’t fully get why anyone would willingly choose to subject themselves to this process, but this journey was more enjoyable with you by my side.

I am also so incredibly grateful and blessed with a truly amazing group of people I’m lucky to call my chosen family. Listing everyone out would easily double the length of this dissertation. So, to my friends throughout every chapter of my life – I will always cherish the amazing moments we’ve spent together. From of the concerts, the hikes, the dancing (including the Zoom dance parties during the pandemic), the pool days, the camping adventures, the late-night drives with the windows down, the puns, the nights full of board games, puzzles, and out-of-tune karaoke, the improv shows, the themed parties, all the time we’ve spent looking up to the stars in the night sky, and oh so many delicious meals together – I am truly moved by how fortunate I am to have so many amazing friends in my life. The

laughter, the tears, and the chisme we've shared over the years have helped keep me sane, lifted my spirits, and helped remind me to not take myself *too* seriously.

Likewise, this product represents the culmination of decades worth of education that I am privileged to have received. I am grateful for all the teachers, mentors, and colleagues in my life who have helped shape my thinking and world view. Additionally, a very special thank-you to the clinicians at the voice centers who partnered with me and helped to recruit participants for my dissertation. This project would literally not have been possible without your help. I would also be remiss to not give a huge shoutout to my Pitt CSD PhD fam who have no doubt helped contributed to my success. From listening to me vent at happy hours to answering my frantic *"Help! My R code won't work!"* messages on Slack, y'all have been a constant source of support and reprieve from the woes of academia.

I am also very lucky to have had such a wonderful dissertation committee throughout this process. Everyone's expertise, insight, and wisdom helped me go further, while simultaneously reeling in my overly ambitious ideas. Jim, you were the professor for my very first class in this PhD program. I am honored to have you on this committee to bookend my PhD training. Throughout this training, your rigorous questions have forced me to deepen and expand my understanding of the mechanisms underlying so many processes that many might accept at face value. Jay, I am forever grateful for your research seminar on advanced data analysis for our field. Like so many people, I think I had just accepted that math was not my forte. Your ability to break down these methods and your patience while I tried to wrap my head around them helped me rediscover how much I actually *enjoy* math. Without this experience, I do not think I would have had the confidence or desire to further my quantitative training, and I cannot thank you enough. Aidan, it has been an honor and privilege to gain a deeper insight into both personality science and the quantitative methods used to study this area. Thank you for expertise and feedback as I scaled these multidisciplinary learning curves.

And finally, Leah – you inspire me. You inspire me to be a better thinker, a better scientist, and a better human. It has been an immense joy and the highest honor to learn from you, to be a part of your lab, and to have you guide me throughout this journey. From

day one, your constant love, support, and high expectations have allowed me to grow into who I am today – a better version of myself than when I started five years ago. You have picked me up from my worst, and pushed me to be my best, and I cannot thank you enough.

So, to anyone that's been a part of this village, I am grateful for you and your role in this journey, no matter how big or small. In the wise words of Tatianna, *"Thank you!"*

1.0 Introduction and Background

Sigmund Freud, the founder of modern Psychology, described how one of his patients, Dora, became completely aphonic (i.e., a total loss of voice) after experiencing sexual abuse by a family friend (Freud, 1905). Six decades later, a group of psychologists were interested in so-called "vocal confrontation" tasks, where researchers documented people's emotional and physical reactions to hearing a recording of their voice and speech played back to them (Holzman et al., 1966, 1967; Holzman & Rousey, 1966). More recent investigations have implicated psychological processes including depression, anxiety, and personality traits as risk factors for developing certain voice disorders (Dietrich et al., 2008; Marmor et al., 2016; Mirza et al., 2003). Practically every textbook about voice disorders includes a section on the psychological aspects of voice disorders; additionally, an entire textbook itself is dedicated to the topic (Rosen et al., 2021). Although these texts provide some information about the voice-psyche relationship, both the scope and depth of our understanding remains limited. The current manuscript seeks to add to this body of knowledge and incrementally advance this area of study.

To achieve this goal, the current manuscript combines contemporary theories and methods routinely used in Personality Psychology. By integrating current practices in Personality Psychology with previous findings in the field of Speech-Language Pathology, we hope to further establish a solid foundation that will allow for future, rigorous work into the voice-psyche relationship. Ultimately, we hope that this line of work will help improve assessment, treatment, and outcomes for people with and without voice disorders.

The following chapters focus on two broad components of the voice-psyche relationship – *communicative congruence* and the *relationships between personality traits and voice disorders*. The first component, *communicative congruence*, is the extent to which one's voice, speech, and/or communication are aligned with their sense of self/identity. Carl Rogers, the founder of Humanistic Psychology, first described the notion of congruence as "optimal psychological adjustment [and is] synonymous with complete

congruence of self and experience," and incongruence between self and experience as a state of "tension and internal confusion" (Rogers, 1959, pp. 203 & 206).

Applying this idea of congruence to one's communication experiences is highly relevant to the field of speech-language pathology. Patients who develop voice disorders regularly describe how they feel they have lost a part of their identity. Similarly, many voice therapists work with transgender and non-binary individuals seeking to better align their voice and their identity. Although voice therapists regularly encounter the voice-identity relationship in the clinic, very little empirical evidence is available to support the existence of this relationship or how it relates to therapeutic outcomes and patients' well-being.

The first study, Chapter 2, represents an initial examination of communicative congruence in a sample of vocally healthy adults. The following study in Chapter 3 expands upon the initial findings in two key aspects. First, this follow-up study replicates the initial findings in a separate, larger, and more gender diverse sample. Second, this study incorporates structural equation modeling, a flexible and powerful analytic framework that has become one of the gold standards in Quantitative Psychology. Together, these two chapters provide a preliminary yet unprecedentedly deep examination of communicative congruence.

This manuscript will also address a second component of the voice-psyche relationship – the association between personality traits and certain voice disorders. Briefly, voice disorders arise when a person's vocal quality, pitch, and/or loudness are inappropriate for their age, gender, cultural background, and/or geographic location and do not meet the occupational or social needs of a speaker (Aronson & Bless, 2009). These disorders can be caused by numerous factors – e.g., smoking, throat cancer, or other physical injuries. Yet, two of the most common voice disorders are not understood, specifically muscle tension dysphonia (MTD) and benign phonotraumatic lesions of the lamina propria (also known as phonotraumatic vocal hyperfunction, PVH).

While the exact nomenclature for these two disorders varies, both MTD and PVH are thought to exist along a continuum of vocal hyperfunction. That is, both disorders stem from vocal hyperfunction, but certain factors predispose some individuals to "clamp down" and

develop MTD while other factors predispose some individuals to incur high "vocal doses" that contribute to the development of phonotraumatic lesions. Evidence suggests that sensorimotor deficits and altered biomechanics may also be components of these disorders (Castro et al., 2022; Espinoza et al., 2017; Stepp et al., 2017; Ziethe et al., 2019). In addition, decades of research dating back to the 1940s has also implicated psychological processes like personality traits and psychological well-being as contributing to developing these voice disorders (Goodstein, 1958; Moore, 1939; Wyatt, 1941).

Early researchers reported correlations between certain voice disorders / vocal qualities and personality traits but lacked a unified framework to understand these relationships until the work of Roy & Bless (2000a). In their seminal 2000 paper and two subsequent research studies (2000a, 2000b), Roy and his colleagues codified what has now become to be known as the *Trait Theory of Voice Disorders*. By integrating Gray's (1970, 1975, 1987) biological basis of personality, Roy et al. combined a then-contemporary and mechanistic approach of personality to examine the personality traits associated with MTD and vocal fold nodules (herein phonotraumatic vocal hyperfunction [PVH]). Roy and his colleagues asserted that people with MTD were "neurotic introverts" and that people with PVH were "neurotic extraverts." This theory has since shaped the subsequent two-and-a-half decades of research into the relationships between voice disorders and personality traits.

The third and final research study in this manuscript (Chapter 4) re-examines the Trait Theory of Voice Disorders. This theory was groundbreaking for its time and continues to have a lasting impact on voice disorder research. However, personality scientists have continued to make theoretical and methodological advances to understand individual differences, and our field has not fully kept pace with those advances. This final study integrates recent advances in both voice and personality science to help rectify some of the discrepancies between the Trait Theory of Voice Disorders and modern Personality Psychology. As a result, these findings will advance our understanding of personality's relationship with these voice disorders and allow future researchers to better integrate more recent findings in Psychology. By integrating contemporary personality science to examine voice disorders,

we will be better poised to improve risk assessment, diagnostic accuracy, therapeutic interventions, and treatment outcomes of these voice disorders.

Together, these three research studies represent the early stages of a programmatic line of research into studying the psychological aspects of voice and communication. The first two studies serve as a thorough proof of concept that communicative congruence is a meaningful construct that bears on individual communication experiences. This notion that one's identity meaningfully relates to their communication has potentially substantial implications for the broader field of Communication Science and Disorders, both for how clinicians approach therapy, as well as a client's therapeutic goals.

The third study applies contemporary theories, measures, and analytic frameworks used in rigorous personality science to reinvestigate one of the most cited theories in our field, the Trait Theory of Voice Disorders. By integrating advances in both voice and personality science, we will have a better understanding of the personality traits and their relationships with these two voice disorders. This refined understanding of these relationships will provide better insight to allow for improved assessment and treatment outcomes for patients with these voice disorders.

Collectively, these studies advance only components of the voice-psyche relationship, i.e., communicative congruence and relationships between personality traits and voice disorders. Although these two topics are important, they are by no means the only aspects of the voice-psyche relationship that come to bear on people's lives and interactions in the therapy room. The subsequent chapters help fortify and expand the foundation for future, more rigorous studies aimed at disambiguating the complexity of the voice-psyche relationship.

2.0 Measuring Communicative Congruence and Communicative Dysphoria in a Non-Disordered Sample

This is the **accepted version** of an article published in the *Journal of Speech, Language, and Hearing Research*. The published version is available at https://doi.org/10.1044/2022_JSLHR-21-00459.

2.1 Introduction

Experienced voice therapists are likely familiar with the patient complaint that "this isn't *my* voice." Complaints like these are often made by people who have developed a voice disorder and feel their dysphonic voice is now incongruent with their sense of self, as well as by patients in voice therapy who feel their new target behaviors are somehow misaligned with important aspects of their identity. Similarly, some transgender and/or nonbinary people work to develop new voice and speech patterns to better align their communication behaviors and gender identity. However, meeting the goals of voice therapy does not necessarily ensure an experience of congruence between one's sense of self and their communication behaviors.

It seems reasonable to expect that a strong sense of incongruence might negatively impact voice therapy adherence and attendance, especially if the recommendations for addressing the patient's voice concerns are in conflict with their sense of self and identity. Further, patients with voice disorders have been shown to have higher rates of depression, anxiety, and report higher levels of stress (Dietrich et al., 2008; Marmor et al., 2016; Martinez & Cassol, 2015). Experiencing incongruence between one's sense of self and their communication may conceivably cause one to experience dysphoria, as incongruence is theoretically linked to increased "psychological entropy," or distress and emotional dysregulation (DeYoung, 2015). Experiences relating to congruence and dysphoria may be highly relevant to the field of speech-language pathology, but scientific investigation into these concepts is lacking in the field.

Here we present early findings on two constructs that relate to one's sense of self and their communication to establish a foundation for future research. While this line of investigation is still in its beginning stages, we propose that these concepts are relevant to both voice therapists as well as the broader field of speech-language pathology. Understanding these constructs may help to facilitate new patient outcome measures, whereby patient progress is not measured by physical discomfort, perceived vocal handicap, or vocal fatigue, but rather one's sense that their communication allows them to authentically convey their sense of self. Such an outcome measure has the potential to be used in areas such as voice, fluency, accent modification, expressive, receptive and/or pragmatic language, or augmentative and alternative communication. Additionally, voice therapy generally has low rates of patient adherence (Hapner et al., 2009; Portone et al., 2008). It seems plausible that prescribing a set of phonatory behaviors that are inconsistent with one's sense of self may prompt the patient to not continue with the prescribed voice therapy regimen. Finally, developing and refining our understanding of these constructs would provide speech-language pathologists an additional evidence-based framework for which to better understand and serve their patients.

2.1.1 Theoretical Background

We define *communicative incongruence* as a state when one's voice, speech, and/or language are not consistent with their identity(-ies).[1] The opposite of this concept—the state in which a person's voice, speech, and/or language are consistent with their prevailing sense of self/self-schemas—we call *communicative congruence*.[2] Potentially irrespective of one's sense of communicative congruence, some individuals also have an experience of disliking the way they sound when they talk. This experience is most popularly referred to as

[1] More detailed preliminary framing of communicative congruence and communicative dysphoria is presented in Welch & Helou (2021). That document should be viewed as an early working draft , with concepts and theoretical framing that will inevitably evolve.

[2] Note that this is a fully distinct construct from that in the literature which relates to speech congruence in dyads and larger groups of speakers.

"vocal dysphoria," though here we extend the same concept to include all spoken communication behaviors and features and thus employ the term *communicative dysphoria*. Clinical experience reveals that communicative dysphoria exists along a spectrum from mild to intense, though no systematic investigations of vocal or communicative dysphoria appear to exist in the extant literature.

The notion of "congruence," or the state of one's lived experience being consistent with their self-schemas, originates from the founder of humanistic psychology, Carl Rogers (1959). The concept of congruence continues to be highly relevant in most modern theories of psychology. For instance, it arises in Goffman's Social Interaction Theory (Goffman, 1959, 1963), Identity Theory (Burke & Stets, 2009), Self-Consistency Theory (Epstein, 1980; Sirgy, 1985), Emotional Intelligence Theory (Bar-On, 2001; Bar-On & Parker, 2000; Salovey & Mayer, 1990), and Embodiment Theory (Botvinick & Cohen, 1998; Longo et al., 2008; Tsakiris, 2016), leaving several options for framing our study of communicative congruence and dysphoria. We decided to frame our constructs within the Cybernetic Big Five Theory of personality, or CB5T (DeYoung, 2015), for several reasons that we will summarize here. The CB5T is a well-developed, rigorously tested, and modern theory of personality. First, it is the most recent "biologically based theoretical account" of the so-called "Big Five" personality traits (John, 2021, p. 70). The CB5T is designed to be inclusive of the full spectrum of human variation, including psychopathologies. The relationships between personality traits and psychopathologies have been well-studied and extend beyond the scope of the present paper (refer, for example, to Bagby et al., 2008; Tackett, 2006; Tackett & Mullins-Sweatt, 2021; Widiger et al., 2019; Widiger & Crego, 2019). However, this inclusivity is valuable to us given our interest in potential relationships between communicative congruence and depression. At its core, communicative congruence is rooted in identity experience and should be no less relevant or meaningful in patients who might have depression or clinical disorders of identity. Another major benefit of framing the present work in the CB5T model is that is has a directly associated and well-validated 100-item self-report personality measure, the Big Five Aspects Scale (BFAS), which we use in this study (DeYoung et al., 2007). Importantly, the CB5T also fully accommodates our conceptualization of

communicative congruence and communicative dysphoria. Specifically, the CB5T asserts that when a person experiences an incongruence between their lived experience and *characteristic adaptations* (i.e., what the lay person might perceive to be one's "identity"), they experience psychological *entropy*. Psychological entropy, which need not be conscious, represents a state of uncertainty, often as a result of threats to our adaptive goals. When severe enough, this entropy can lead to "emotional, motivational, cognitive, and behavioral dysregulation," as well as contribute to depression or other psychopathologies (DeYoung, 2015, p. 49). In order to rectify problematic incongruencies and decrease psychological entropy, a person must adapt or change their characteristic adaptations. What we refer to as communicative dysphoria maps onto the CB5T as the psychological entropy that people experience due to communicative incongruence.

CB5T asserts that personality traits are "probabilistic descriptions of relatively stable patterns of emotion, motivation, cognition, and behavior, in response to classes of stimuli that have been present in human cultures over evolutionary time" (DeYoung, 2015, p. 35). Further, the CB5T identifies that each trait plays a specific function within the broader cybernetic mechanism of "personality." Of particular interest here, the higher order metatrait Plasticity is the cybernetic mechanism that allows a person to easily update their characteristic adaptations. Said differently, a person who scores higher in Plasticity will more easily adapt their characteristic adaptations (i.e., be willing to shift or modify their "identity") and thus more quickly resolve any psychological entropy compared to a person who scores lower on Plasticity. Alternatively, the metatrait of Stability is the cybernetic mechanism that helps to prevent psychological entropy when conflicting information is presented. As such, a person who is higher in Stability will require a greater magnitude of discrepancy before they experience psychological entropy.

Having contextualized the concepts of communicative congruence and communicative dysphoria within the CB5T, we will now further describe our goals with the present study. By way of background, both authors have worked clinically with patients who have articulated experiences of what we have defined as communicative congruence and communicative dysphoria. Our clinical experience has suggested that higher levels of

communicative incongruence and communicative dysphoria might mediate therapeutic engagement and behavioral change. Importantly, though, a desire for communicative congruence and no dysphoria seems widespread if not universal, rather than limited to the population of patients seeking voice therapy. Before these constructs can be examined as potential mediators of clinical experience and behavior, they should first be understood at the simplest possible level and in a manner that generates data against which patient data might be later compared. For these reasons, we first sought to characterize and measure both constructs in a non-treatment-seeking sample. Given that both constructs of interest are decidedly complex and higher-order (that is, comprised of two or more as-yet unidentified independent random variables), and in light of central limit theorem (which predicts a normal distribution even if the compositional variables are not normally distributed), we hypothesized that communicative congruence and communicative dysphoria would both be normally distributed in a non-treatment-seeking sample.

Second, we wanted to measure the relationship between communicative congruence and communicative dysphoria. A central expectation in our theoretical framing of these constructs is that people who experience communicative *incongruence* should experience more communicative dysphoria (or psychological entropy, in CB5T terms). We hypothesized that people who report lower levels of communicative congruence (i.e., greater communicative *in*congruence) would report higher levels of communicative dysphoria.

Third, because we have contextualized communicative congruence and communicative dysphoria within the CB5T, we sought to empirically test if these constructs are consistent with the cybernetic mechanism of personality as described by DeYoung (2015). Specifically, we were interested in whether people who score lower in communicative congruence would be more likely to experience higher rates of depressive symptoms. This logic derives from DeYoung's stance that incongruence results in psychological entropy, which is theoretically thought to reduce one's psychological wellbeing and possibly contribute to depression.

At a broader personality level, we are also interested in whether people who score higher in the metatrait Plasticity are more likely to report more communicative congruence. This idea stems from the notion that people who are higher in Plasticity will more readily adapt their characteristic adaptations to minimize any incongruencies with their communication behaviors. We leveraged the BFAS to probe whether communicative congruence maps onto Plasticity in particular, or any of the other traits in the personality trait hierarchy of CB5T. Since it is the personality metatrait of Plasticity that theoretically allows people to adapt and change their characteristic adaptations, we hypothesized that people who score higher in Plasticity will report more communicative congruence.

Finally, as we previously noted, the concept of congruence is not new. However, the possibility that one's sense of self could be congruent with one's voice and speech has received relatively little attention in a programmatic line of research. To our knowledge, only Crow et al. (2019) have interrogated the construct of congruence in spoken communication/voice. In their study, they utilized a newly developed self-report measure of vocal congruence, the Vocal Congruence Scale (VCS). The VCS was adapted from another self-rating questionnaire designed to quantify the phenomenon of "embodiment" (Longo et al., 2008), and is designed to measure "the degree to which an individual identifies with their voice and if they believe their voice reflects their personhood" (Crow et al., 2019. p. 4). It poses questions such as "it seemed like my voice belonged to me" and "it seemed like my voice reflected who I am." The VCS is scored by summing responses using a scale from 1-5 (van Mersbergen, 2022). Although still in its early stages of validation, VCS is currently the best tool available to assess convergent validity with the construct of communicative congruence presented here. We hypothesized that our measure would display strong convergent validity with the VCS (Crow et al., 2019). If communicative congruence, which specifically encompasses more than just voice *per se*, does not demonstrate moderate to high convergent validity with the VCS, then further refinement of these ideas will be warranted.

By testing these hypotheses, we hope to advance the relatively modest extant literature on congruence with voice and speech behaviors. Measuring the distribution of

these constructs in the general population may better inform future studies and provide data that can be used to prospectively conduct power analyses. To our knowledge, this is the first study seeking to probe the relationship between communicative congruence and communicative dysphoria, both of which seem relevant to the practice of speech-language pathology. Additionally, by using the CB5T to generate testable hypotheses regarding these constructs, we can A) probe whether the CB5T is an appropriate theory onto which we can pin these constructs, and B) thoughtfully guide further refinement of how these constructs are defined, operationalized, and interpreted.

2.2 Materials and Methods

2.2.1 Participants

We recruited participants of all genders between the ages of 18-70 years old with no known presence of a voice disorder. We excluded adults above the age of 70 due to the increased likelihood of structural and physiological changes to the phonatory system related to presbyphonia. We recruited participants through flyers, social media posts, Pitt+Me (a university-based research recruitment tool supported by the National Institutes of Health through Grant Number UL1 TR001857, KL2 TR001856, and/or TL1 TR001858), and word of mouth. Recruitment materials indicated that participants would record themselves speaking, that their speech would be played back to them, and that they would have the opportunity to receive a $100 Amazon gift card.

2.2.2 Data Collection

The University of Pittsburgh's Institutional Review Board reviewed and approved this research study (STUDY19030430). Prior to the SARS-CoV-2/COVID-19 pandemic, we recruited participants via traditional flyers, word of mouth, and online postings, to complete

the study in person. During the pandemic, we suspended in-person data collection and recruited participants through online postings and collected data through a custom-built website (Hable, 2020). These data were collected as a portion of a broader ongoing research study.

The order of information presented in the manuscript mirrors the order in which participants engaged with the measures and tasks in the research study. For data collected in-person recordings were made in a sound treated booth. Participants completed a demographic questionnaire, the Big Five Aspects Scales (BFAS) (DeYoung et al., 2007), the Center for Epidemiological Studies – Depression (CES-D) scale (Radloff, 1977), and the Voice Handicap Index – 10 (VHI-10, Rosen et al., 2004). The demographic questionnaire asked participants to report their age, race, languages spoken, English proficiency, sex, gender, socioeconomic status, the type of setting they grew up in versus where they are currently living (e.g., suburban, rural), highest level of education received, their current job/occupation, hearing status (e.g., good, mild impairment, severe impairment), and the devices used to listen to and record their speech samples.

The BFAS is a validated personality scale where respondents answer 100 questions using a 5-point Likert scale from “Strongly Disagree” to “Strongly Agree” (DeYoung et al., 2007). Certain items are reverse scored. Each item corresponds to one of the ten aspects in the CB5T; subjects’ responses are averaged to yield a value for each of the aspects, ranging from 1 to 5. Scores from the corresponding aspects are averaged together to generate a participant’s score for each domain and metatrait. The domains (or Big Five) are Neuroticism, Agreeableness, Conscientiousness, Extraversion, and Openness/Intellect. These domains are combined to yield the two metatraits, Stability and Plasticity. Stability corresponds with Agreeableness, Conscientiousness, and the inverse of Neuroticism; Plasticity corresponds with Extraversion and Openness/Intellect. Refer to the Supplemental Materials for details.

The CES-D is a well-studied and validated measure of depression that asks respondents to rate how frequently in the last week they have experienced 20 symptoms of depression. Respondents answer using a 4-point Likert scale, ranging from 0 = “Rarely or

none of the time" to 3 = "Most or all of the time." After reverse scoring some of the items, participants' responses are summed together to generate a score from 0-60. It is important to acknowledge that the CES-D is a measure of depressive symptomatology at the time of administration and on its own is insufficient to diagnose someone with clinical depression (Lewinsohn et al., 1997; Radloff, 1977).

The VHI-10 is a validated measure of a person's perceived voice handicap. Participants rate how frequently they experience a series of 10 statements people use to describe their voice and the impacts it has on their lives. Respondents answer using a 5-point Likert scale, ranging from 0 = "Never" to 4 = "Always." Participants' scores are totaled to yield a score from 0-40. A previous study has established that scores above 11 are considered abnormal (Arffa et al., 2012).

All in-person data were collected and stored using Research Electronic Data Capture (REDCap) hosted at the University of Pittsburgh. REDCap is a secure, web-based platform designed to collect and manage data for research studies (National Institutes of Health support through Clinical and Translational Sciences Institute (CTSI) at the University of Pittsburgh (Grant Number UL1-TR-001857).

Participants then sat across from a free-standing microphone (Blue Yeti USB microphone; Baltic Latvian Universal Electronics, LLC, Westlake Village, CA, USA), which was set to a cardioid polar pattern and situated 46cm from their mouth, as measured manually by the investigator just prior to recording. Mouth-to-mic distance was visually monitored by the investigator for the duration of the brief speech samples, and re-measured if the participant appeared to shift their mouth-to-mic location substantially during the recording session. This microphone captures ultra-high resolution 24-bit/192kHz digital recordings with a frequency response of 20-20kHz, sensitivity of 4.5 mV/Pa (1 kHz), and maximum SPL of 120dB (THD: 0.5% 1kHz). The microphone was attached to a laptop computer (Dell Latitude 5590 running Microsoft Windows 10 Pro). Attached to the laptop were two Bose Companion 2 Series II Multimedia speakers (Bose Corporation, Framingham MA) placed in a stereo configuration at approximately 60^{o}s. Speech samples were recorded into Audacity (version 2.3.3, sampling rate 44,100 Hz). Participants were instructed to

produce all speech samples at a comfortable and typical pitch and volume. The prompts included: "Say 'ah' for 3-5 seconds," "Recite the months of the year," the six sentences from the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V; Kempster et al., 2009), The Rainbow Passage Fairbanks, 1960), the prompt "Describe how to make a peanut butter and jelly sandwich," and the updated Cookie Theft picture (Miro Inc. in Berube et al., 2019) with the instructions "Describe what is happening in this picture." Detailed instructions can be found in the Supplemental Materials.

After the participants completed their recordings, their recordings were then played back to them in the sound field at a comfortable volume. As the participants listened to their recordings, they completed the Vocal Congruence Scale (VCS; Crow et al., 2019). The VCS is a self-report measure where respondents use a 5-point Likert scale from 1 = "Strongly Disagree" to 5 = "Strongly Agree" to respond to a series of questions after performing a speaking or listening task. Participants also completed two additional communicative congruence and communicative dysphoria questions. The first custom question measured communicative congruence by prompting participants to respond to the following prompt with a visual analog scale (VAS)[3]: "*How congruent do you feel your voice and speech are with your sense of self? That is, individuals with HIGH congruence feel that their voice and speech accurately reflect who they are. Individuals with LOW congruence feel that their voice and speech do not match their sense of self.*" The VAS was marked with one anchor on each end, where "Not congruent" was on the left (equaling 0) and "Highly congruent" was on the right (equaling 100).

In the same manner, participants rated their sense of communicative dysphoria by responding to the following prompt: "*How do you feel about your voice and speech?"* with the anchors "Hate it so much that it negatively affects my life" (0) and "Love it so much that it positively affects my life" (100). Additionally, we provided a free form text box to type a

[3] We opted to use a VAS because it approximates an interval-level scale and is more information-dense (Matejka et al., 2016; Reips & Funke, 2008), more sensitive to small changes, and less likely to bias responses as compared to ordinal scales. These features appealed to us in this early endeavor to understand experiences of communicative congruence and dysphoria, since we lacked information on which we would base any ordinal markers. Any future work involving the validation of measures of communicative congruence and dysphoria must explore the tradeoffs of using one scale versus the other.

response to the prompt *"Why do you feel that way about your voice and speech?"* Finally, we also asked participants to rate their confidence in their responses using a VAS from "Not at all confident" to "Very confident."

The COVID-19 pandemic interrupted in-person data collection. We then used our custom-built website (Hable, 2020) to engage participants in the same processes described above, but in a quiet environment of their own choosing. All participants created a unique profile on the website before completing the demographics questionnaire, BFAS, VHI-10, and the CES-D. They were then prompted with written instructions to record their speech samples. Participants recorded the speech samples one at a time in the same order as the in-person participants. All recording prompts instructed participants to record their audio in a quiet location, and no further guidance was provided. After recording all their speech samples, participants were directed to a page to complete the VCS and the congruence and dysphoria questions while their speech samples automatically began to play back to them. In total, this experiment lasted 15-20 minutes. Our research team manually verified absence of invasive background noise by listening to each speech file before including it for analysis; no files were excluded on this basis as all were perceptually deemed to be absent of background noise. The custom-built website to collect data included a feature that exported the data into a Microsoft Excel Spreadsheet. These data were exported, downloaded, and then imported into the statistical analysis software as described below.

2.2.3 Statistical Analyses

All data were reduced and analyzed in R 4.0.2 (R Core Team, 2020). Because of the differences in participant engagement (in-person versus online), all statistical models in the current manuscript were compared across recruitment groups, though none of the analyses showed any statistically significant differences so all participants were grouped together in reported analyses. The coefficient estimates, t-values, and *p* values of the fixed effects for the method of data collection are included in the Supplemental Materials. We combined the in-person and online data frames and calculated each participant's scores for the

personality traits on the BFAS, CES-D, and VCS. We normalized all scores to z-scores to allow us to compare scores across scales. Data and code scripts are available upon request.

To test our first hypothesis that communicative congruence and dysphoria are normally distributed, we used Shapiro-Wilk tests and Q-Q plots to assess normality. We used a simple linear regression to test the remainder of our hypotheses: (1) that lower communicative congruence predicts higher measures of communicative dysphoria; (2) that individuals who report higher levels of communicative congruence score lower on a measure of depression; and (3) that people who score higher in the personality trait Plasticity will report higher levels of communicative congruence. To assess convergent validity, we examined the scores on our question of communicative congruence and the VCS using a Pearson correlation. In addition to testing these hypotheses, we also performed exploratory analyses to see whether any of the 16 remaining personality variables from the BFAS predicted congruence. In total, with the exploratory analyses, we completed 19 linear regressions. To avoid possible Type 1 errors for these post-hoc analyses, we calculated a Bonferroni correction and adjusted our alpha to .0026.

2.3 Results

2.3.1 Participant Demographics

In total, 197 participants participated. However, one participant entered nonsensical responses in multiple free response boxes and their data were removed, resulting in a final n = 196. Participant demographic information is in Table 2-1. Our sample consists of primarily native English speaking, white cisgender women. Of the 196 participants, 43 participated in-person (22%) and the remaining 153 participated online (78%). The mean VHI-10 score was 7.3 (SD = 4.8). Scores on VHI-10 indicated that n=162 participants were within the normal healthy range (i.e., ≤11) and n=34 were outside of that range (i.e., >11).

The mean VHI-10 scores for the 162 participants within the healthy range was 5.6 (*SD* = 3.2), whereas those above that cutoff had a mean score of 15.1 (*SD* = 3). Given that we recruited participants who explicitly denied having a known voice disorder, these data indicate that up to 17% of our participants might have subclinical vocal impairment. Scores on CES-D ranged from 0 to 60. Lewinsohn et al. (1997) proposed a cutoff score of 16 to identify individuals at increased risk for being clinically depressed. The mean CES-D scores for all participants fell below that cutoff at 13.77 (*SD* = 13.2), and n=67 (34%) of our respondents at or above the cutoff of 16 (*Mean*=28.7, *SD* = 11.4).

2.3.2 Distribution of Communicative Congruence and Dysphoria

We hypothesized that both communicative congruence and communicative dysphoria would be normally distributed in a non-treatment-seeking sample population. Figure 2-1 shows the distribution of communicative congruence in our sample (*M* = 71.39, *SD* = 20.99, *Mdn* = 75). To test for normality, we visualized the Q-Q plots and utilized a Shapiro-Wilk test. Both the visual inspection of the Q-Q plot (Figure 2-2) and the Shapiro-Wilk test ($W = .94$, $p < .001$) indicate that communicative congruence is not normally distributed in our sample.

Figure 2-3 shows the distribution of communicative euphoria (the inverse pole of dysphoria) in our sample (*M* = 59.39, *SD* = 17.7, *Mdn* = 58). To test for normality, we visualized the Q-Q plots and utilized a Shapiro-Wilk test. Both the visual inspection of the Q-Q plot (Figure 2-4) and the Shapiro-Wilk test ($W = .99$, $p = .15$) indicate that communicative dysphoria is normally distributed in our sample.

Table 2-1 Demographic information of the current sample.

Sex	***N* (%)**	**Gender Expansive**	***N* (%)**	**Hearing Status**	***N* (%)**
Female	132 (67.3%)	No	189 (96.4%)	Excellent	105 (53.6%)
Male	64 (32.7%)	Yes	7 (3.6%)	Good	67 (34.2%)
Gender		**Race/Ethnicity**		Some difficulty	19 (9.7%)
				Much difficulty	2 (1%)
Agender	1 (.5%)	Asian	18 (9.2%)	Little or no hearing	3 (1.5%)
Female	127 (64.8%)	Black	10 (5.1%)	**English Proficiency**	
Genderqueer	1 (.5%)	Hispanic	6 (3.1%)		
Male	64 (32.7%)	Native American	3 (1.5%)	Beginner	0
Non-binary	3 (1.5%)	Other	2 (1%)	Moderately proficient	1 (.5%)
		Prefer not to say	1 (.5%)	Fluent	19 (9.7%)
		White	156 (79.6%)	Native	176 (89.8%)

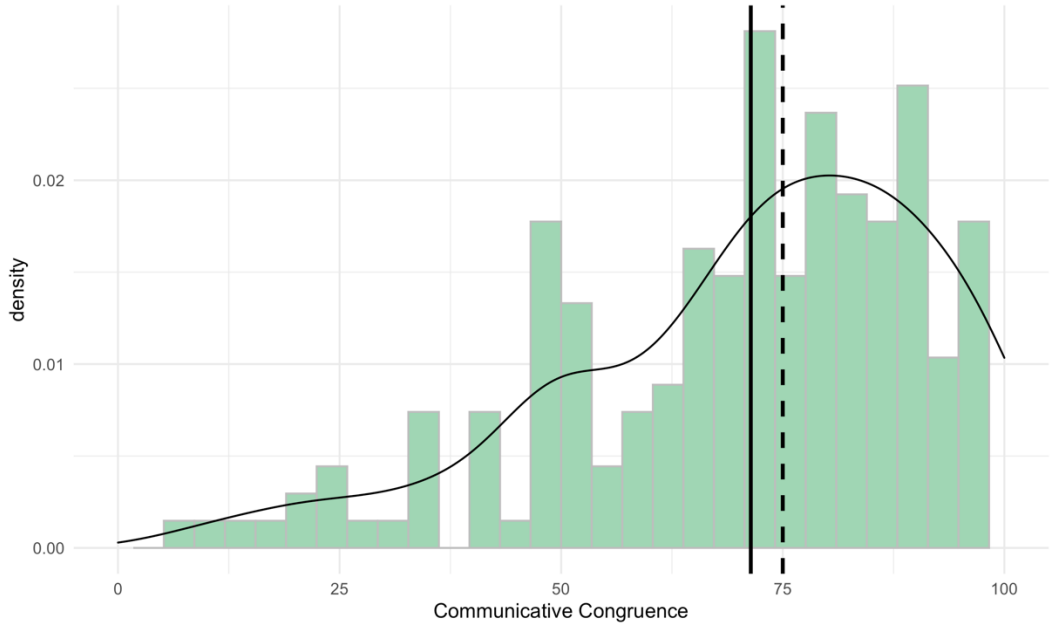

Figure 2-1 Congruence distribution. The distribution of participants' responses to "How congruent do you feel your voice and speech are with your sense of self? That is, individuals with HIGH congruence feel that their voice and speech accurately reflect who they are. Individuals with LOW congruence feel that their voice and speech do not match their sense of self." where 0 = "Not congruent" and 100 = "Highly congruent." The solid line represents the sample's mean (71.39), and the dashed line represents the sample's median (75).

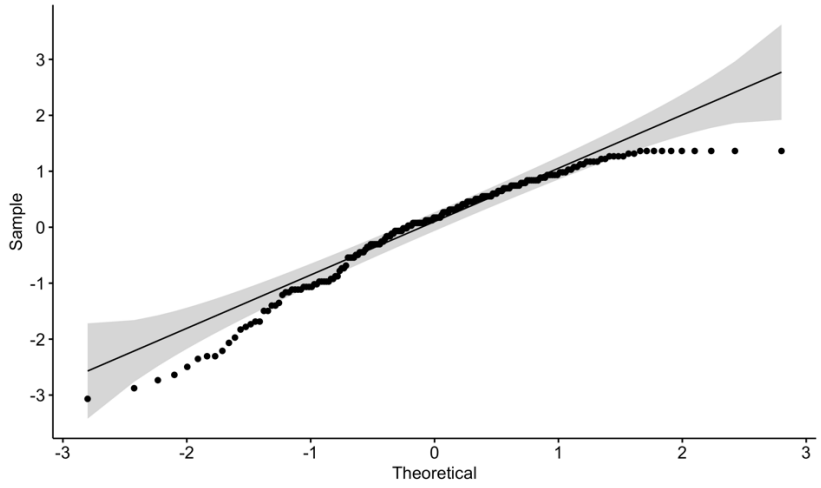

Figure 2-2 A Q-Q plot of the normalized communicative congruence distribution. The sample scores are normalized to show the mean score = 0 and the standard deviation = +/-1.

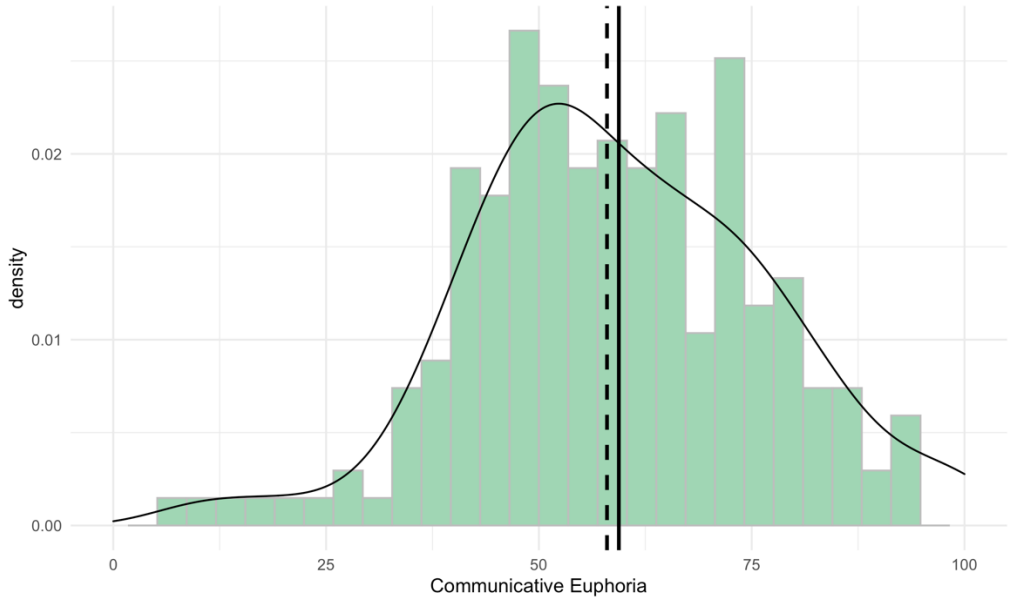

Figure 2-3 Communicative dysphoria distribution. Participants' responses to "How do you feel about your voice and speech?" where 0 = "Hate it so much that it negatively affects my life" and 100 = "Love it so much that it positively affects my life." The solid line represents the sample's mean (59.39), and the dashed line represents the sample's median (58).

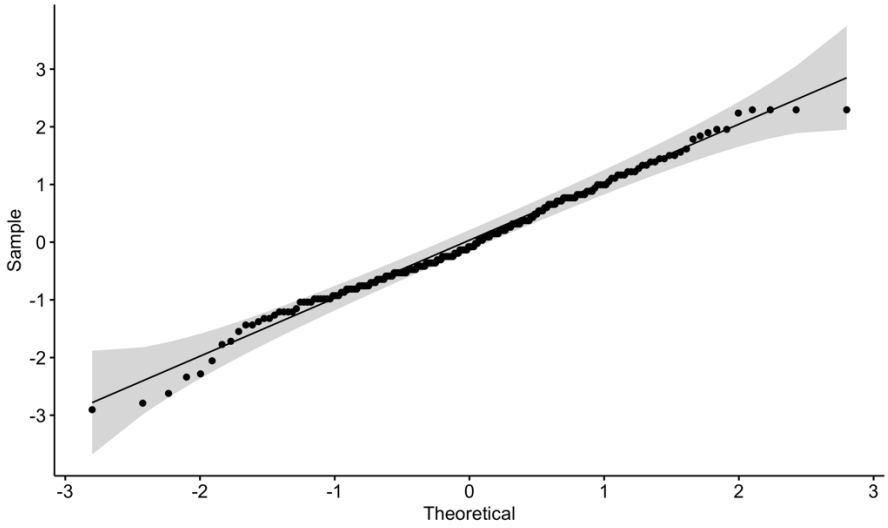

Figure 2-4 A Q-Q plot of the normalized communicative euphoria distribution. The sample scores are normalized to show the mean score = 0 and the standard deviation = +/-1.

2.3.3 Communicative Dysphoria Predicting Communicative Congruence

We hypothesized that communicative dysphoria would predict communicative congruence. Results from a simple linear regression indicated that one's score on the communicative dysphoria question significantly predicts their score of communicative congruence (β = .62, 95% CI [.51, .73], F(1, 194) = 119.3, p < .001), with an R^2 of .38. Figure 2-5 shows this relationship.

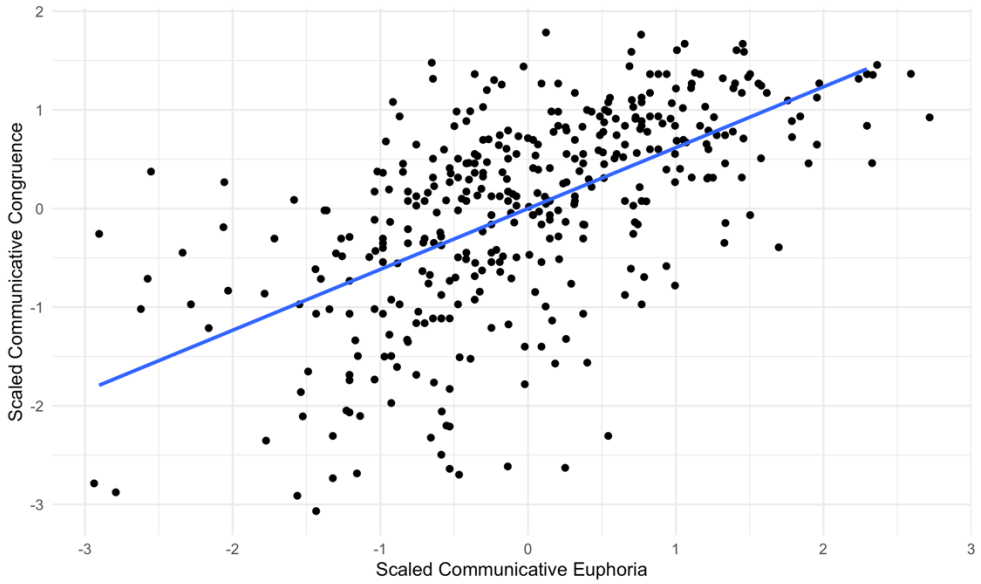

Figure 2-5 Relationship between communicative congruence and communicative dysphoria. Self-reported level of communicative dysphoria significantly predicts a person's self-reported score of communicative congruence. The x-axis represents the spectrum of dysphoria (negative values) to euphoria (positive values) continuum. The y-axis represents the spectrum of communicative incongruence (negative values) to congruence (positive values). Both scores are normalized to show the mean score = 0 and the standard deviation = +/-1.

2.3.4 Communicative Congruence and Depression

Based on our proposed theoretical foundation of communicative congruence, we hypothesized that one's communicative congruence would significantly predict their score

on the CES-D, a validated scale used to measure depressive symptoms. Results from a simple linear regression revealed that communicative congruence scores predict scores on the CES-D (β = -.28, 95% CI [-0.42, -0.14], F(1, 194) = 16.52, p < .001), with an R^2 of .08, shown in Figure 2-6.

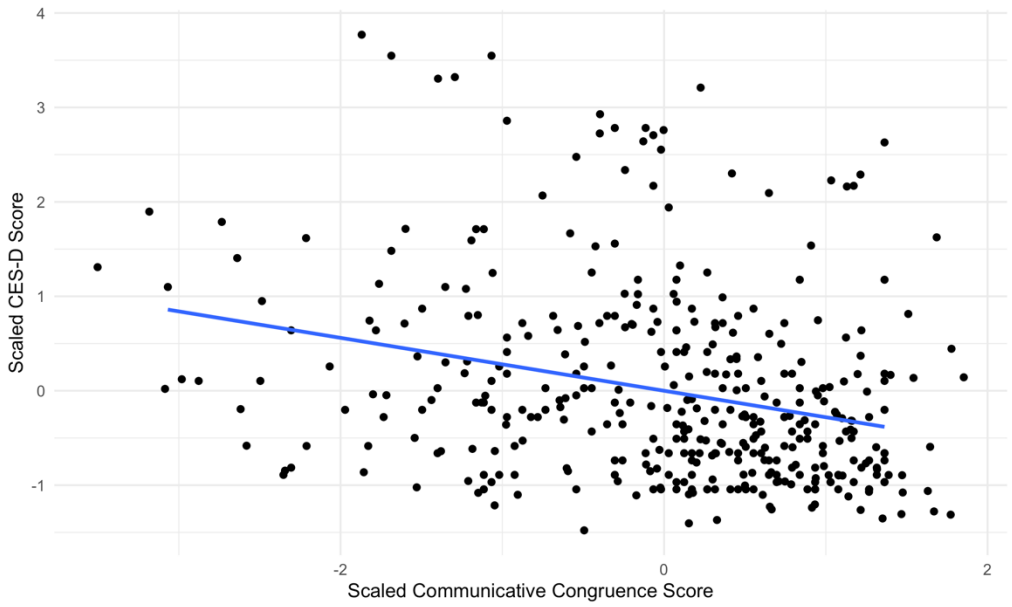

Figure 2-6 Relationship between communicative congruence and depression. All scores are normalized so that 0 = the mean and SD = +/- 1.

2.3.5 Communicative Congruence and Personality

2.3.5.1 Plasticity

Because CB5T asserts that the personality trait Plasticity is the mechanism that facilitates adjustments to one's characteristic adaptations, we hypothesized that participants who scored higher in the metatrait Plasticity would report higher levels of communicative congruence. Results from a simple linear regression supported this hypothesis (β = .22, 95% CI [.08, .36], F(1, 194) = 9.945, p = .00187) with an R^2 of .05. Figure 2-7 shows this relationship.

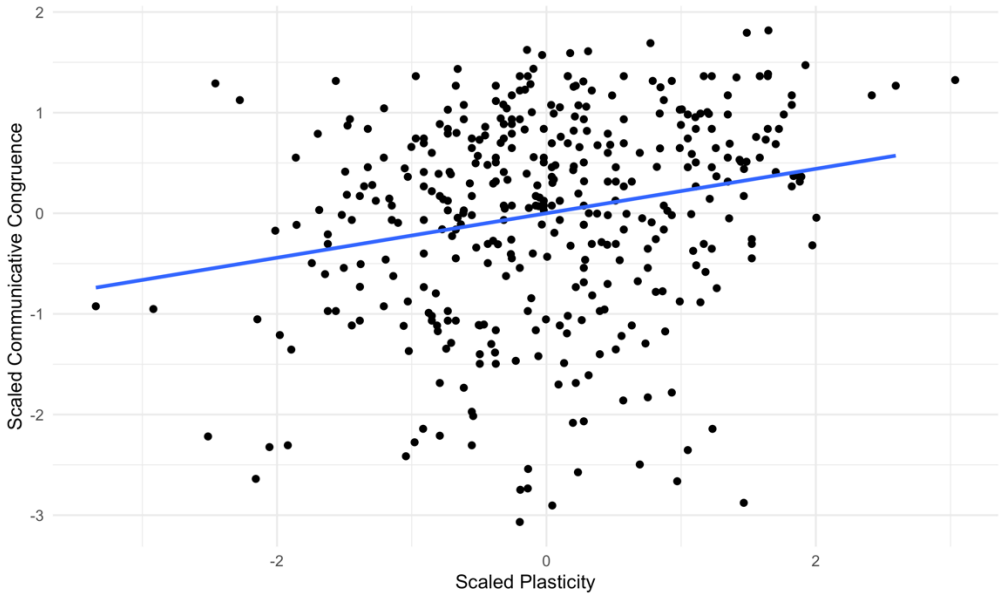

Figure 2-7 Relationship between Plasticity and communicative congruence.

2.3.5.2 The Remaining Metatraits, Domains, and Aspects of Personality

Due to the preliminary nature of our proposed constructs of communicative congruence, we sought to understand whether other variables within the personality hierarchy predicted communicative congruence. Analyses revealed a statistically significant relationship between communicative congruence and Extraversion and the two aspects that load onto it, Enthusiasm and Assertiveness, as well as Withdrawal (an aspect of Neuroticism). Figure 2-8 shows the traits and their corresponding *p*-values. Table 2-2 provides the results of the linear regressions for all of the personality traits and their relationship to communicative congruence. Figure 2-9 shows the relationship between each personality trait (not including Plasticity) and communicative congruence.

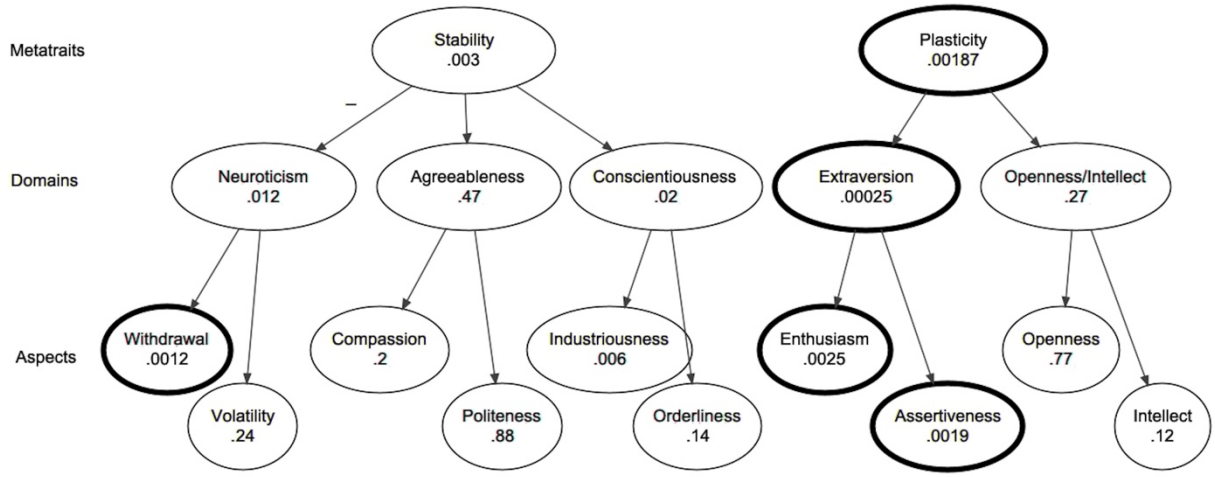

Figure 2-8 P-values of personality traits and communicative congruence. The personality traits in the Cybernetic Big Five Theory and the corresponding p-values from linear regressions where each personality trait served as the predictor variable for communicative congruence. Bolded circles represent p-values that reach statistical significance with a Bonferroni corrected alpha of .00263. Neuroticism is negatively related to Stability.

Table 2-2 Linear regressions between personality traits and communicative congruence. The results from each personality trait as the predictor variable for communicative congruence. Stability and Plasticity are the two broadest metatraits in the hierarchy. The Big Five domains correspond to their respective metatraits; Neuroticism is inversely related to Stability. Each domain has two corresponding aspects. The personality traits marked with * achieved statistical significance with a Bonferroni corrected alpha of .00263.

Trait	Regression Estimate	95% CI [LL, UL]	t-value	R^2	*p*-value	F statistic (1, 194)
Stability	.21	[.07, .35]	3.00	.04	.003	9.01
Neuroticism	-.18	[-.32, -.04]	-2.54	.03	.012	6.43
Withdrawal*	-.23	[-.37, -.09]	-3.30	.05	.001	10.87
Volatility	-.08	[-.23, -.06]	-1.18	.01	.239	1.39
Agreeableness	.05	[-.09, .19]	0.73	.00	.467	0.53
Compassion	.09	[-.05, .23]	1.29	.01	.2	1.65
Politeness	-.01	[-.15, .13]	-0.16	.00	.877	0.02
Conscientiousness	.17	[.03, .31]	2.41	.03	.017	5.8
Industriousness	.20	[.06, .33]	2.78	.04	.006	7.75
Orderliness	.10	[-.04, .25]	1.47	.01	.144	2.15
Plasticity*	.22	[.08, .36]	3.15	.05	.002	9.95
Extraversion*	.26	[.12, .40]	3.73	.07	.0003	13.92
Enthusiasm*	.21	[.08, .35]	3.06	.05	.003	9.36
Assertiveness*	.22	[.08, 36]	3.15	.05	.002	9.95
Openness/Intellect	.08	[-.06, .22]	1.11	.01	.266	1.24
Openness	.02	[-.12, .16]	0.29	.00	.772	0.08
Intellect	.11	[-.09, .25]	1.57	.01	.119	2.45

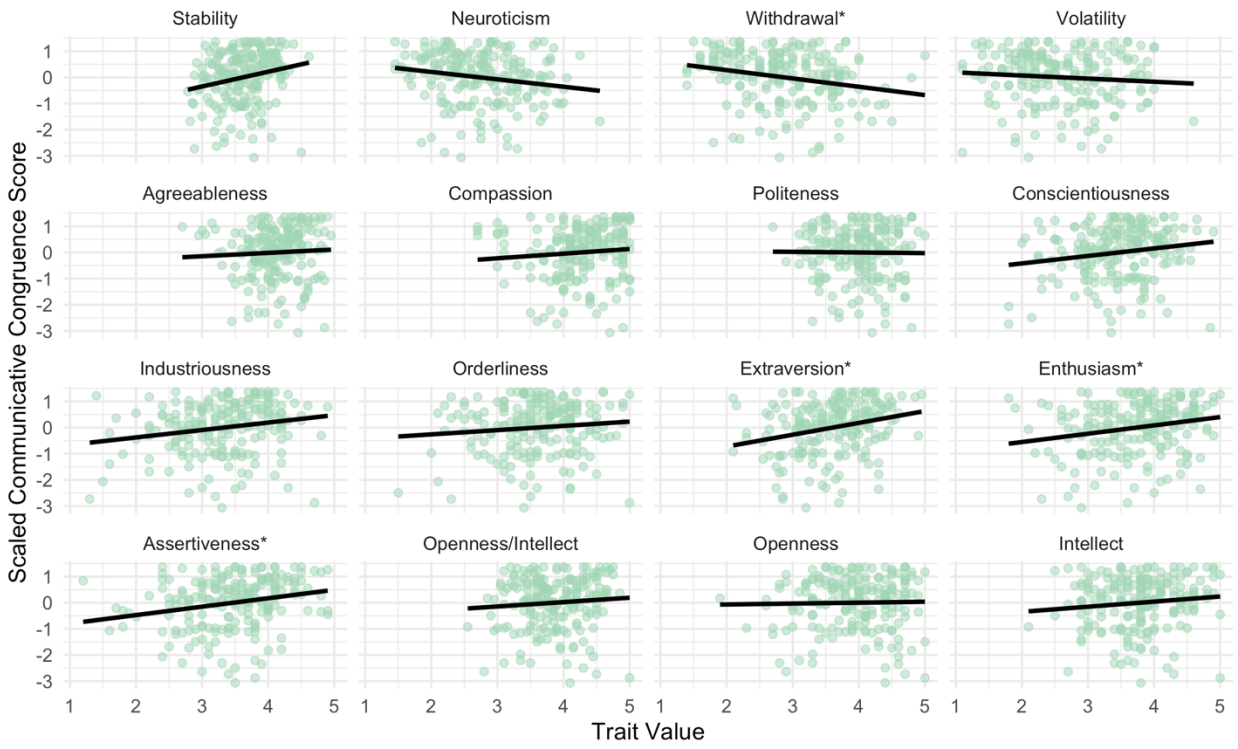

Figure 2-9 Scatterplots of personality traits and communicative congruence. Each graph depicts the linear regression between each personality trait and its relationship with communicative congruence. The relationship between Plasticity and communicative congruence is shown in Figure 7. Personality traits marked with * indicate that the relationship is statistically significant with a Bonferroni corrected alpha of .00263.

2.3.6 Convergent Validity with VCS

We hypothesized that our proposed construct, communicative congruence, would show convergent validity with a related construct, vocal congruence, as measured by the VCS. Figure 2-10 shows the relationship between these two constructs. Correlations where $r \geq .50$ are considered to have achieved convergent validity, with correlations $r \geq .70$ considered to be a more robust criterion of convergent validity (Carlson & Herdman, 2012). Our analysis shows that these two constructs are positively correlated and achieve high convergent validity, $r(194) = .69$, 95% CI [.60, .75], $p < .001$.

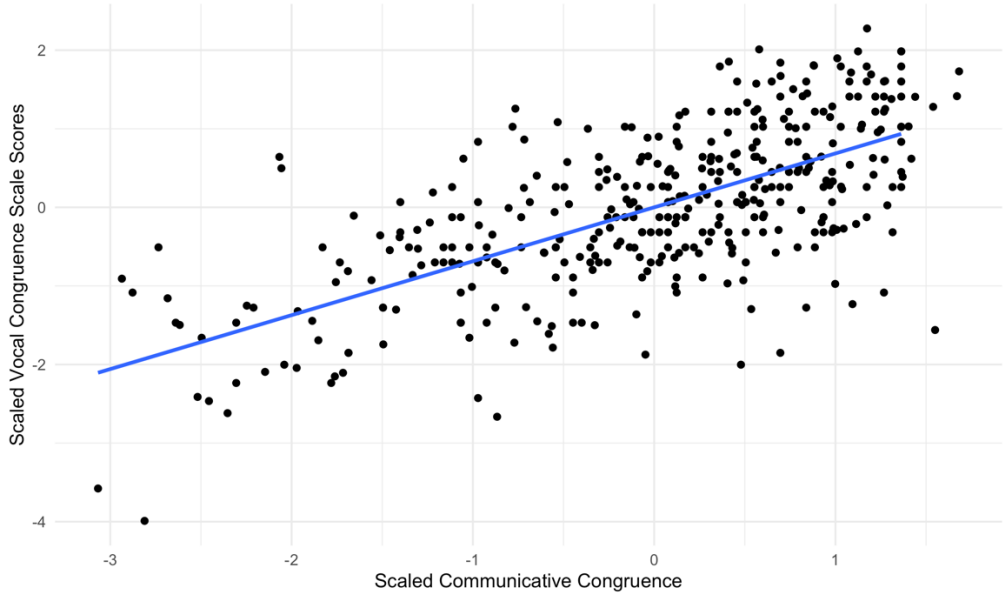

Figure 2-10 Scatterplot of communicative congruence and the Vocal Congruence Scale.

2.3.7 Post-Hoc Analysis

Approximately 83% of respondent's VHI-10 scores fell below the established "normal" cut-off score of 11 (Arffa et al., 2012). Only participants who denied the presence of a known voice disorder were eligible to participate. However, because most of the data were collected online, we were unable to verify that all participants did not have a clinical voice or other communication disorder prior to their participation. In listening to the recorded speech samples, none of the research assistants (undergraduate and graduate students in communication science and disorders) and the first author (a nationally certified speech-language pathologist who specializes in voice) identified overt dysphonia or signs of other speech disorders in any of the recordings. As such, we decided to group participants into two groups, those whose scores fell within the established normative values of the VHI-10 ($\leq$ 11), and those whose scores were > 11, which we termed "subclinical," given their assertion that they had not been diagnosed with and were not actively seeking treatment for a voice disorder.

After classifying participants into these two groups, we utilized a logistic regression to determine if one's reported communicative congruence significantly predicted which

group participants belonged to. All assumptions for logistic regression were met. The model indicated a significant relationship between their communicative congruence scores and classification into the subclinical group, $\chi^2(1, 194) = 154.43$, $p < .001$, OR = .38, 95% CI [.25, .56]. This preliminary finding suggests that people with a lower sense of communicative congruence might experience more perceived vocal handicap compared to their more communicatively congruent peers.

2.4 Discussion

Communicative congruence and communicative dysphoria are familiar concepts but newly operationalized constructs for purposes relevant to the field of speech-language pathology. Here we contextualized them within a modern, comprehensive, and mechanistic theory of personality, the Cybernetic Big Five Theory. To our knowledge, the present study is the first study to examine the relationships between these two constructs, as well as between communicative congruence and an existing measure of vocal congruence, depressive symptoms, and personality traits.

We hypothesized that communicative congruence and communicative dysphoria would be normally distributed. This was true in the present sample for communicative dysphoria, but not for communicative congruence which had a mild negative skew. The non-normality of the residuals for communicative congruence may be the result of self-selection bias. Individuals who experience relatively high levels of communicative incongruence and/or communicative dysphoria might be less likely to participate in a research study where one's speech recording would be played back to them, for fear of experiencing discomfort, psychological entropy, and/or an episode of dysphoria. A simple web search reveals numerous online discussions in which individuals claim to hate the sound of their own voice and speech to the point that they would avoid recording or listening to it, and in some cases even to the point of self-harm ideation. Further, our recruitment experience revealed that individuals with these perspectives were not motivated to participate in our

study; some said that the financial compensation would have to be exponentially greater to motivate their participation. Thus, we suspect that in the general population, many individuals exist who would rate themselves at the lowest bounds of communicative congruence, thereby reflecting a more normal distribution. However, skewed data certainly do exist in nature, e.g., life expectancy (GBD 2015 Mortality and Causes of Death Collaborators, 2016), and it is possible that people's sense of communicative congruence does in fact skew towards more congruence than incongruence. For instance, there may be sociocultural differences that influence the distribution of these data. At this time, we defer from drawing such firm conclusions given the preliminary nature of this study.[4] Future studies will need to probe these possibilities through different study designs, recruitment strategies, and compensation tactics.

Results supported our hypothesis that communicative congruence and communicative dysphoria would be statistically significantly related. As anticipated, participants who reported lower levels of communicative congruence were more likely to report that their voice and speech negatively affect their lives, while people who reported experiencing more communicative congruence reported more positive experiences with their voice and speech. However, the fact that less than half the variance of communicative congruence predicted communicative dysphoria reflects a possibility that these constructs might be more unrelated than they are related, at least in the way in which they were measured in the present study. This finding supports our definitional and theoretical premise that these two constructs are related but distinct from each other. Certainly, we can imagine scenarios where one feels they communicate in a way that is veridical but undesirable, e.g., "I don't sound confident because I am not confident [congruent], but that bothers me when I hear it in my voice or speech [dysphoric]," though this was a relatively uncommon pattern in the present study. More research will be required to rigorously measure and parse these constructs with good psychometric fidelity.

[4] To our knowledge, the present study and the initial study of the VCS (Crow et al., 2019) are the only published studies examining congruence with voice and/or speech. However, descriptive statistics for the VCS were not reported in Crow, et al. (2019), which further limits our ability to compare distribution of both measures (communicative congruence and vocal congruence).

Data also support our third hypothesis that people who report higher levels of communicative congruence would be more likely to score lower on a measure of depressive symptoms. The relationship between communicative congruence and CES-D scores was statistically significant, and communicative congruence explained 7.8% of the variance in CES-D scores. Although the effect size (r = -.28) is considered "small" (Gaeta & Brydges, 2020), depression is such a multifactorial and complex condition that for a single question probing our construct of communicative congruence to explain 7.8% of the variance is quite surprising. Clearly, some individuals report high levels of communicative congruence *and* high scores on the CES-D, and vice-versa. Relatedly and as mentioned above, one could feel congruent but also dysphoric about their communication, though relatively few people displayed that pattern in the current data set. These facts, combined with our clinical experience, leads to the interpretation that while a compromised sense of communicative congruence might not have strong negative impact on mental well-being for all individuals, it might indeed be an important mediator of mental health for some. As we continue to study communicative congruence and communicative dysphoria, future work might further identify which factor or combination of factors mediate this relationship for some, but not all, individuals. Finally, depression and other clinical disorders (e.g., anxiety) are associated with motor and behavioral changes (Bewernick et al., 2017), even specifically within the domains of voice and speech (Harati et al., 2018; Pampouchidou et al., 2017). As such, future research efforts should focus on identifying the subset of individuals within the larger group whose mental well-being might be meaningfully mediated by communicative congruence, and determine whether communicative congruence itself is related to actual communicative behaviors and engagement in the context of voice therapy.

Our fourth hypothesis—that individuals higher in Plasticity would report more communicative congruence—also stems from CB5T, which holds that the personality metatrait Plasticity facilitates the flexibility of one's characteristic adaptations (or what is often colloquially referred to as "identity"). The present data support the hypothesis that people higher in Plasticity report higher scores on our measure of communicative congruence. We interpret this finding to mean that a person who scores higher in Plasticity

may be better equipped than someone low in Plasticity to resolve any incongruences between their characteristic adaptations and their lived communication experiences. For instance, when working with a patient diagnosed with benign, phonotraumatic, mid-membranous lesions (i.e., "vocal fold nodules"), a common treatment goal may be to use an "easier" resonant voice. A person lower in Plasticity may resist adopting this less phonotraumatic resonant voice and state something along the lines of "That is just not how *I* talk." Conversely, a person higher in Plasticity in the same situation may more readily update their characteristic adaptations and seamlessly adopt the less phonotraumatic and more resonant phonatory behaviors.

To probe the relationship between personality traits and communicative congruence, we explored the first, second, and third levels of the personality trait structure in CB5T, which are respectively the two metatraits of Stability and Plasticity, the Big Five domains, and the ten corresponding aspects. Communicative congruence and Stability trended toward being positively correlated, but the initial statistically significant relationship did not withstand our statistical adjustments for multiple comparisons. It seems worth noting, though, that in the cybernetic system that is personality, DeYoung (2015) defines Stability as a mechanism for protecting one's characteristic adaptations from disruption; it does not necessarily directly influence behavior. Rather, a person high in Stability may require a greater magnitude of discrepancy before experiencing a sense of incongruence and/or the negative effects of psychological entropy. It is possible that such a person might feel that their communication is congruent with who they are, but this could derive principally from the fact that their communication behaviors (and any potential discrepancies) are not so severe that they experience communicative *in*congruence.

We also found that Extraversion, its two corresponding aspects Enthusiasm and Assertiveness, and the aspect Withdrawal predicted measures of communicative congruence. The grouping of these variables is in line with the findings related to Depression. Considerable evidence exists demonstrating a relationship between depression and

Extraversion, the aspects that load onto Extraversion, and Withdrawal[5] (DeYoung et al., 2007; Hakulinen et al., 2015; Karsten et al., 2012; Kotov et al., 2010; Watson et al., 2015, 2019). Therefore, we take these findings to suggest that people who experience communicative incongruence might be at an increased risk to also experience depression, and relatedly, might be expected to score lower on measures of Extraversion and its aspects, and higher in Withdrawal (an aspect of Neuroticism). Of course, we did not design this study to allow for any causal interpretations. Notably, the personality traits only explain a very small portion of the variance measured for communicative congruence. We interpret these findings to suggest that communicative congruence may be a separate construct than any one personality trait. This would be in contrast to other scenarios wherein one construct can be subsumed by existing personality hierarchies (e.g., it has been shown that the construct of personal "grit" can be explained by and integrated into the trait structure of conscientiousness (Schmidt et al., 2018). However, it remains possible that people who experience higher levels of communicative congruence are more likely to be extraverted and regularly engage in communication, a social activity, whereas introverted individuals may refrain from situations that involve communication, thus drawing awareness to their sense of communicative incongruence. Future research might identify whether these variables predict communicative behaviors.

Finally, results support our hypothesis that our single-item measure of communicative congruence demonstrates convergent validity with the VCS (r = .69). Definitionally, both vocal congruence and communicative congruence seem to examine one very similar construct of "congruence" relating to voice, speech, and personal identity/sense of self. However, they are derived from differing theoretical frameworks. As presented by Crow et al. (2019), the vocal congruence construct seems largely concerned with potential *mechanisms* of voice-related self-identity, and specifically the extent to which interoception drives this form of self-identity in comparison to exteroception. This is an important question for our field. At the same time and without awareness of our

[5] Higher scores in Neuroticism are also highly related to psychopathologies like depression. However, in our present study, only Withdrawal, an aspect of Neuroticism, reached statistical significance.

overlapping efforts, we attempted to operationalize and measure the construct of communicative congruence, though with different motivations and framing. Specifically, we sought to couch communicative congruence within an established theory of personality, and specifically within the CB5T, which seems to be a good fit for our constructs of interest. Although other theories have addressed issues of congruence, the CB5T has the major benefit of an associated personality battery that is modern and rigorously validated. Our experimental design was also influenced by our clinical perspective that congruence and dysphoria are distinct but strongly "yoked" experiences, so we were explicit about measuring them at the same time in one cohort. Finally, we were also purposeful in using the term "communicative" rather than "vocal," since voice is rarely perceived or produced in isolation from other speech and paralinguistic features. Even in voice therapy when phonatory and resonatory behaviors are ostensibly the main focus of attention, it is almost inevitable that some features of speech (e.g., timing, articulation, voice onset) are also modified. Likewise, when a person is asked to assess how they perceive the voice of themselves or others, they are likely incorporating their perceptions of their own speech as well rather than strictly voice-related features per se. It is important to note that although distinctions exist between vocal congruence and communicative congruence, these constructs are not at odds or mutually exclusive.

2.4.1 Limitations

We acknowledge several limitations of the present study. First, we recognize that online data collection has some inherent drawbacks. We recruited individuals without a known vocal pathology yet did not directly verify that individuals did not have a voice or other speech disorder. However, one undergraduate researcher and one certified, practicing, voice-specialized speech-language pathologist (BW) listened to each sample with the express purpose of identifying overt signs of a communication impairment, and none were identified. Second, because 78% of participants participated online, different types of microphones and speakers that vary in audio quality may have introduced variance into a

participant's perception of their communicative congruence. While our analyses indicated that responses from people who participated online did not meaningfully differ from those who participated in-person with standardized equipment, unknown variance is inevitably introduced when such variables are unaccounted for.

Although we sought to recruit as diverse a sample as possible, our cohort was not demographically representative of the US population in terms of sex assigned at birth or race/ethnicity. Notably, communicative congruence and communicative dysphoria have high relevance for transgender and non-binary individuals who may wish to work with a speech-language pathologist and/or voice coach. In the present sample, we are underpowered to draw conclusions about the impacts of gender identity on these constructs. However, future work may seek to measure these constructs in a sample of gender expansive individuals and compare those findings to the current largely cisgender sample.

Respondents reported varying degrees of English proficiency and hearing status. While individuals who self-reported non-native English fluency (.5%) and at least "some" difficulty hearing (12.2%) were relatively uncommon in our sample, we acknowledge that not controlling for these variables introduces some degree of extraneous variance in our data. These demographic questions were meant to be qualitative and not an inclusion or exclusion criteria since we could not actually verify or measure a person's English proficiency or hearing status. We would have benefitted from asking if hearing was aided during the research study, rather than only asking participants to affirm that they could hear themselves and the recorded samples sufficiently, and that they were completing the tasks in a quiet environment. Despite these shortcomings, the fact remains that individuals' experience of communicative congruence and communicative dysphoria remains legitimate irrespective of their English fluency and hearing status. Ultimately, we wish to know how these variables affect our proposed constructs of communicative congruence and dysphoria; however, we are underpowered to explore these questions given the current data and will try to parse these features in future studies.

Another limitation is that of self-selection bias that might influence our findings. As noted in the Methods section, these data were collected as part of a larger research study that involved collecting data and speech samples from individuals (our participants) and then playing those speech samples to a large group of listeners who would use the recordings as a basis for rating various demographic and personality features of the speaker. We would expect that individuals highest in communicative dysphoria or lowest in communicative congruence would have a relatively lower likelihood of participating in this research paradigm. A next step will be to recruit these individuals programmatically into a research paradigm that does not involve playing back participants' speech samples to cohorts of listeners.

Finally, and most notably, we lack validated measures to assess communicative congruence and communicative dysphoria. This study was undertaken in part to determine if measurement development and validation might be worth pursuing, and in service to that determination, we used custom-designed questions to quantify communicative congruence and communicative dysphoria. Our proxy for communicative dysphoria utilized a spectrum ranging from negative to positive valence (i.e., dysphoria to euphoria). However, we could alternatively speculate that the opposite of communicative dysphoria might *not* be euphoria, but rather the absence of communicative dysphoria. A more appropriate measure might prompt individuals to indicate the magnitude of their experienced communicative dysphoria from none (0) to overwhelming (100), instead of very negative to very positive. Future research should probe the construct and experience of communicative dysphoria further to optimize psychometric approaches.

Despite these shortcomings, we generated falsifiable hypotheses based on our theoretical framework and our analyses supported most of our predictions. While preliminary, these results support our proposed constructs of communicative congruence and communicative dysphoria, and demonstrate that these constructs are compatible and consistent with CB5T, the theory of personality in which these constructs are framed. More rigorous investigations into these constructs are warranted, including possible development and validation of a scale to measure these constructs.

2.4.2 Future Directions

This first study examining communicative congruence and communicative dysphoria leaves us with more questions than answers about these constructs and how they might relate to communication behaviors and voice therapy-related outcomes. As such, we refrain from drawing strong conclusions beyond describing their distribution and asserting that they warrant further investigation, as they may be relevant to both voice therapists and patients. It remains to be seen if communicative congruence is a state that varies highly depending on situation, or if it is more trait-like and consistent across situations. We suspect it may be a bit of both, akin to how anxiety can be experienced as both a state and a trait. Certain situations may cause an increase or decrease in one's sense of communicative congruence (e.g., feeling more congruent when speaking with friends than when speaking in a more formal register with professional colleagues). Alternatively, some people may experience quite stable levels of communicative congruence across time and situations. For instance, such an individual might hold that they have little volitional control over their communication behaviors and that "this is just the way I talk." Or, those whose identities and communication behaviors are most socially "mainstream" might enjoy relative stability of communicative congruence as compared to individuals who do not have the privilege and/or power we might associate with adhering easily to mainstream standards.

Additionally, it remains to be seen if one's sense of communicative congruence can be primed or manipulated. Future investigations may seek to establish the boundaries at which one's speech signal crosses from congruent to incongruent (or vice-versa) when manipulated systematically (e.g., in terms of mean fundamental frequency, resonance, rate). Understanding the dynamic aspects of communicative congruence will help further our understanding of communicative congruence and dysphoria and how they may relate to patients in the voice therapy room. Specifically, we speculate that baseline levels of communicative congruence and/or dysphoria might predict engagement in the work of behavioral change or outcomes of therapy. It also seems plausible that purposefully

modifying a patient's experience of congruence and/or dysphoria might facilitate engagement in behavioral communication change.

Future studies would benefit from including a non-skewed sample of people with communicative congruence, or from recruitment of two dichotomized samples wherein one group is characterized by low communicative congruence and the other by high communicative congruence. Our understanding of these constructs might also be strengthened by a qualitative approach such as a focus group or a survey that allows for open-ended answers in response to prompts about experiences of communicative congruence and communicative dysphoria.

2.5 Conclusion

This study is an early investigation into the constructs of communicative congruence and communicative dysphoria. Our findings show that communicative congruence and communicative dysphoria exist and vary in a sample population of individuals who deny the presence of a voice disorder. Our findings also demonstrate that a statistically significant relationship exists between communicative congruence, communicative dysphoria, and a validated measure of depressive symptoms. Additionally, our findings suggest that the personality trait of Plasticity may facilitate a person's sense of communicative congruence. Our exploratory findings also show that the aspect of Withdrawal, the domain of Extraversion and its two aspects, Enthusiasm and Assertiveness, also relate to communicative congruence, though these relationships may be due in part to the relationship between communicative congruence and depression. Additionally, we reached convergent validity with another measure of congruence, the VCS. These results were consistent with our predictions based on our theoretical framework. Future investigations into these constructs are warranted, as they may be highly relevant to the field of speech-language pathology more broadly. These constructs have the potential to inform new patient outcome measures, advance clinical care by providing clinicians with a novel framework to

better serve their patients, and to provide more insight into patient behaviors such as therapy adherence.

3.0 Examining Communicative Congruence and Dysphoria in Cisgender and Transgender/Non-Binary Adults

3.1 Introduction

Many people claim to "hate" the sound of their own voice. A simple online search reveals numerous online articles, blogs, and forums offering explanations and experiences of people hating the sound of their own voice. Informative articles describe the physics behind the differences in hearing one's speech played back on a recording through air conduction only. Yet, some users in online forums describe hating their voice when they speak in vivo. The bone/air conduction explanation would not apply to these experiences, and instead suggests that these experiences may be better explained by some other process(es), perhaps psychological in nature.

Welch & Helou (2021) provide a possible additional explanation for this phenomenon by proposing the concepts of *communicative congruence* and *communicative dysphoria*. Communicative congruence (CC) is the extent to which a person feels that their voice, speech, and/or communication are consistent with their identity/sense of self. Communicative dysphoria (CD) is the emotional, motivational, cognitive, and behavioral dysregulation that results from *communicative incongruence*. Some readers may be more familiar with the term "vocal dysphoria," a term often used within the transgender/non-binary community to describe feelings of dysphoria that arise due to their voice. We explicitly use the term "communicative" because the aspects contributing to one's experiences of in/congruence and dysphoria may be more readily attributable to aspects of speech, language, and/or communication rather than any specific phonatory aspects of the voice.

Although concepts of CC and CD are still in their empirical infancy, preliminary data suggest that CC and CD may have relevance to people with and without voice disorders. Welch & Helou (2022) examined CC and CD using two visual analogue sliders (VAS) in a

cohort of vocally healthy, predominantly cisgender adults (97%). In those 196 participants, CC approached a normal distribution (but skewed toward more congruent) and CD was normally distributed. As predicted, participants who reported lower levels of CC (i.e., incongruence) reported higher levels of CD. Data also supported the hypothesis that CC would be significantly related to Plasticity, a higher-order personality trait that is theoretically related to how well a person can update or modify their identity or characteristic adaptations (i.e., goals, interpretations, and strategies). Most notably, a significant relationship existed between CC and a validated measure of depression, where participants who reported higher levels of CC tended to report lower levels of depression symptomatology. These findings in a vocally healthy, cisgender sample provide initial evidence that experiencing a sense of incongruence between one's communication and identity may have implications for one's psychological well-being.

Although these data largely support the authors' hypotheses, we note several limitations and caveats. First, these results need to be replicated in a separate, larger sample. While the findings aligned with their theoretical framework, replicating results is an important part of the scientific process. Second, the sample likely had a self-selection bias since participants were required to record a speech sample that was later played back to them and other listeners. It is likely that individuals who experience high levels of communicative *incongruence* and/or high levels of CD would choose to not participate. This sample bias limits the ability to fully understand these constructs, and future work may benefit from a study design that does not require participants to hear a recording of their voice played back to them or others.

Third, the predominantly cisgender sample limits our ability to understand CC and CD in transgender/non-binary (TNB) individuals. Understanding CC and CD in TNB individuals is important for speech-language pathologists as some individuals from this community seek out voice therapists to create a more congruent communication profile. To date, the field lacks empirical evidence of CC in TNB individuals. Without empirical evidence, clinicians' abilities remain limited in terms of accurately assessing, treating, and measuring clients' outcomes of CC when providing gender-affirming voice care.

Fourth, more rigorous methods and analyses are necessary to better understand these processes. Because it was a preliminary study, the authors leveraged only simple regressions to avoid overfitting the data. Additionally, when the authors examined the relationships between CC and personality traits, they used the mean scores for each of the traits. This approach has two major limitations. First, calculating the mean score for each of the personality traits does not account for measurement error. Second, the higher order metatraits are defined as the shared covariance of their respective lower-order traits. Thus, by simply calculating the mean score, these scores contain extraneous variance due to measurement error and components of lower-order traits not relevant to the higher-order traits of interest.

One analytic approach to address these limitations is structural equation modeling (SEM). SEM is a highly flexible analytic framework, allowing researchers to test hypothesized relationships between variables by imposing model constraints. SEM has several key benefits, including the ability to incorporate latent variables which accounts for measurement error and provides a theoretically "purer" measure of the construct of interest. Additionally, researchers can specify multiple outcome variables within a hypothesized model and simultaneously estimate it, which reduces the likelihood of Type I errors that may occur due to calculating multiple, separate regressions.

We designed the current study to address the aforementioned limitations of Welch & Helou (2022). With this current study, we seek to replicate our previous findings in a larger, more gender diverse sample of participants. We also removed the recording and playback portion of the study design to minimize a self-selection bias in participants with lower CC and/or high CD. Finally, we leverage SEM to examine the relationships between variables and test our hypothesized model. We hypothesize that – 1) CC will be inversely related to CD severity; 2) TNB individuals will report lower average levels of CC, 3) the metatrait of Plasticity will significantly relate to CC, and 4) CC will be inversely related to a measure of depression.

3.2 Methods

The current study is one component of a larger research project designed to further investigate CD. The methods relevant to the current study will be discussed here. The current study is a cross-sectional survey design that was approved by the University of Pittsburgh's IRB (#STUDY19030430). Participants completed the online survey via the Research Electronic Data Capture (REDCap) platform, a secure, web-based platform to collect and manage data (National Institutes of Health support through Clinical and Translational Sciences Institute [CTSI] at the University of Pittsburgh [Grant Number UL1-TR-001857]).

3.2.1 Recruitment

Participants were recruited online from August 30th, 2021 through November 8th, 2022. To recruit participants, members from the research team shared flyers around the University of Pittsburgh campus, created posts on social media platforms (e.g., Facebook, Reddit), shared study information on listservs, and created a post on Pitt+Me, a participant recruitment database hosted by the University of Pittsburgh. Participants who completed the online REDCap survey were given the opportunity to receive a $100 electronic gift card. The study's inclusion criteria were participants who were at least 18 years old, proficient with reading/understanding English, and located in the United States. Exclusion criteria included anyone less than 18 years old and/or anyone located outside of the United States.

3.2.2 Measures

Participants were asked a series of demographic questions and then were provided a definition of CD. All questions in the survey were optional. Participants then responded to 17 questions about their experiences with CD. The results of these items will be reported elsewhere. Only one question about participants' experiences with CD is used for the

current study – *How would you describe the severity of your communicative dysphoria?* Participants responded using a VAS from "None" (0) to "Extreme" (100).[6]

Participants then responded to a series of eight questions designed to measure their experiences of CC, herein referred to as the Communicative Congruence Questions (CCQ). Participants responded to each item with a 7-point Likert scale from "Strongly disagree" (0) to "Strongly agree" (6); certain items were reverse scored. Because the survey was designed to encompass a wide variety of experiences relating to communication, including various communication disorders, two questions contained additional response options beyond the 7-point Likert scale. Specifically, the question *"People tend to make correct assumptions about me based on how I communicate"* had an additional response option "*I have no idea what assumptions people make about me based on how I communicate"*; likewise, the question *"I am fine with hearing myself on recordings, because the voice generally matches the way I think I sound"* had the additional response option *"Not applicable."* Items on the CCQ were designed to probe three different aspects of CC – i.e., voice, speech, and effects of communicative incongruence. Higher scores theoretically relate to more CC. Table 3-1 displays the items used for this measure.

[6] In Welch & Helou (2022), the concept of communicative dysphoria was framed from negative to positive – i.e., dysphoria to euphoria. However, here we chose to frame communicative dysphoria in terms of magnitude of severity – i.e., from absent to extreme.

Table 3-1 Items developed for the communicative congruence questions. Each item is intended to measure components of communicative congruence as it relates to voice, speech, and consequences due to (in)congruence. * = reverse scored.

Communicative Congruence Questions	
Voice Items	
1.	My voice matches my gender
2.	I think my voice should belong to someone else*
3.	I feel like my voice accurately represents "me"
Speech Items	
4.	The way I talk reflects my personality
5.	People tend to make correct assumptions about me based on how I communicate
6.	I am fine with hearing myself on recordings, because that voice generally matches the way I sound
Consequences Items	
7.	I have low self-esteem related to how I communicate*
8.	I feel I have to compensate in other ways to express who I am (e.g., physical presentation), because my communication is not sufficient*

The CCQ items used were generated from expert consensus. A series of 20 items were developed. A group of expert reviewers (voice-specialized speech-language pathologists and PhD students who do not study voice or voice disorders) provided feedback on the initial item set. All reviewers agreed that the questions were easy to understand but stated that some of the questions were repetitive. For the current study, we chose eight of the initial items that we judged to adequately reflect the three theoretical domains of interest – i.e., voice, speech, and consequences related to communicative incongruence. Items for the respective domains are summed together and used for the remainder of the analysis. If a participant did not respond to one of the items, the respective domain sum score for that participant was not calculated to avoid biasing the sum scores with artificially lower values.

Next, participants completed the Center for Epidemiologic Studies Depression Scale Revised (CESD-R; Eaton et al., 2004). The CESD-R is a 20-item scale of depression symptomatology. Participants report how frequently they have experienced each of the 20 symptoms in the last two weeks using a 5-point Likert scale from "Not at all or less than one day" (0) to "Nearly every day for 2 weeks" (4). Lewinsohn et al. (1997) suggest that a sum

score of 16 or greater indicates a risk of clinical depression, but also notes that the self-report measure alone is insufficient to diagnose depression.

Finally, participants completed the Big Five Aspect Scales (BFAS; DeYoung et al., 2007). The BFAS is a 100-item personality battery based on the CB5T. The BFAS contains 10 items for each of the 10 personality aspects. Participants respond to each item using a 5-point Likert scale from "Strongly Disagree" (1) to "Strongly Agree" (5). Participants receive a score between 1-5 for each personality trait by averaging the respective items associated with each trait, after reverse scoring certain items. The BFAS is a well-validated measure of a five-factor model of personality that measures three levels of the personality trait hierarchy (DeYoung et al., 2007; Weisberg et al., 2011).

3.2.3 Data Reduction and Analysis

All data were processed and analyzed in R (v4.0.2; R Core Team, 2020) via REDCap's secure application programming interface. Packages used to process and analyze the data included: *tidyverse* (v1.3.0, Wickham et al., 2019), *semTools* (v.0.5-6, Jorgensen et al., 2022), *and lavaan* (v.0.6.14, Rosseel, 2012). For the current study, we removed participants who did not complete the survey through the CESD-R. We also removed participants whose responses to free text items were perceived to be gibberish and/or whose responses did not appear to relate to the content of the question. Participants who responded to the additional response options of the two CCQ items (i.e., responses not following the 7-point Likert scale) were removed to maintain a parallel response structure for analysis.

The CCQ items represent a set of preliminary, unvalidated items to probe CC. Although the current study is not designed to be a validation study of these items, we fit two confirmatory factor analysis (CFA) models to examine the validity of these items for the purpose of the current study. First, we fit a three-factor CFA model to the CCQ items to examine if the items fit the theoretical three-factor structure – i.e., voice, speech, and consequences of incongruence. Then we fit a one-factor CFA to the data to examine if the individual items all map onto a single latent construct, CC.

The two CFA models were estimated via *lavaan* using maximum likelihood (ML) estimation. The latent variables' variances were set to 1 for model identification for the CFAs. We use the following global fit indices and their generally accepted cut offs to help aid with interpreting model fit. While these cut off values are generally well-accepted for assessing global fit, these values should not be viewed as perfect determinants of model fit (Marsh et al., 2004). We assess model fit via the χ^2, comparative fit index (CFI; > .95), Tucker-Lewis index (TLI; > .95), root mean square error of approximation (RMSEA; < .06), and the standardized root mean square residual (SRMR; < .08; Hu & Bentler, 1999; West et al., 2023). We set our alpha to .05 to determine statistical significance. If the model did not fit the data based on the global fit measures, the modification indices were inspected. The model was respecified based on the modification indices and then re-estimated until acceptable model fit was achieved.

Figure 3-1 depicts our hypothesized model based on the four hypotheses in Section 3.1. We tested our hypothesized model via *lavaan* using ML estimation. Since participants were not required to answer any of the questions, some data are missing (see Section 3.3.1). Four latent variables exist in the hypothesized model: the metatraits of Plasticity and Stability, CC, and depression. We used item parceling as indicators for the latent variables to improve power and better approximate a continuous variable (Sterba & Rights, 2023). Item parceling involves combining multiple individual items to serve as an indicator for a latent variable. For the traits of Plasticity and Stability we used six indicator parcels each; the 40 items of the BFAS for Plasticity and the 60 items of the BFAS for Stability were randomly allocated across their respective parcels. We used a similar approach for the latent variable of depression, distributing the 20 CESD-R items across four indicator parcels. The latent variable for CC had three parcels, reflecting the sum score of the respective voice, speech, and consequences of communicative incongruence items.

Because the indicators for Plasticity, Stability, and depression were randomly allocated, different results would be obtained depending on the items within the parcel. To address this limitation, we followed the random allocation procedure described by Sterba & MacCallum (2010) and Sterba (2011). Items for the respective latent constructs were

randomly assigned to an indicator parcel and the hypothesized model was fit. This process was repeated 100 separate times with parcels containing different combinations of items for each latent construct. The results reported herein are the pooled model parameter estimates using Rubin's (1987) rules with the weighted sum of the within- and between-imputation components. Tests of direct, indirect, and total effect of the latent variables were conducted via the Delta method .

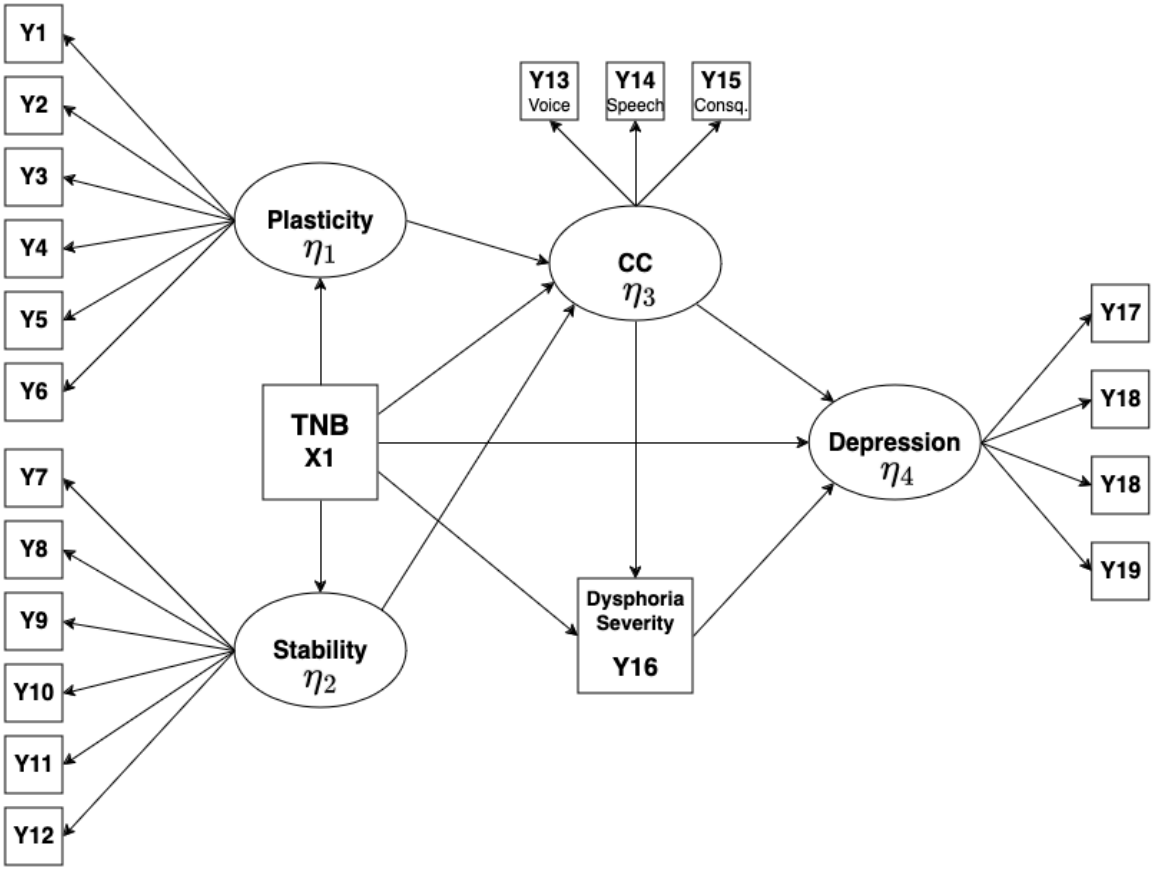

Figure 3-1 Initial hypothesized model. Ovals and square represent latent and manifest variables, respectively.

3.3 Results

3.3.1 Participants and Missing Data

A total of 382 participants consented to participate. After removing participants whose responses were deemed inconsistent with the questions and those who did not complete the depression measure (i.e., CESD-R), the final sample size was *N* = 243. Table 3-2 displays the frequency of missing data. Table 3-3 displays the demographics of the current sample. Overall, the sample was predominantly white, not Hispanic or Latinx/e. Although the sample was majority cisgender, 39.9% of the participants self-identified as transgender/non-binary.

Table 3-2 Frequency of missing data.

Variable	Missing *n* (%)
Sex assigned at birth	3 (1.23)
Communicative Congruence Questions – Domains	
Voice	2 (0.82)
Speech	3 (1.23)
Consequences	3 (1.23)
Communicative Dysphoria Severity	6 (2.47)
Center for Epidemiologic Studies Depression Scale – Revised	0
Big Five Aspect Scales (BFAS)	18 (7.41)

Table 3-3 Participant demographic information.

	Transgender *n* (%)		Cisgender *n* (%)		Full Sample *n* (%)	
Assigned sex at birth						
Female	73 (75.26)		104 (71.23)		177 (72.84)	
Male	22 (22.68)		41 (28.08)		63 (25.93)	
Intersex	2 (2.06)		1 (0.68)		3 (1.23)	
Gender Identity						
Female	15 (15.46)		93 (63.70)		108 (44.44)	
Male	20 (20.62)		34 (23.29)		54 (22.22)	
Agender	6 (6.19)				6 (2.47)	
Not disclosed	8 (8.25)		19 (13.01)		27 (11.11)	
Gender fluid	1 (1.03)				1 (0.41)	
Gender queer	4 (4.12)				4 (1.65)	
Non-binary	43 (44.33)				43 (17.70)	
Race						
Asian	9 (8.74)		18 (11.76)		27 (11.11)	
Black	3 (2.91)		11 (7.19)		14 (5.76)	
Native American	5 (4.85)		5 (3.27)		10 (4.12)	
Pacific Islander	0		1 (0.65)		1 (0.41)	
Prefer not to say	3 (2.91)		1 (0.65)		4 (1.65)	
White	83 (80.58)		117 (76.47)		200 (82.30)	
Ethnicity						
Hispanic or Latinx/e	9 (3.70)		21 (8.64)		30 (12.35)	
Not Hispanic or Latinx/e	85 (34.98)		116 (47.74)		201 (82.72)	
Unknown / Not reported	3 (1.23)		9 (3.90)		12 (4.93)	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**
Age	27.74 (8.55)	19-70	27.44 (8.30)	19-64	27.56 (8.38)	19-70

3.3.2 Response Distributions

Table 3-4 contains the descriptive statistics of the CD VAS, CCQ, CESD-R, Plasticity, and Stability for the two participant groups and for the overall sample. Figure 3-2 displays the distributions for these measures separated across the two participant groups.

Table 3-4 Descriptive statistics of variables in hypothesized model. VAS = visual analogue scale.

	Transgender *n* (%)	Cisgender *n* (%)	Total *n* (%)
Plasticity			
Mean	3.45	3.32	3.37
SD	0.45	0.49	0.48
Median	3.50	3.34	3.38
Min	2.30	1.88	1.88
Max	4.33	4.53	4.53
Stability			
Mean	3.17	3.30	3.25
SD	0.39	0.39	0.39
Median	3.15	3.25	3.20
Min	2.27	2.22	2.22
Max	4.07	4.62	4.62
Dysphoria Severity VAS			
Mean	64.52	44.70	52.73
SD	18.55	24.25	24.14
Median	67.5	50	60
Min	10	0	0
Max	100	83	100
Communicative Congruence Scale – Total Sum			
Mean	14.78	24.01	20.29
SD	7.57	8.16	9.12
Median	13.5	23	20
Min	1	2	1
Max	35	45	45
Center for Epidemiologic Studies Depression – Revised Sum Score			
Mean	31.27	22.80	26.18
SD	17.12	14.80	16.27
Median	28	19.50	24
Min	3	0	0
Max	75	58	75

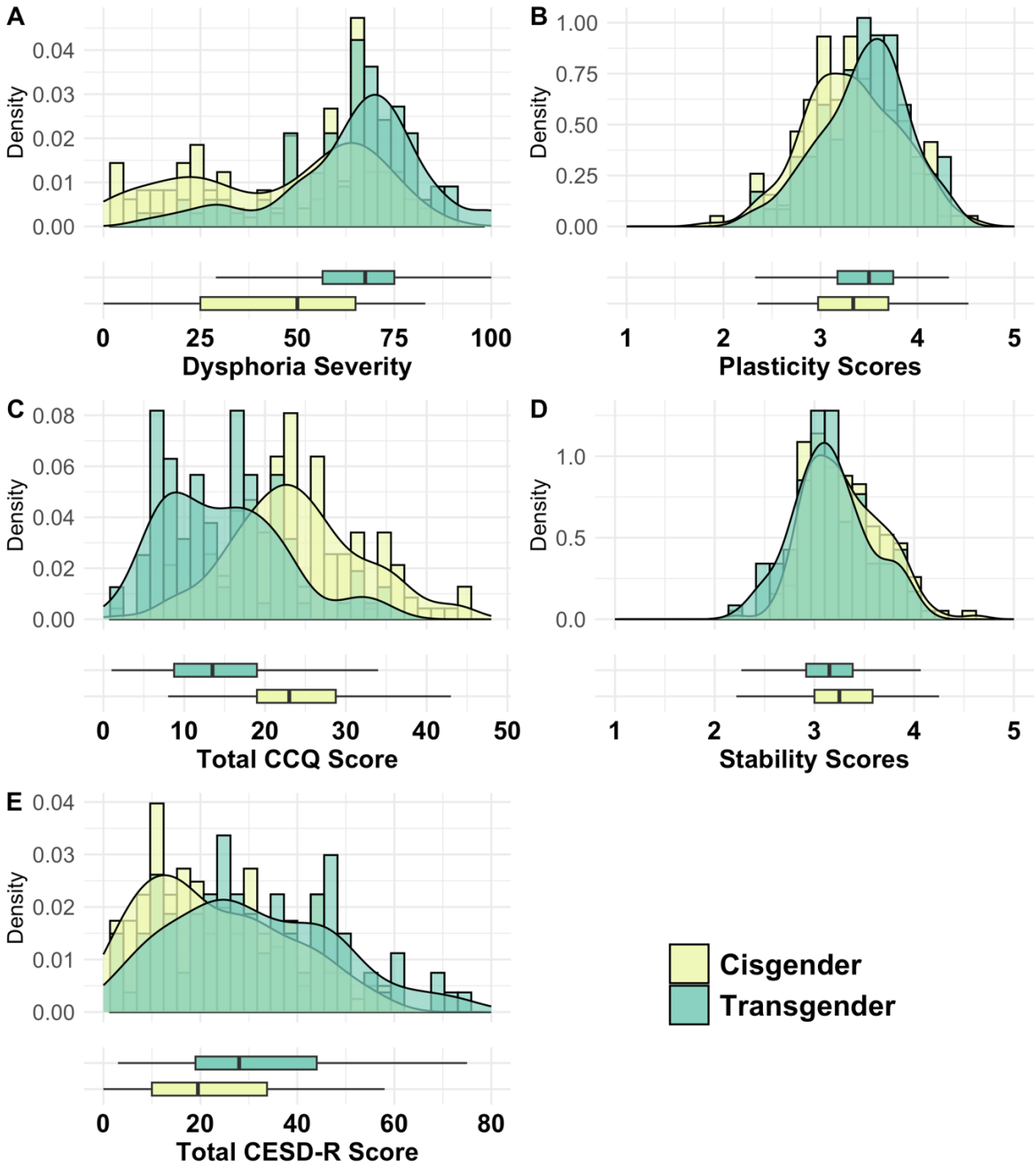

Figure 3-2 Density distributions of variables. Participants' responses distributions to self-reported measures of dysphoria severity (A), plasticity (B), total communicative congruence questions (CCQ; C), stability (D), and the sum score on the Centers for Epidemiologic Studies – Depression – Revised (CESD-R; E).

3.3.3 CFA on the CCQ Items

The first CFA tested they hypothesized three-factor structure of the CCQ items. Figure 3-3 displays the factor loadings and covariances of the three factors. Table 3-5 contains the model parameter estimates for the three-factor model. The fit indices for all the CFA models in this section are reported in Table 3-6.

The second CFA examined the factor loadings of the individual CCQ items on the latent construct of CC. The fit indices for the original one-factor model are reported in Table 3-6 for the CFA model "1-Factor." Based on the model fit, we examined the modification indices. The modification indices indicated that fit would be improved by allowing the errors of the two consequences items to covary. We made this modification and re-estimated the model; its fit indices are reported in Table 3-6 with "1-Factor – Mod." Figure 3-4 displays the factor loadings for the 1-factor model and Table 3.7 contains the model estimates.

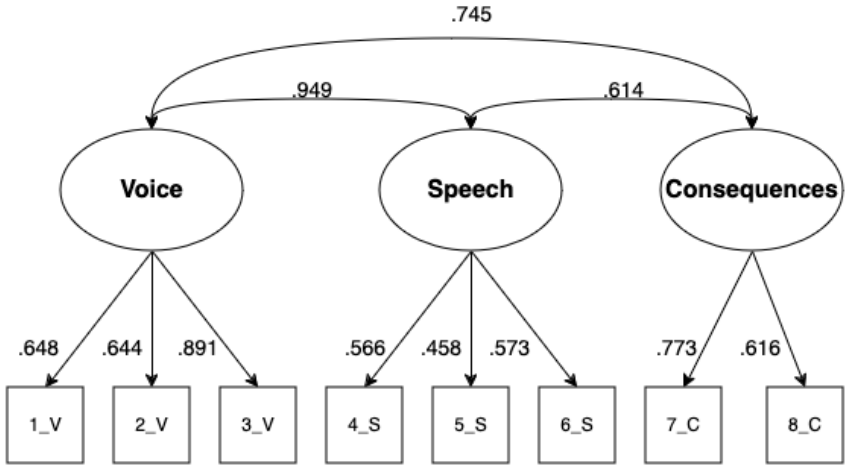

Figure 3-3 Confirmatory three-factor model of communicative congruence questions. Items from the communicative congruent questions are represented by squares; V, S, and C refer to the Voice, Speech, and Consequences subscales, respectively.

Table 3-5 Confirmatory three-factor model parameters. * = fixed model parameter for identification.

Parameter	Standardized Estimate	95% CI [LL, UL]	SE	*p*-value
Factor Loadings				
1_V	.648	[.563, .732]	.043	<.001
2_V	.644	[.559, .729]	.043	<.001
3_V	.891	[.838, .945]	.027	<.001
4_S	.566	[.455, .676]	.056	<.001
5_S	.458	[.339, .578]	.061	<.001
6_S	.573	[.463, .683]	.056	<.001
7_C	.773	[.665, .881]	.055	<.001
8_C	.616	[.507, .725]	.056	<.001
Covariances				
Voice & Speech	.949	[.835, 1.062]	.058	<.001
Voice & Consq	.745	[.629, .862]	.059	<.001
Speech & Consq	.614	[.437, .790]	.090	<.001
Variances				
Voice	1.000*			
Speech	1.000*			
Consequences	1.000*			
1_V	.580	[.471, .690]	.056	<.001
2_V	.585	[.475, .695]	.056	<.001
3_4	.205	[.110, .300]	.048	<.001
4_S	.680	[.555, .805]	.064	<.001
5_S	.790	[.681, .899]	.056	<.001
6_S	.672	[.546, .798]	.064	<.001
7_C	.402	[.236, .569]	.085	<.001
8_C	.621	[.486, .755]	.069	<.001

Table 3-6 Global fit indices for the comfirmatory factor analyses.

CFA Model	*df*	χ^2	*p-value*	CFI	TLI	RMSEA	SRMR
3-Factor	17	30.254	.025	.975	.959	.057	.038
1-Factor	20	54.45	<.001	.935	.909	.085	.053
1-Factor - Mod	19	33.146	.023	.973	.961	.056	.042

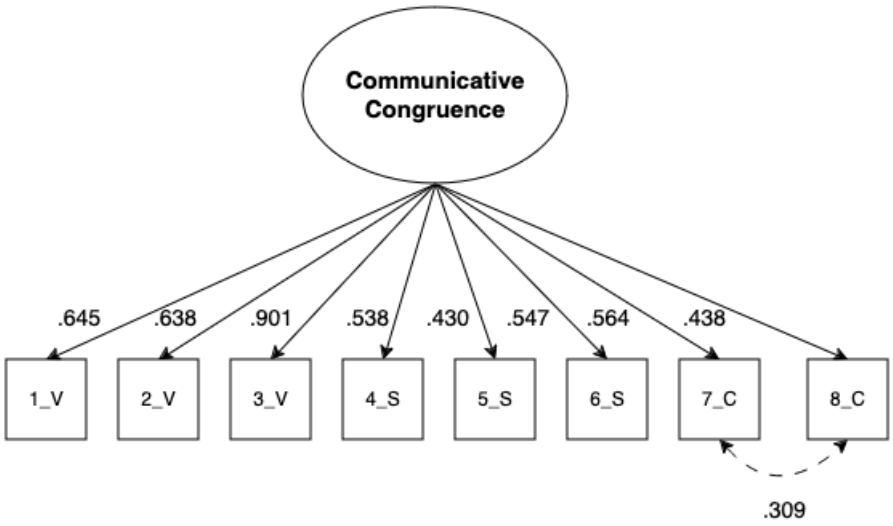

Figure 3-4 Factor loadings for confirmatory one-factor model. The dashed line represents the modified parameter to improve model fit.

Table 3-7 Confirmatory one-factor model parameters. * = Fixed model parameter for identification.

Parameter	Standardized Estimate	95% CI [LL, UL]	SE	*p*-value
Factor Loadings				
1_V	.645	[.560, .730]	.043	<.001
2_V	.638	[.552, .724]	.044	<.001
3_V	.901	[.851, .950]	.025	<.001
4_S	.538	[.438, .638]	.051	<.001
5_S	.430	[.318, .543]	.057	<.001
6_S	.547	[.448, .645]	.050	<.001
7_C	.564	[.467, .660]	.049	<.001
8_C	.438	[.326, .550]	.057	<.001
Covariances				
7_C & 8_C	.309	[.189, .429]	.061	<.001
Variances				
CC	1.000*			
1_V	.584	[.474, .693]	.056	<.001
2_V	.593	[.483, .702]	.056	<.001
3_4	.189	[.099, .279]	.046	<.001
4_S	.711	[.603, .818]	.055	<.001
5_S	.815	[.718, .912]	.049	<.001
6_S	.701	[.593, .809]	.055	<.001
7_C	.682	[.573, .791]	.056	<.001
8_C	.808	[.710, .906]	.050	<.001

3.3.4 Hypothesized Model

After examining the fit of the CCQ items, we tested the hypothesized model. The model successfully converged with admissible solutions for each of the 100 model estimations. The parameter estimates reported here are based on the pooled covariance matrix calculated as the weighted sum of the within-imputation and between-imputation components. All the global fit indices were within their accepted cut-off ranges except for the SRMR (SRMR = .156). We examined the modification indices, which indicated to regress the latent variables of depression on Stability (MI = 48.461). We fit this modified model using the same 100 random allocation procedure. The global fit indices were again all within their accepted cut-off range except for SRMR (SRMR = .114). We again inspected the modification indices, which indicated to allow the residuals of Plasticity and Stability to covary (MI = 25.867). We repeated the model estimation process again, and all the global fit indices were within their accepted ranges of good model fit. The global fit indices for each of the estimated models is in Table 3-8.

Table 3-8 Global fit indices for the hypothesized model and its modifications.

Hypothesized Model	*df*	χ^2	*p-value*	CFI	TLI	RMSEA 95% CI [LL, UL]	SRMR
Initial	181	36.729	1.000	1.000	1.324	0 [0, 0]	.156
Modification 1	180	19.141	1.000	1.000	1.363	0 [0, 0]	.114
Modification 2	179	10.270	1.000	1.000	1.383	0 [0, 0]	.033

Figure 3-5 contains the parametrized final model with the two modifications depicted by a dashed line. Table 3-9 contains all the model parameter estimates. When controlling for Plasticity, Stability, CC, and dysphoria severity, the direct effect of TNB on depression was not statistically significant (β_{Direct} = .280, 95% CI [-.117, .676], SE = .202, p = .167). However, these other variables significantly mediated the relationship between TNB-status and depression, with a total indirect effect of $\beta_{Indirect}$ = .507, 95% CI [.174, .841], SE = .170, *p*

= .003. Thus, the total effect of TNB on depression was also statistically significant (β_{Total} = .787, 95% CI [.428, 1.146], SE = .183, $p < .001$). Similarly, while the direct effect between CC and depression was not statistically significant, the relationship between CC and depression was significantly mediated by dysphoria severity ($\beta_{Indirect}$ = -.135, 95% CI [-.251, -.019], SE = .059, p =.023). The total effect of CC on depression was not statistically significant (β_{Total} = -.156, 95% CI [-.323, .011], SE = .085 p = .066). Plasticity was not significantly related to depression ($\beta_{Indirect}$ = .-.045, 95% CI [-.111, .013], SE = .032, p = .124), but Stability was significantly related to depression, as suggested by the modification indices (β_{Direct} = -.660, 95% CI [-.850, -.470], SE =.097, $p < .001$). While this direct effect was significant, the total indirect effect of Stability on depression was not significantly mediated by the other variables in the model ($\beta_{Indirect}$ = -.013, 95% CI [-.044, .019], SE = .016, p = .432). Thus, the total effect of Stability on depression was statistically significant (β_{Total} = -.673, 95% CI [-.865, -.481], SE = .098, $p < .001$).

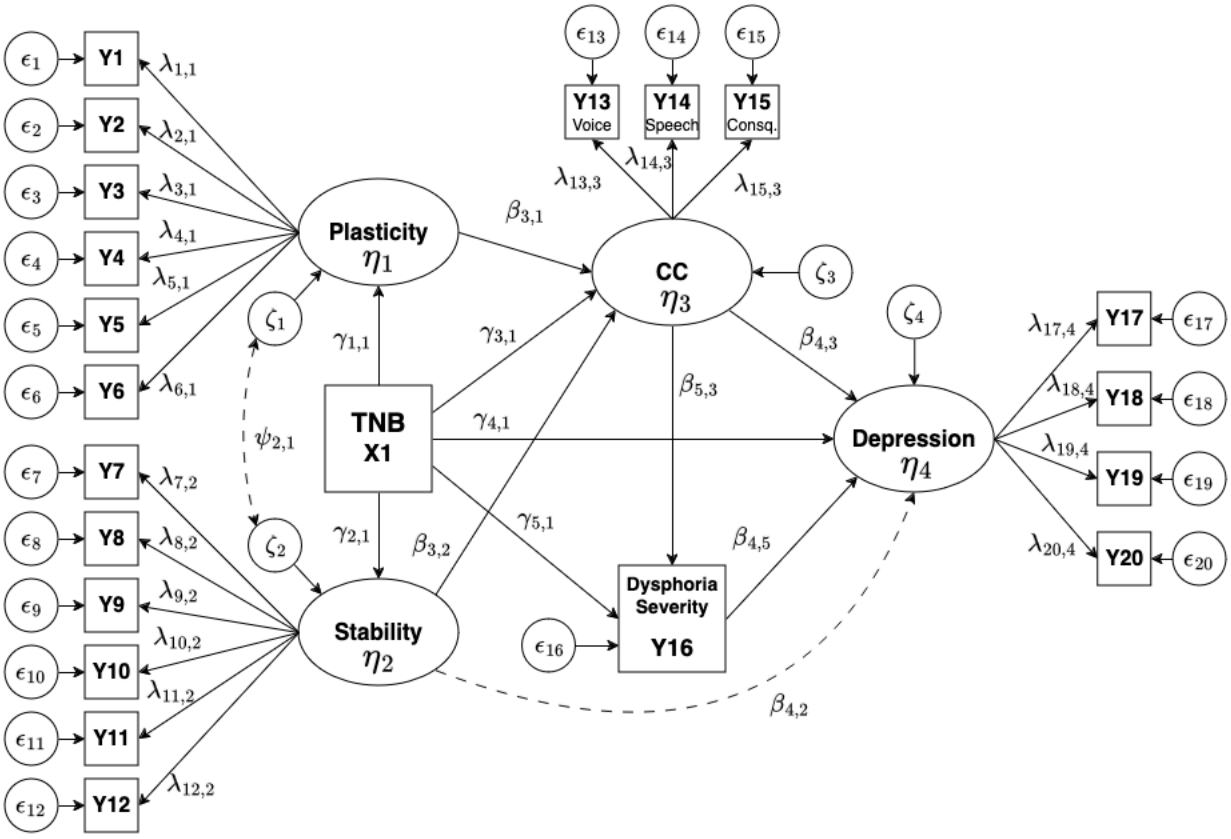

Figure 3-5 Final hypothesized model. The model fit of the initial hypothesized model improved after adding additional modified parameters (dashed lines).

Table 3-9 Pooled model parameters for the final hypothesized model. * = Fixed parameter for model identification.

Parameter	Estimate	95% CI [LL, UL]	SE	*p*-value
Factor Loadings				
Plasticity				
$\lambda_{1,1}$	.773	[.611, .936]	.083	< .001
$\lambda_{2,1}$	.767	[.611, .923]	.080	< .001
$\lambda_{3,1}$	.777	[.630, .923]	.075	< .001
$\lambda_{4,1}$	.771	[.594, .949]	.090	< .001
$\lambda_{5,1}$	.751	[.597, .904]	.078	< .001
$\lambda_{6,1}$	.759	[.595, .923]	.083	< .001
Stability				
$\lambda_{7,2}$	.767	[.612, .923]	.079	< .001
$\lambda_{8,2}$	.760	[.590, .930]	.087	< .001
$\lambda_{9,2}$	.761	[.584, .939]	.090	< .001
$\lambda_{10,2}$	.761	[.586, .935]	.089	< .001
$\lambda_{11,2}$	.746	[.572, .920]	.088	< .001
$\lambda_{12,2}$	.761	[.571, .950]	.096	< .001
Communicative Congruence				
Voice $\lambda_{13,3}$	.648	[.545, .751]	.053	< .001
Speech $\lambda_{14,3}$	.470	[.369, .571]	.052	< .001
Consequences $\lambda_{15,3}$	.503	[.403, .603]	.051	< .001
Depression				
$\lambda_{17,4}$	.677	[.575, .779]	.052	< .001
$\lambda_{18,4}$	.676	[.572, .780]	.053	< .001
$\lambda_{19,4}$	.680	[.575, .784]	.053	< .001
$\lambda_{20,4}$	.676	[.571, .781]	.053	< .001
Regressions				
Plasticity ~ TNB $\gamma_{1,1}$	.239	[-.058, .536]	.151	.114
Stability ~ TNB $\gamma_{2,1}$	-.382	[-.679, -.085]	.151	.012
CC ~ TNB $\gamma_{3,1}$	-1.679	[-2.095, -1.263]	.212	< .001
Depression ~ TNB $\gamma_{4,1}$	.280	[-.117, .676]	.202	.167
DS ~ TNB $\gamma_{5,1}$	.013	[-.288, .314]	.153	.931
CC ~ Plasticity $\beta_{3,1}$	.313	[.122, .503]	.097	.001

Table 3-9 (continued)

CC ~ Stability $\beta_{3,2}$	.082	[-.103, .267]	.094	.383
Depression ~ Stability $\beta_{4,2}$	-.660	[-.850, -.470]	.097	< .001
DS ~ CC $\beta_{5,3}$	-.513	[-.634, -.392]	.062	< .001
Depression ~ CC $\beta_{4,3}$	-.022	[-.239, .195]	.111	.844
Depression ~ DS $\beta_{4,5}$	.262	[.043, .482]	.112	.019
Variances & Covariances				
Stability & Plasticity $\psi_{2,1}$	.399	[.268, .530]	.067	< .001
Plasticity	1.000*			
ϵ_1	.386	[.189, .583]	.100	< .001
ϵ_2	.396	[.211, .581]	.094	< .001
ϵ_3	.382	[.218, .545]	.083	< .001
ϵ_4	.387	[.167, .608]	.112	.001
ϵ_5	.422	[.244, .599]	.090	< .001
ϵ_6	.408	[.217, .600]	.097	< .001
Stability	1.000*			
ϵ_7	.383	[.194, .572]	.096	< .001
ϵ_8	.393	[.178, .609]	.109	< .001
ϵ_9	.391	[.173, .608]	.110	.001
ϵ_{10}	.392	[.172, .612]	.111	.001
ϵ_{11}	.415	[.196, .633]	.111	< .001
ϵ_{12}	.391	[.150, .632]	.112	.002
Communicative Congruence	1.000*			
ϵ_{13}	.256	[.156, .356]	.051	< .001
ϵ_{14}	.606	[.477, .735]	.066	< .001
ϵ_{15}	.550	[.428, .671]	.062	< .001
Dysphoria Severity ϵ_{16}	.527	[.405, .648]	.062	< .001
Depression	1.000*			
ϵ_{17}	.209	[.074, .345]	.068	.003
ϵ_{18}	.211	[.066, .356]	.073	.005
ϵ_{19}	.204	[.069, .339]	.068	.003
ϵ_{20}	.211	[.070, .353]	.072	.004

Table 3-10 R^2 values for the endogenous structural variables.

Variable	R^2
Plasticity	.013
Stability	.033
Communicative Congruence	.432
Dysphoria Severity	.471
Depression	.409

3.4 Discussion

The current study recruited a relatively large sample of cisgender and TNB adults to measure CC and CD, and assessed how these constructs map onto personality traits related to identity (i.e., the metatraits of Plasticity and Stability) and depression. This study represents one of the largest investigations into CC and CD and sought to replicate the preliminary findings of Welch & Helou (2022). This study departs from previous investigations into CC and CD through its use of SEM, a highly flexible analytic framework routinely used in rigorous personality science.

To our knowledge, a validated measure of CC does not currently exist. To overcome this limitation, we generated a novel set of items designed to probe CC in the domains of voice, speech, and consequences of communicative incongruence. First, to ensure that the items corresponded to three hypothetical domains, we fit a three-factor CFA using the individual items. This three-factor structure fit the data well, supporting the hypothesized three subdomains related to CC we sought to measure with these questions. After demonstrating that the items corresponded to their respective domains, we fit a second CFA to examine how the individual items mapped onto a single latent variable of CC. This second CFA of CC also fit the data well, after allowing the residual variances of the two consequences items covary. We have two possible explanations for why these residuals covary. First, this additional covariance may be due to measurement artifact, i.e., these two

items were the only reverse-scored of the group of questions. Second, the notion of "consequences" of communicative incongruence may overlap with other constructs we did not measure (e.g., anxiety), and might explain the shared residual covariance.

After providing preliminary evidence of construct validity for the CCQ items, we used the CCQ components as indicators for a latent variable of CC to test our larger hypothesized model. We randomly allocated items into their respective indicator parcels and pooled the results across the 100 separate models. All 100 models successfully converged with admissible solutions. Following established model estimation, evaluation, and respecification procedures (Hoyle, 2023), we added to two additional model parameters that were not included in the initial hypothesized model, i.e., regressing depression on Stability and allowing the residuals of Plasticity and Stability to covary.

We included Stability in the current model for two reasons. First, both Plasticity and Stability are theoretically linked to identity/characteristic adaptations. Plasticity is the personality trait that allows for a person to update and modify their identity, while Stability is the personality trait prevents a person's characteristic adaptations from being disrupted (DeYoung, 2015). Of the entire personality trait hierarchy, these two personality traits are most pertinent to one's identity, and thus we included Stability in the model due to its possible relationship with CC. Second, in Welch & Helou, the relationship between Stability and CC approached statistical significance ($p < .003$) but was not statistically significant due to a conservative Bonferroni corrected alpha.

Although we did not hypothesize that Stability would directly relate to depression, the model fit the data better once we allowed for Stability to have a direct effect on depression. This significant, inverse relationship between Stability and depression is consistent with the extant literature. Stability is defined as the shared variance between the personality domains of Neuroticism (reversed), Conscientiousness, and Agreeableness. Although we are not aware of any studies specifically examining Stability and depression, previous research has found significant relationships between high Neuroticism and low Conscientiousness with higher levels of depression (e.g., Hakulinen et al., 2015; Klein et al., 2011; Kotov et al., 2010; Naragon-Gainey & Simms, 2017).

Given that Stability is the shared variance between Neuroticism (reversed), Conscientiousness, and Agreeableness, these well-documented relationships between Neuroticism, Conscientiousness, and depression provide empirical support to include a direct effect of Stability on depression in the current model. The relationship between Stability and depression was statistically significant.

The second modification to the original model was allowing the residuals of Plasticity and Stability to covary. We initially restricted these constructs from covarying, as these higher order metatraits are theoretically uncorrelated (DeYoung, 2015) and shown to be uncorrelated when using a multi-informant approach to measurement (DeYoung, 2006). Yet, imposing orthogonality on these variables resulted in model misspecification. After allowing these residuals to covary, the global model fit improved. Chang et al. (2012) demonstrated that relying on self-report measures of personality led to measurement artifacts that inflated the correlation between the metatraits Plasticity and Stability. The observed correlation between Plasticity and Stability based on self-report (r = .399) mirrors other published self-report correlations between the two metatraits (r = .45, DeYoung et al., 2002; r = .46, DeYoung et al., 2008).

This final model provides empirical support for most of our hypotheses. First, regardless of one's gender identity, CC was inversely related to CD severity. This finding is similar to Welch & Helou's (2022) initial investigation to CC and CD, with the caveat that here we chose to examine CD magnitude, i.e., absent to severe instead of negative to positive (dysphoria to euphoria). Second, controlling for Plasticity and Stability, TNB individuals reported significantly lower average levels of CC compared to the cisgender cohort.

Third, the metatrait of Plasticity was significantly related to CC. In addition to replicating the original findings in Welch & Helou (2022), this finding is slightly higher than the original correlation reported (r = .22). This increased relationship found in the current study A) controls for whether or not a person identifies as TNB, and B) is arguably a more accurate reflection of the strength of this relationship. The previous analysis did not account for measurement error, which may have attenuated the observed relationship. Although this

finding is promising, we also acknowledge that further validation of the items used to measure CC is necessary.

Unlike our previous study, a significant direct relationship did not exist between CC and depression. The current study provides a novel insight into our understanding of this relationship, whereby the relationship between CC and depression is mediated by dysphoria severity. The relationship between dysphoria severity and depression was significantly related, as was the total indirect effect of CC on depression through this connection. These results demonstrate that, although people who report lower levels of CC generally report higher levels of communicative dysphoria severity, people who feel a sense of incongruence may not report higher levels of depression unless they also experience a sense of dysphoria from that incongruence.

In addition to the specific hypotheses that we sought to replicate from Welch & Helou (2022), our hypothesized model revealed other notable findings. As mentioned previously, the relationship between Stability and depression was significantly inversely related. Additionally, the TNB participants reported significantly lower Stability. We are limited in our ability to examine why this group was significantly lower in Stability. We speculate that the process of transitioning (i.e., the process of aligning one's gender presentation with their gender identity) might be relevant to this finding, though we did not ask participants to provide any information regarding their desire for or experience with any social or medical transitions. The process of transitioning is a highly variable and person-specific journey that inherently involves shifting one (or likely more) component(s) of one's identity/characteristic adaptations. While the trait of Plasticity is associated with exploration and updating one's characteristic adaptations, transitioning likely involves uncertainty and instability around components of one's identity (e.g., *What does it mean for my children to no longer call me "Dad?"*), which may be reflected in lower trait Stability. While this relationship was statistically significant, it only explained 3.3% of the variance in Stability. This finding warrants further investigation before drawing a firm conclusion.

The hypothesized model likewise demonstrated that the TNB participants reported significantly higher depression, but that this difference was mediated by Plasticity, Stability,

CC, and dysphoria severity in the current model. The direct effect of TNB on depression was not statistically significant, but the total effect of TNB and depression in the model was statistically significant. This finding is consistent with prior literature demonstrating that LGBTQIA+ individuals and specifically TNB individuals report higher levels of depression (e.g., Azeem et al., 2019).

In our previous study, a simple regression between CC and depression accounted for 7.8% of the variance in the depression scores. In our final model, the exogenous and endogenous variables explained 40.9% of the variance of the latent variable of depression. This R^2 is much higher than our initial study; however, we employed a much more complex model than our previous investigation. Additionally, most of this explained variance is from adding a direct path between Stability and depression. Our initial model did not have a direct path between these variables and the variance of depression was much lower (R^2 = .179). Future work would likely benefit from continuing to examine these relationships, while ensuring to control for Stability, given its significant relationship with depression. Relatedly, we previously found that Plasticity explained 5% of the variance of CC. In the current study, Plasticity, Stability, and TNB-status explains 43.2% of the variance of CC. We attribute this increase to variance explained to the multivariate approach and accounting for measurement error in the current study.

The current study provides new insight into the constructs of CC and CD. Collectively, we interpret these findings to suggest that all individuals experience a range of CC, but that TNB individuals generally experience lower levels of CC. Additionally, CC and CD severity display an inverse relationship, regardless of gender identity. In contrast to Welch & Helou (2022), only people who reported higher levels of CD severity reported significantly higher levels of depression. This finding suggests that some people may experience lower levels of CC (i.e., incongruence), but are not likely to report higher levels of depression unless they also experience higher CD severity. This finding highlights CD severity as a mediating variable on the relationship between CC and depression.

3.4.1 Limitations and Future Directions

We acknowledge several limitations in the present study. First, the cross-sectional study design used limits one's ability to disambiguate inter- and intra-participant variability. We expect that one's experiences of CC and CD severity will vary over time and setting, and future work would benefit from a longitudinal design to better understand this variability. Second, we lack a validated set of items to measure both CC and CD. A key strength of this study is the use of multiple items and covariance modeling to use a latent variable of CC, a theoretically "purer" measure of the construct. However, further work is necessary to develop and refine items that could be used to measure CC. To date, other scales have been developed to measure "congruence," but these scales are still in the early stages of validation. Additionally, these scales often examine congruence specifically as it relates to voice (e.g., the Vocal Congruence Scale; Crow et al., 2019) or specifically as congruence relates to gender and voice (e.g., the Gender Voice Index [previously the Gender Spectrum Voice Inventory]; Van Hook & Duffy, 2021). More work is necessary to develop a set of items to probe CC at varying levels for all individuals, regardless of their gender identity. Future work would similarly benefit from developing multiple items to measure CD severity, allowing future research to use latent variable modeling.

Finally, the current study sought to recruit a relatively large, heterogenous sample of both cisgender and transgender individuals. Although we achieved a sample of almost 40% TNB individuals, this population is not a monolith. Although some TNB individuals may seek out gender-affirming voice services from voice professionals, not all individuals in this population will experience incongruence or seek services to change their voice. Likewise, in the current analyses we did not control for individuals' experiences with or desire for receiving gender-affirming voice care. Additionally, it is not true that gender-affirming voice care is only relevant for TNB individuals. The author has worked with several cisgender individuals who experience communicative incongruence as it relates to both their gender and other aspects of their identity. This area of voice care is a multi-faceted topic and future researchers should be mindful to not be reductive in their approach to studying this area of

voice and communication. Future investigations would benefit from having patients report their experiences with CC and dysphoria during voice (re)habilitation.

3.5 Conclusion

The current study sought to measure CC, CD severity, and depression in a large, heterogenous sample of cisgender and TNB participants. We found that the TNB participants reported lower levels of CC, and that CC was inversely related to CD severity, regardless of gender identity. These results also demonstrate that CD severity mediates the relationship between CC and depression – i.e., people are more likely to report higher levels of depression if they experience higher levels of CD due to experiencing communicative incongruence. Collectively, these findings replicate previous research into CC while also advancing our understanding of these constructs and their interactions.

4.0 Integrating Advances in Voice and Personality Science to Re-Examine the Trait Theory of Voice Disorders

4.1 Introduction

In the United States, approximately 30% of people will experience voice problems at some point in their lives, and an estimated 8% of adults currently report difficulties with using their voice (Bhattacharyya, 2014; Roy et al., 2005). People with voice disorders also report higher levels of suicidal ideation and suicide attempts (Kim et al., 2023) and higher levels of depression, anxiety, and decreased quality of life (Cohen, 2010; Dietrich et al., 2008; Marmor et al., 2016; Martinez & Cassol, 2015; Mirza et al., 2003). Additionally, people with voice problems report lower productivity at work, increased activity impairment, and may require a short-term disability leave of absence, annually costing the US economy $179 - $295 million (Cohen et al., 2012a, 2012b; Meyer et al., 2013).

Two of the most common voice disorders include *primary muscle tension dysphonia* (MTD) and *benign phonotraumatic lesions of the lamina propria*, also known as *phonotraumatic vocal hyperfunction* (PVH). These voice disorders comprise approximately 40% and 10-15% of voice disorder clinic caseloads, respectively (Altman et al., 2005; Coyle et al., 2001; Van Houtte et al., 2010). Unlike other voice disorders, MTD and PVH are thought to result from suboptimal respiratory and phonatory coordination – i.e., vocal hyperfunction – in the absence of an alternative etiology. When this vocal hyperfunction causes dysphonia in the absence of any structural changes or neurological impairment, it is considered MTD (also known as non-phonotraumatic vocal hyperfunction). When this vocal hyperfunction results in benign tissue changes to the lamina propria (i.e., vocal fold nodules, polyps, and reactive lesions), it is considered PVH (Hillman et al., 2020).

Despite the negative psychological, social, and economic consequences associated with voice disorders, the mechanisms underlying the pathogenesis and maintenance of MTD and PVH continue to not be well understood. Stress appears to play a key factor in MTD,

as laboratory studies have demonstrated increased intrinsic and extrinsic laryngeal muscle activation during acute stressors in vocally healthy women (Dietrich et al., 2019; Dietrich & Abbott, 2014; Dietrich & Verdolini Abbott, 2012; Helou et al., 2013, 2018, 2020). However, millions of people routinely experience stress, but manage to not develop MTD. Likewise, many people engage in high vocal doses and/or engage in phonotraumatic behaviors but do not develop phonotraumatic lesions. Essentially, these behaviorally driven voice disorders result from an otherwise healthy individual who, in a relatively short period of time, begins to engage in suboptimal phonatory behaviors that result in dysphonia warranting medical intervention.

Several lines of evidence suggest possible etiological factors that may contribute to MTD and PVH. Hillman et al. (2020) provide an excellent summary of these different lines of evidence, which are reviewed briefly here. First, individuals who develop PVH might be more susceptible to vocal fold tissue alteration/damage due to irritants (e.g., tobacco use) or genetic factors. Although this idea is accepted clinically, little-to-no empirical evidence exists to demonstrate conclusive findings. Second, individuals with MTD and PVH may engage in aberrant biomechanics when phonating, such as reduced aerodynamic measures (Espinoza et al., 2017) and increased intrinsic laryngeal muscle tension (Heller Murray et al., 2017). These findings support the idea that individuals with MTD and PVH use "inefficient" phonatory behaviors that contribute to developing/maintaining these disorders.

Additional evidence suggests that individuals with MTD and PVH might have anomalistic sensorimotor functioning, as they exhibit "non-typical" responses to pitch-shift paradigms (Stepp et al., 2017; Ziethe et al., 2019). However, what is considered a "typical" response to a pitch-shift paradigm remains unclear, as no known factors predict whether a person will oppose or follow the pitch change (e.g., Burnett et al., 1998; Franken et al., 2018). Although these findings suggest contributions from altered auditory feedback, more work is needed to better understand if altered auditory feedback is causal in nature. Finally, and most germane to the present project is the recognition that individual psychological differences may increase the risk of developing these voice disorders.

Relative to PVH, clinicians and researchers have generally considered MTD's etiology more psychological in nature. This perspective is apparent given the various names used to describe MTD in the literature, including *psychogenic dysphonia*, *conversion dysphonia,* and *hysterical dysphonia*. Early research described MTD as the result of an internal personality conflict or as a neurotic voice disturbance (Moore, 1939; Wyatt, 1941). Notably, these studies relied on early personality scales at a time when the field of Personality Psychology lacked a broad consensus on personality trait structure. Subsequent voice literature has suggested a psychoanalytic notion of "conflict over speaking out" (e.g., Baker, 2003; House & Andrews, 1988). Many individuals with these disorders, especially women, have been considered "emotionally unstable," and/or thought to have histrionic or hysterical personality traits (House & Andrews, 1987, p. 484, 1988).

Conversely, Yano et al. (1982) was one of the first studies that examined personality traits in patients diagnosed with vocal fold polyps or nodules (i.e., PVH). These authors found that individuals with PVH exhibited significantly higher Extraversion scores. Several years later, Green (1989) reported that children with VFNs displayed significantly higher scores on traits of Acting Out, Distractibility, Disturbed Peer Relations, and Immaturity.

While these early studies found meaningful relationships between personality traits and voice disorders, they lacked a comprehensive framework to understand these relationships. Roy & Bless (2000a) integrated then-contemporary ideas in Personality Psychology, including Eysenck's (1967) three-factor model of personality traits (i.e., Neuroticism, Extraversion, and Psychoticism) and Gray's neuropsychological model of the conceptual nervous system (Gray, 1975, 1987). Roy & Bless posited that people with vocal fold nodules were "neurotic extraverts" and that people with MTD were "neurotic introverts." This landmark paper has since become known as the *Trait Theory of Voice Disorders* (TTVD) and has influenced much of the research into personality traits and voice disorders in the decades since.

Generally, studies demonstrate that people with VFNs are higher in Extraversion and Psychoticism while lower in Constraint and Agreeableness (Mattei et al., 2017; Roy et al., 2000a, 2000b). Although Roy & Bless (2000a) hypothesized that people with PVH would

score higher on Neuroticism, these findings have been less robust,[7] with the most significant relationship between PVH and Neuroticism measured in children (Lee et al., 2021). Broadly, these studies converge on the idea that people with PVH are more social (and thus have higher vocal demand), but also may tend to be more socially dominant, aggressive, impulsive, and/or less agreeable. Researchers speculate that these combinations of traits lend individuals to be in the social limelight, or to speak over others in "an aggressive verbal style" (Roy et al., 2000a, p. 762). These behaviors and implied "vocal abuse" could then lead to the tissue changes associated with PVH.

Roy et al. (2000a, 2000b) also found that people with MTD were more introverted (low Extraversion) and scored higher on Neuroticism/Negative Emotionality and their facets, particularly Stress Reaction. These findings were consistent with the TTVD's prediction that people with MTD would score higher on Neuroticism and lower Extraversion. Additionally, Roy et al. (2000b) found that individuals with MTD scored higher on Constraint (inversely related to Eysenck's Psychoticism scale), although not all studies have replicated these differences (van Mersbergen et al., 2008).

Other researchers have tested the hypothesized relationships of the TTVD in different populations as well. Toles et al. (2021) reported that female singers with VFNs scored higher in the lower-order traits of Social Potency and Control compared to vocally healthy singers. Research into children with VFNs has found they exhibit higher levels of Extraversion (Verduyckt et al., 2019) and higher levels of Neuroticism and lower levels of Agreeableness and Conscientiousness (Lee et al., 2021).

While the exact findings differ across studies, collectively, these studies support the idea that certain personality traits may serve as risk factors for developing MTD or PVH. The TTVD was seminal for its time and has guided and informed research in the decades since. However, in its current form, the TTVD is inconsistent with contemporary theories and

[7] Mattei et al. (2017) also claim that the temperament trait Harm Avoidance "is positively correlated with Eysenck's Neuroticism Scale" (p. 1914), though the authors do not provide any empirical evidence to support this claim. Conversely, Harm Avoidance is a facet of Constraint in the Multidimensional Personality Questionnaire (MPQ), and not Negative Emotionality – the higher-order trait of the MPQ that is synonymous with Neuroticism. However, the naming of personality traits has been a source of confusion throughout much of personality psychology's history (John, 2021), sometimes known as the jingle-jangle fallacy.

methods in robust personality science. If researchers seek to better understand these relationships, then it is essential to adopt theories and methods used in modern, rigorous personality science. The following paragraphs identify several theoretical and methodological discrepancies that could be improved upon to better understand the relationship between personality traits and voice disorders.

As previously mentioned, the TTVD integrated then-contemporary evidence to expand the field's understanding of personality traits and voice disorders. The following section identifies a few discrepancies between the TTVD and current trends in Personality Psychology. First, personality scientists have overwhelmingly adopted a five-factor model (FFM) of personality (John, 2021). These five broad personality trait domains ("The Big Five") are Neuroticism, Agreeableness, Conscientiousness, Extraversion, and Openness/Intellect.[8] These traits are hierarchically arranged from the most-narrow traits (facets), intermediate-level traits (aspects), the five broad domain traits, and the highest-order / most broad traits (metatraits). Figure 4-1 shows this trait hierarchy. Importantly, personality researchers have not reached a consensus on the number or nature of the lowest-order traits, facets.

[8] The name associated with this last trait, Openness/Intellect, varies and is sometimes referred to as Openness to Experience or just Openness. We use Openness/Intellect to be consistent with the Cybernetic Big Five Theory of Personality.

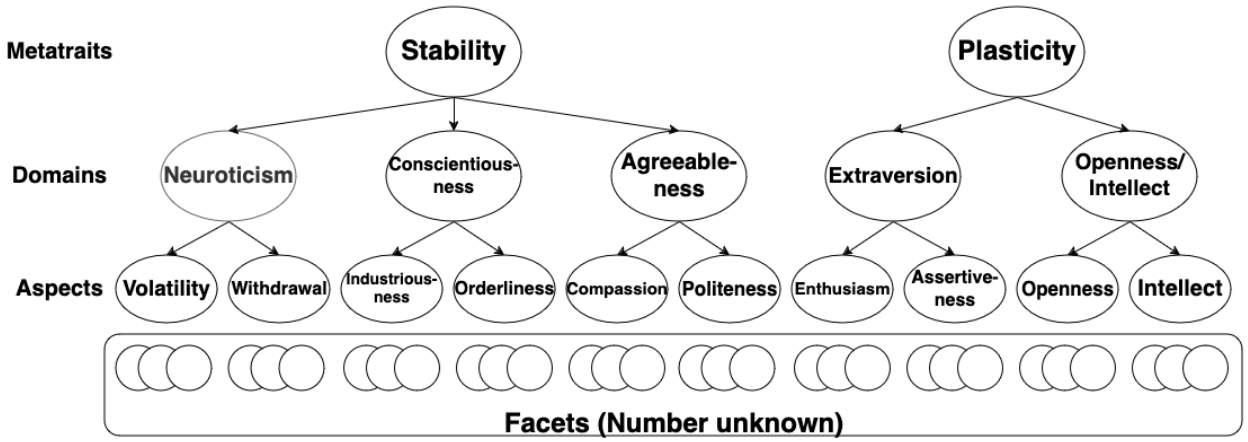

Figure 4-1 Personality trait hierarchy in the Cybernetic Big Five Theory of Personality.

Investigations into personality traits and voice disorders in adults have overwhelmingly used a three-factor model of personality. Amir et al. (2023) is one of the few studies using a FFM in adults, but they examined a wide variety of voice disorders not previously associated with personality traits (e.g., sulcus, paresis). Using a FFM has been more common to study children with PVH. These studies reported that these children had higher levels of Neuroticism and lower levels of Agreeableness and Conscientiousness (Lee et al., 2021), or only higher levels of Extraversion (Verduyckt et al., 2019).

The TTVD could also be improved upon by adopting a comprehensive theory of personality. Jeffrey Alan Gray was a student of Eysenck, who proposed biological mechanisms to explain Eysenck's two-factor model of personality, Extraversion and Neuroticism (1947).[9] This biopsychological theory of personality later evolved into the Reward Sensitivity Theory (RST; Gray, 1975, 1978, 1981). The RST asserted that the Behavioral Inhibition System (BIS), Behavioral Activation System (BAS), and the Fight-Flight-Freeze System (FFFS)[10] are responsible for individual differences to reward and punishment, and thus may be viewed as a biological basis for personality traits. Roy and Bless (2000)

[9] A third dimension, Psychoticism, was later added (Eysenck & Eysenck, 1976).

[10] Gray's earliest work described a third component as an "arousal system." His later work begins to use the label Fight-Flight System (FFS), whereas his most contemporary work uses labels this third system as the Fight-Flight-Freeze System (FFFS). We assume this third component is synonymous with the Nonspecific Arousal System (NAS) described by Roy and Bless (2000) in the TTVD.

integrated the RST to the TTVD, providing a mechanistic explanation for the relationships between personality and voice disorders.

In the decades since, the RST has been revised and the mechanisms associated with personality traits are now inconsistent with the original TTVD (Gray & McNaughton, 2000). Although Gray's work helped to pioneer the biological basis of personality, neither the RST nor its revision are comprehensive theories of personality. One theory that meets this criterion is the Cybernetic Big Five Theory of Personality (CB5T). The CB5T is arguably the first "comprehensive, synthetic, and mechanistic" theory of personality; this theory seeks to "explain not only *how* individuals differ from each other in their persisting patterns of emotion, motivation, cognition, and behavior, but also *why*" (DeYoung, 2015, p. 33, emphasis in original). As a result, the CB5T is "the most recent biologically based theoretical account of the Big Five" personality traits (John, 2021, p. 70). DeYoung acknowledges that room for improvement in this theory exists. This room for improvement notwithstanding, to date, the CB5T represents the most comprehensive, biologically motivated, and mechanistic explanation for personality, by integrating empirical research from personality neuroscience, genetics, and observational studies (Allen & DeYoung, 2016; DeYoung, 2010, 2015; DeYoung et al., 2010, 2021). Framing our understanding of personality and voice disorders within such a theory will allow future research to generate novel, testable hypothesis regarding physiological mechanisms that may contribute to certain voice disorders.

In addition to adopting a comprehensive and mechanistic theory of the "Big Five" traits, future investigations into the TTVD would benefit considering how to measure these traits. Most of the research examining the TTVD has used either the Eysenck Personality Questionnaire (EPQ; Eysenck & Eysenck, 1975) or the Multidimensional Personality Questionnaire (MPQ) or its corresponding brief form (MPQ-BF; Patrick et al., 2002; Tellegen & Waller, 2008). The EPQ requires participants to respond "yes" / "no" to a series of 90 statements, while participants respond "true" / "false" to a series of 300 statements for the MPQ (155 for the MPQ-BF). These dichotomous response options have mathematical

limitations when using factor analysis. Current evidence suggests using at least a 3-point response option, but ideally 5- or 7-point options (Lee & Ashton, 2007; Simms et al., 2019).

An ideal FFM personality battery would balance participant burden with internal consistency and use polytomous response options. The *Big Five Aspect Scales* (BFAS; DeYoung et al., 2007) meets these criteria and is a well-validated personality battery rooted in the CB5T. The BFAS measures the personality trait hierarchy at the levels of the aspects, domains, and metatraits shown in Figure 4-1.

Finally, future investigations into personality and voice disorders need to adopt the more advanced analytic methods currently used in rigorous personality research. Roy et al. (2000a) categorized individuals as "high" or "low" on a trait via a median split. Median splits were once a common approach when analyzing data via ANOVAs. However, artificial dichotomization reduces statistical power and effect sizes, attenuates correlations, and introduces measurement error via a nonlinear transformation of a continuous variable (Cohen, 1983; Decoster et al., 2011; McClelland et al., 2015). Additionally, Roy et al. (2000a, 2000b) used a stepwise logistic approach to examine group differences across personality traits. Stepwise regression has been highly criticized and shown to inflate Type I errors and spuriously identify "significant" predictor variables (Derksen & Keselman, 1992; Smith, 2018). These analytic limitations pose serious threats to internal validity. Subsequent studies have often replicated these methods, which may, in part, contribute to the inconsistent findings reported across these studies.

To address these limitations, researchers should adopt analytic methods used by rigorous quantitative personality psychologists. One of these methods is structural equation modeling (SEM), a highly flexible analytic framework that has become one of the gold-standards in rigorous multivariate research. SEM is a family of analytic methods that allows researchers to model "the mechanisms presumed to give rise to observed variability, covariation, and patterns in the data" (Hoyle, 2023, p. 3). With SEM, researchers can use latent variables, theoretically "purer" measures of the construct of interest that account for measurement error in the observed variables. Additionally, unlike regression-based

approaches that are mathematically just-identified, SEM uses over-identified models, allowing researchers to impose constraints and test their theoretical model.

So far, this chapter has provided a thorough overview of two of the most common voice disorders, i.e., MTD and PVH. Recent evidence suggests sensorimotor deficits and/or altered biomechanics may contribute to developing these disorders. Additionally, since the 1940s researchers have suggested that psychological factors may also contribute to the pathogenesis and maintenance of these voice disorders. At the turn of the century, Roy and Bless published the TTVD, a theoretical framework that provided a mechanistic explanation for personality's relationships with MTD and PVH. Their subsequent findings did not match their hypotheses exactly, but enough for the authors to conclude that "these results support the essential tenets" of the TTVD (Roy et al., 2000b, p. 540).

In the decades since, researchers have repeatedly found personality differences in groups with and without voice disorders. However, these findings often differ across studies and populations (e.g., children versus adults). Despite continued attempts to understand the relationships between personality traits and voice disorders, many of these studies are theoretically or methodologically inconsistent with current personality science best practices.

This study addresses these inconsistencies by adopting some of the current theories, measures, and methods used in personality science. Using the CB5T, a comprehensive and mechanistic theory of personality, we measure a hierarchical FFM of personality using the BFAS, and analyze these relationships via SEM. We also adopt Hillman et al.'s (2020) *Updated Theoretical Framework for Vocal Hyperfunction* to contextualize our findings within a current framework of vocal hyperfunction. Additional work will be necessary to fully align our understanding of these voice disorders with contemporary Personality Psychology. But addressing the aforementioned discrepancies will help establish a solid foundation for future, more rigorous research into the potential psychological processes associated with MTD and PVH for years to come.

4.1.1 Hypotheses

The current study has two main goals – to replicate Roy et al.'s (2000a, 2000b) initial TTVD studies, and to do so within a contemporary, mechanistic, and comprehensive theory of personality. To achieve these goals, we propose a series of hypotheses to translate between the three- and five-factor personality structures. Additionally, we hypothesize relationships based on the original premise of the TTVD as well as the findings of Roy et al. (2000a, 2000b).

First, compared to controls, we hypothesize that individuals with MTD will score higher on Neuroticism and its two aspects, Withdrawal and Volatility. This hypothesis aligns with the TTVD's original premise that people with MTD have elevated levels of Neuroticism and with Roy et al. (2000a, 2000b). Second, we hypothesize that the MTD group will score lower on Extraversion and its two aspects, Enthusiasm and Assertiveness, compared to controls. Like the first hypothesis, we generated this hypothesis from the TTVD and Roy et al.'s (2000a, 2000b). Together, these first two hypotheses test the TTVD's premise that people with MTD are "neurotic introverts."

Third, we hypothesize that the PVH cohort would score higher on the aspect of Volatility compared to controls. The TTVD asserted that people with PVH also have higher levels of Neuroticism. However, Roy et al. (2000a, 2000b) did not find strong evidence for this relationship. They did report that these individuals exhibited higher levels of Aggression, a facet of the MPQ's Negative Emotionality. In the FFM, MPQ's Aggression most closely correlates with Hostility (Church, 1994), a facet that loads onto the aspect of Volatility (DeYoung et al., 2007). It stood to reason that, if the TTVD's claim that people with PVH are higher in Neuroticism, that this difference may be due to the lower-order trait of Volatility.

Our fourth hypothesis is that the PVH group would score significantly higher on Extraversion and its two aspects, Assertiveness and Enthusiasm. The TTVD indicates that people with PVH will score higher on Extraversion. While Yano et al. (1982) found that patients with PVH scored higher on Extraversion compared to controls, Roy et al. (2000a, 2000b) did not replicate this finding. However, the PVH group in Roy et al. (2000b) scored

higher on Social Potency, a facet of MPQ's Positive Emotionality. In the FFM, Social Potency significantly correlates with Assertiveness (Church, 1994; DeYoung et al., 2007). As a result, we hypothesize that the PVH group will report higher levels of Assertiveness compared to controls.

Currently, no evidence exists suggesting that this group would score higher on Enthusiasm. This trait is characterized by "the tendency toward gregarious social interaction" (DeYoung, 2015, p. 42); Roy et al. speculated that people with PVH may have "a predilection for socializing," (2000b, p. 538). Based on this speculation, we hypothesize that the PVH group will score higher compared to controls. Collectively, the third and fourth hypotheses interrogate the "neurotic extravert" assertion of the TTVD.

Fifth, we hypothesize that the PVH group will score significantly lower on Conscientiousness and its two aspects, Industriousness and Orderliness. Roy et al. (2000a, 2000b) found that individuals with PVH reported significantly higher scores on the EPQ's Psychoticism and lower scores on the MPQ's Constraint (which are inversely related). MPQ's Constraint most strongly correlates with the FFM's Conscientiousness domain (Church, 1994). Roy et al. (2000b) also found that the PVH group reported significantly lower scores compared to vocally healthy controls on Control, a facet of MPQ's Constraint. MPQ's facet of Control correlates with the five-factor facets Order, Dutifulness, Achievement, and Deliberation (Gaughan et al., 2009). These facets load onto both of Conscientiousness' aspects, Industriousness and Orderliness (DeYoung et al., 2007).

Finally, our last hypothesis concerns the difference between the PVH and the MTD groups. The theoretical basis of the TTVD asserts that the PVH and MTD groups will differ only by higher and lower scores on Extraversion, respectively. While Roy et al. (2000a, 2000b) did not find significant differences in Extraversion in the PVH group compared to controls, the PVH group was significantly higher on Extraversion and the facets of Positive Emotionality compared to the MTD group. We seek to replicate this difference and hypothesize that the PVH group will be significantly higher on Extraversion and its aspects, Enthusiasm and Assertiveness, when compared to the MTD group.

4.2 Methods

The following methods were reviewed and approved by the University of Pittsburgh's IRB (STUDY23010171). We partnered with seven specialized voice disorder clinics around the country to recruit a diverse sample of participants receiving a first-time diagnosis of a voice disorder. Clinicians at each of the clinics handed out recruitment flyers to eligible participants. Because clinicians at these clinics only handed out flyers and did not serve as a representative for this research study, the University of Pittsburgh's IRB determined that these individuals did not meet the threshold of being "engaged" in the research activities, and thus a multi-site IRB was not necessary. Other institutions' IRBs were made aware of this decision and were allowed to review the approved IRB protocol upon request to reach to their own determination.

4.2.1 Participants

All participants were community dwelling individuals who sought out medical intervention for their voice complaint at their respective interdisciplinary voice disorder clinic. All participants underwent each clinic's own voice evaluation protocols, which included auditory perceptual evaluations and laryngeal imaging. Participants were evaluated with an interdisciplinary voice care model (typically a voice-specialized speech-language pathologist and a board-certified laryngologist or laryngology physician assistant overseen by a board-certified laryngologist). While the specific procedures may differ across clinics, all clinic recruitment sites were chosen for their reputations of providing gold-standard voice assessment and treatment.

If the patient being evaluated received a qualifying diagnosis and met the other inclusion and exclusion criteria, a clinician from the healthcare team would provide the potential participant with a recruitment flyer. Participants met the inclusion criteria if they were between the ages of 18-60, demonstrated fluency with written and spoken English, and received a first-time diagnosis of MTD or a diagnosis related to PVH. Hillman et al. (2020)

defines PVH as a benign bilateral mid-membranous lesion, with or without a reactive lesion, specifically diagnoses of vocal fold nodules or unilateral/bilateral polyp(s), with or without a reactive lesion. Although Hillman et al. (2020) acknowledge that non-intubation related granulomas might also exist within this phonotraumatic vocal hyperfunction category, we refrained from recruiting these individuals given the uncertainty around including this diagnosis in the PVH category.

Participant exclusion criteria included: anyone outside the 18-60 age range, a concomitant voice or upper airway diagnosis (except for laryngopharyngeal reflux, which was allowed given its high concomitance with MTD and PVH), and a history of receiving a previous voice/upper airway diagnosis and/or speech therapy for a voice/upper airway issue. Participants who previously received speech therapy for other issues not related to a voice or upper airway disorder (e.g., articulation therapy in elementary school) were allowed to participate. Additionally, clinicians at the voice clinics were instructed to recruit classic, unambiguous presentations of the vocal pathologies. We aimed to minimize/avoid recruiting patients who presented with ambiguous or complex presentations – e.g., a patient presenting with dysphonia and edema / "pre-nodules."

Each clinic was given a set of two recruitment flyers. One set of flyers was used to recruit people presenting with non-phonotraumatic vocal hyperfunction (i.e., primary MTD) and the other set of flyers were used to recruit people receiving a diagnosis of a benign lesion of the lamina propria (i.e., vocal fold nodules, polyp[s]/reactive lesion). Each flyer had a QR code and URL that was unique to each clinic and diagnostic group.

All data were collected using Research Enterprise Data Capture (REDCap; support from National Institutes of Health through Clinical and Translational Sciences Institute at the University of Pittsburgh Grant Number UL1-TR-001857). Individuals who were interested in participating scanned the QR code / used the URL on the flyer to access the online REDCap survey and participate in the study. All participants completed the study on their own personal electronic device. Ideally, participants were recruited at the time of their evaluation and when they received their diagnosis. However, due to slow recruitment, we also allowed clinicians to recruit individuals at the time of their first voice therapy

appointment in case the patient did not receive a recruitment flyer at the time of their evaluation. Individuals were ineligible to participate if they were not recruited by their first voice therapy appointment.

After consenting to participate, the participants completed a series of online questionnaires. Participants were encouraged to complete the study in one sitting; however, participants could quit or resume the study at any point. Participants were prevented from going back and changing answers on previous pages of the survey. If a participant did not finish the survey in its entirety, any data provided was used for analysis. Participants who successfully completed the survey and wished to be reimbursed for participating were given an electronic gift card to their choice of a major retailer (i.e., Amazon, Starbucks, or Target). Initially, reimbursement was set at $10. After a period of slow recruitment, we increased reimbursement to $20 and finally to $40. Most participants who competed the survey received a $40 gift card.

The data for the vocally healthy controls were collected were collected from a separate research study. Briefly, in a previous research study, we collected both personality and perceived vocal handicap (i.e., Voice Handicap Index – 10 [VHI-10]) data from online users who agreed to listen and rate speech samples. From this separate listening study, we collected data from 1,843 of individuals. For the current study, we kept individuals only between the ages of 18-60 (the listening study did not have an upper age limit) who did not have any missing data (N = 1,811). Because these individuals did not receive a multidisciplinary voice evaluation, we retained data from participants with a VHI-10 sum score ≤ 3 based on previous research indicating that the average VHI-10 score of vocally healthy individuals is 2.83 (SD = 3.93; Arffa et al., 2012). With this conservative cut-off, we use the personality data from these individuals as a “vocally healthy” control group (N = 415).

4.2.2 Measures

After completing a brief screening questionnaire, participants read and completed the online consent form. Individuals who consented to participate then filled out a brief demographic questionnaire and were asked a series of general voice questions (e.g., singing history, dysphonia symptoms). Participants were also asked to indicate what diagnosis they received.

We employed two methods aimed at improving the quality of the data collected. First, participants were asked to "commit to providing accurate and honest information." Participants answered whether they do or do not commit to providing accurate and honest information prior to completing the measures described below. Regardless of their answer, participants were allowed to continue with the survey. These types of commitment questions have been used in face-to-face interviewing and shown to improve the accuracy and quality of participants' responses. Recent work demonstrates that these questions also improve the accuracy of responses from online participants (Hibben et al., 2022). Additionally, we embedded three "traditional" attention check items (e.g., "Select 'Strongly Agree' for this item"). Participants who missed the first two attention check items were prompted to "pay close attention to the questions and provide as much accurate and honest information as possible" at the three-quarter mark of the survey.

Participants filled out a series of well-validated self-report measures of personality, perceived vocal handicap, depression, anxiety, and perceived stress. Participants also completed an abbreviated measure of internalizing and externalizing psychopathology, adapted from Wright et al. (2015). These measures are described in-depth below. However, the analyses in the current study only use the Big Five Aspect Scales personality measure. The other measures will be used for future research and are reported for transparency.

Perceived Vocal Handicap – The *Voice Handicap Index – 10 (VHI-10)* is a 10-item self-report measure of perceived vocal handicap because of one's voice disorder. Participants respond to a series of statements using a 5-point Likert scale from Never (0) to Always (4). Participants' responses are summed to yield a score from 0-40, with higher

scores indicating higher levels of perceived vocal handicap. Prior research suggests a score greater than 11 should be considered "abnormal" and indicative of a possible vocal impairment (Arffa et al., 2012).

Personality – The *Big Five Aspect Scales (BFAS)* is a rigorously tested personality battery that measures personality traits at three separate levels of abstraction – i.e., personality aspects, domains, and metatraits (DeYoung et al., 2007). These traits at all three levels theoretically serve a specific role in the evolved cybernetic mechanism of personality (DeYoung, 2015). The BFAS requires individuals to use a 5-point Likert scale to respond to a series of statements from Strongly Disagree (1) to Strongly Agree (5). Certain items are reverse scored. Items corresponding to each aspect, domain, and metatrait can be averaged to yield an approximation of the trait score between 1-5.

Participants also completed a second, brief FFM personality measure, the *Mini-IPIP* (Donnellan et al., 2006). The Mini-IPIP was developed based on the longer 50-item International Personality Item Pool (IPIP) five-factor model (Goldberg, 1999). The Mini-IPIP requires individuals to use a 5-point Likert scale to respond to a series of statements from Strongly Disagree (1) to Strongly Agree (5). Certain items are reverse scored. Each of the five personality domains is measured by four of the items. Previous research demonstrates that the Mini-IPIP demonstrates good short-term test-retest reliability, good convergent validity with longer FFM personality measures, and good criterion validity (Baldasaro et al., 2013; Donnellan et al., 2006). However, the Mini-IPIP has demonstrated only poor-to-moderate fit of a five-factor structure via confirmatory factor analysis (CFA), but does demonstrate a five-factor structure with minimal item cross-loadings via exploratory factor analysis (EFA). Authors of these studies attribute these findings to the abbreviated length of this measure, and generally conclude that the Mini-IPIP is an acceptable, brief measure of the five personality domains (Baldasaro et al., 2013; Cooper et al., 2010).

Internalizing/Externalizing Psychopathology – Historically, psychopathologies have been conveyed as distinct, separate clinical entities (e.g., the *Diagnostic and Statistical Manual of Mental Disorders – V*). More recent empirical evidence demonstrates

that psychopathologies exist along a series of five spectra[11] that correlate with the five broad personality domains (e.g., Kotov et al., 2021; Widiger et al., 2019). The internalizing and externalizing spectra represent broad patterns of disorder covariation and are associated with mood disorders (e.g., depression, anxiety) and substance abuse disorders/antisocial personality disorders, respectively (Kotov et al., 2021; Krueger, 1999; Wright et al., 2013).

To the best of our knowledge, researchers have not investigated psychopathology as spectra in people with voice disorders. However, many of the existing measures used for this dimensional approach to psychopathology are long and/or require an individual to be interviewed. We adopted an abbreviated measure of internalizing and externalizing psychopathology used by Wright et al. (2015). This measure contains 16 behaviors encompassed by the internalizing and externalizing spectra. Participants were asked to indicate how frequently they experience each of the 16 statements using an 8-point Likert scale from "Not at All" (0) to "Very Much So" (7).

4.2.3 Data Processing and Cleaning

All data from participants recruited from voice clinics were imported and processed in R (v.4.0.2, R Core Team, 2020) via REDCap's secure application programming interface. Data from vocally healthy controls were imported from a previously cleaned .csv file from a separate project. Packages used to process and analyze the data included: *tidyverse* (v1.3.0, Wickham et al., 2019), *semTools* (v.0.5-6, Jorgensen et al., 2022), *and lavaan* (v.0.6.14, Rosseel, 2012). Participants who missed all three attention check items were removed.

All participants received a flyer that directed them to either the "tension" or "lesion" online survey specific to that clinic. This step was done, in part, to ensure that participants were categorized into the correct group based on the clinician's decision, rather than relying

[11] An additional sixth spectrum exists (i.e., Somatoform). Of all the spectra, the Somatoform spectrum is the least-understood and does not currently have an associated personality domain (Kotov et al., 2017; Sellbom et al., 2022; Woodling et al., 2022).

solely on self-reported diagnosis from the participants. However, participants were still asked to indicate their diagnosis. Whenever a discrepancy existed (e.g., a person filling out the "tension" study indicated that they received a diagnosis of bilateral lesions), the Principal Investigator (PI) contacted the participant for clarification. Based on the information received, the participant was manually coded to the correct group. A total of four discrepancies existed. Of these four discrepancies between diagnosis and survey completed, three participants responded to the PI's inquiry, and they were added to the correct group. The fourth participant did not respond, and they were moved to the group consistent with their self-reported diagnosis.

4.2.4 Statistical Analysis

4.2.4.1 *A Priori* Power Analysis

The initial hypothesized model for this study sought to examine the interactions between personality traits and the other measures collected (e.g., psychopathology) across the groups. Researchers have a few different options to conduct power analyses with SEM compared to regression-based approaches. One option is a Monte Carlo simulation, which does not rely on strict assumptions about the data and provides estimates of global model fit as well as individual parameters.

We generated a plausible model using previously collected data from other studies to approximate a model of similar complexity to the originally proposed hypothesized model for the current study. This plausible model (df = 388) was simulated 201 times with 100-300 participants. Table 4-1 contains the simulated global model fit estimates for 100, 150, 200, 250, and 300 participants. The results of this simulation indicate that "adequate" model fit could be achieved with as few as 100 participants per group. However, the overall model fit improves with larger sample sizes, with 300 individuals per group demonstrating the best global fit indices.

Table 4-1 Global fit indices from Monte Carlo *a priori* power analysis.

N	χ^2	RMSEA	CFI	AIC	BIC
100	494.51	.050	.951	4091.88	4299.46
150	481.57	.042	.961	6014.52	6243.26
200	648.64	.035	.972	7937.17	8187.06
250	455.71	.027	.983	9859.82	10130.86
300	442.78	.020	.993	11782.47	12074.66

While the study was designed to recruit a large sample of participants by partnering with multiple voice clinics, recruitment was substantially slower than anticipated. Due to the slow recruitment, completing the initial hypothesized model was not possible as the model would not converge. Even if the original model was able to converge, its estimates would be unreliable due to the small sample size. To overcome this issue, the data were analyzed using a different SEM approach and focused only on personality trait differences.

4.2.4.2 Multiple Indicator and Multiple Causes Model

We tested our hypothesized group differences in Section 4.1.1 via three multiple indicator and multiple causes (MIMIC) SEM models (Joreskog & Goldberger, 1975). MIMIC models provide similar information about group differences; these models express group mean differences via regression parameters instead of latent variable means. Additionally, this approach assumes that the constructs measured (e.g., Extraversion) are non-invariant across the groups. As a result, MIMIC models do not require as large of sample sizes for each group compared to multi-group SEM approaches.

The first MIMIC model examined the differences of the broadest personality traits, the metatraits. The second MIMIC model tested the differences of the five personality domains. The third MIMIC model tested the differences of the ten personality aspects. Together, these three MIMIC models provide a comprehensive examination of differences across the personality trait hierarchy.

All three MIMIC models were estimated via maximum likelihood estimation and contained the same exogenous predictors (i.e., age, sex, and two dummy variables – MTD

versus controls and PVH versus controls).[12] Age and sex were included as exogenous variables to examine group-level differences while controlling for known personality differences across the life span and by biological sex (Caspi et al., 2005; Roberts et al., 2006, 2008; Roberts & Delvecchio, 2000; Soto et al., 2011; Weisberg et al., 2011).[13]

Figures 4-2, 4-3, and 4-4 display the hypothesized path diagrams for the metatrait, domain, and aspect-level MIMIC models, respectively. For each of the three MIMIC models, we fixed the latent variables' variances to 1 for identification and used random parcel allocation for the respective manifest indicators. For each model, the latent variable's residuals were allowed to covary based on previous evidence that these traits are intercorrelated (DeYoung et al., 2002, 2007; Digman, 1997). Although the metatraits are theoretically orthogonal (DeYoung, 2015), metatraits demonstrate inflated correlation when measured via self-report (Change et al., 2012). As a result, the hypothesized model allows their residuals to correlate.

The metatrait model includes six parcels for each for Stability and Plasticity, while the domain and aspect models have four parcels for each respective latent variable. Parceling is a procedure where multiple items are averaged together to serve as an indicator for a latent variable. This method helps to increase power by reducing the number of indicators needed in the model and more closely approximates a continuous, normal distribution, compared to item-level Likert responses (Sterba, 2011; Sterba & MacCallum, 2010; Sterba & Rights, 2023). However, this approach yields different results depending on which items are included in the parcel. To address this limitation, random parceling allocation randomly assigns a latent variable's respective items to different indicator parcels and fits the model to each set of parcels. The results of each of these 100 model estimates are pooled following Rubin's (1987) established protocol.

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[12] A second set of three MIMIC models was also conducted but used the MTD group as the comparison for the group differences. This step was completed to examine the differences between the MTD and PVH groups. Except for the parameter estimates comparing the MTD and PVH groups, the other parameter estimates are identical across the two sets of models.

[13] Extant personality literature almost exclusively examines biological sex through a binary lens. We recognize that biological sex is not binary and include sex as a binary variable in the current study as none of the participants reported being intersex.

We use the following global fit indices and their generally accepted cut offs to help aid with interpreting model fit. While these cut off values are generally well-accepted for assessing global fit, these values should not be viewed as perfect determinants of model fit (Marsh et al., 2004). We assess model fit via the χ^2, comparative fit index (CFI; > .95), Tucker-Lewis index (TLI; > .95), root mean square error of approximation (RMSEA; < .06), and the standardized root mean square residual (SRMR; < .08; Hu & Bentler, 1999; West et al., 2023). We set our alpha to .05 to determine statistical significance.

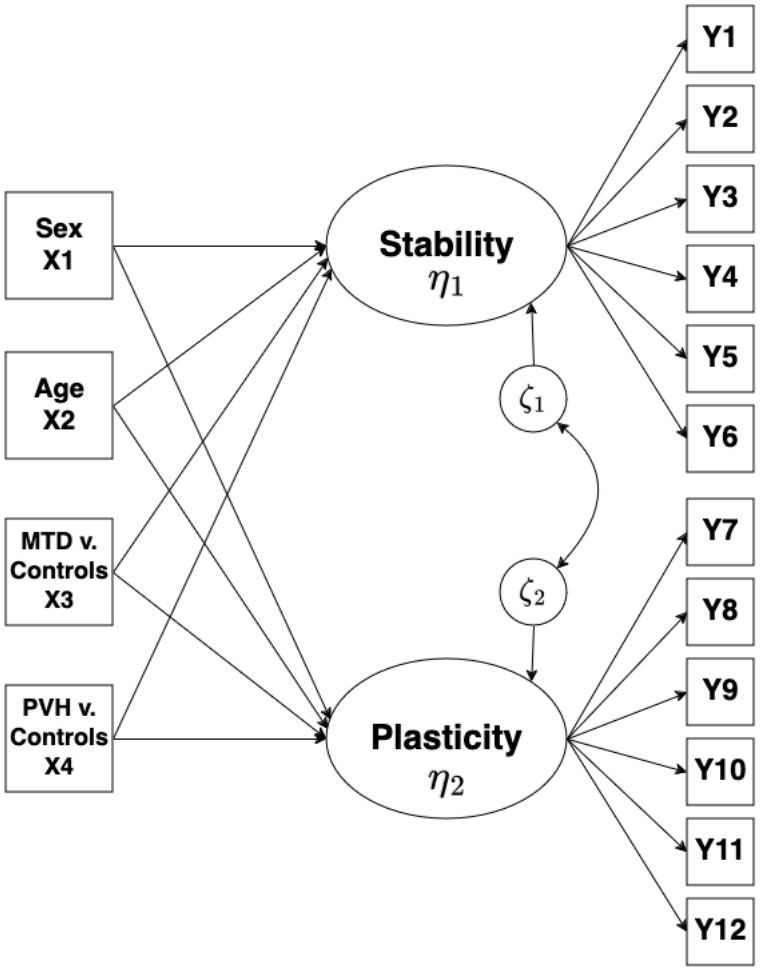


Figure 4-2 Multiple indicator multiple causes model for the metatraits. Regressions, factor loadings, and endogenous manifest residual variances omitted. MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

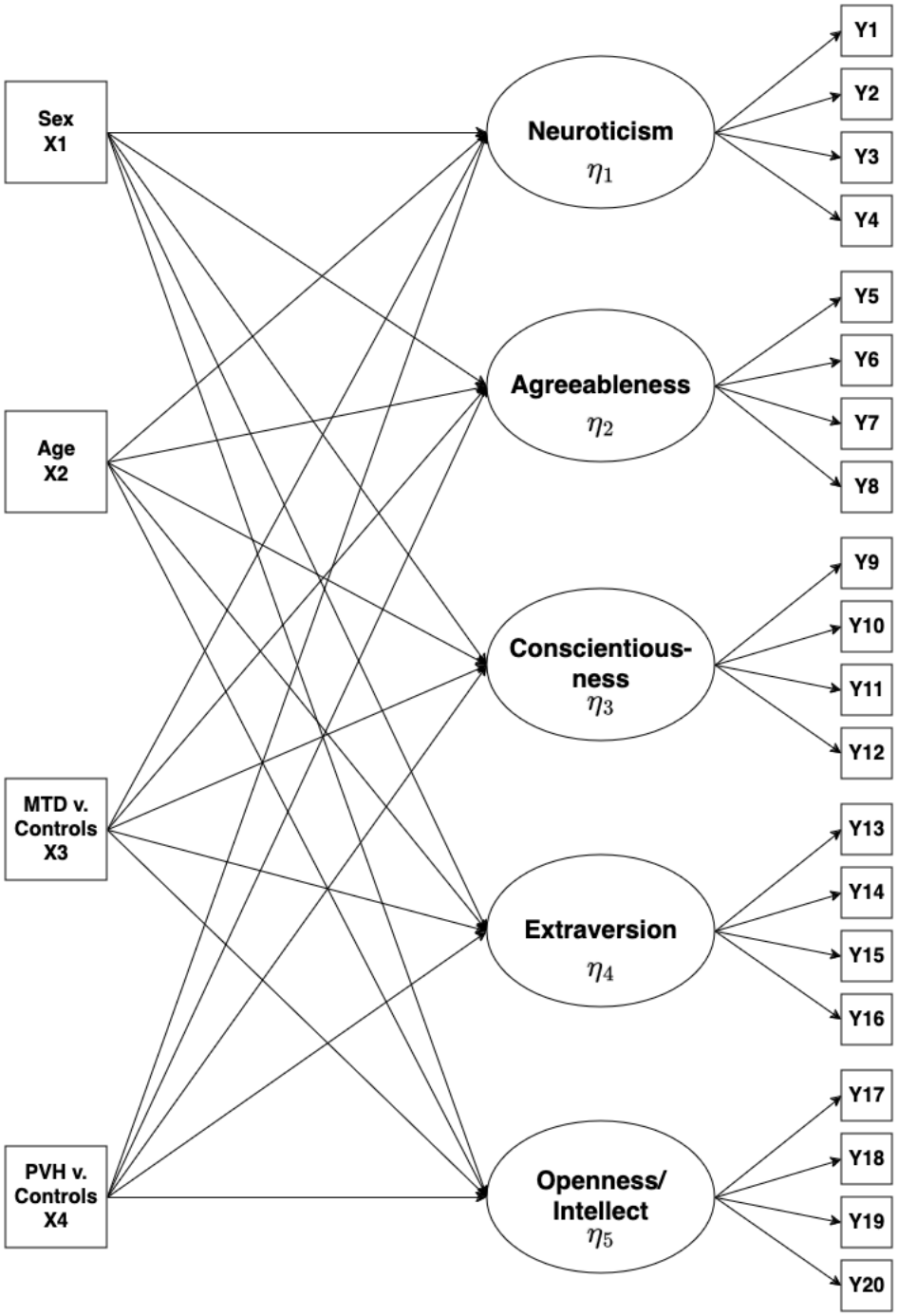


Figure 4-3 Multiple indicator multiple causes model for the domains. Regressions, factor loadings, and endogenous manifest residuals and variances omitted. MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

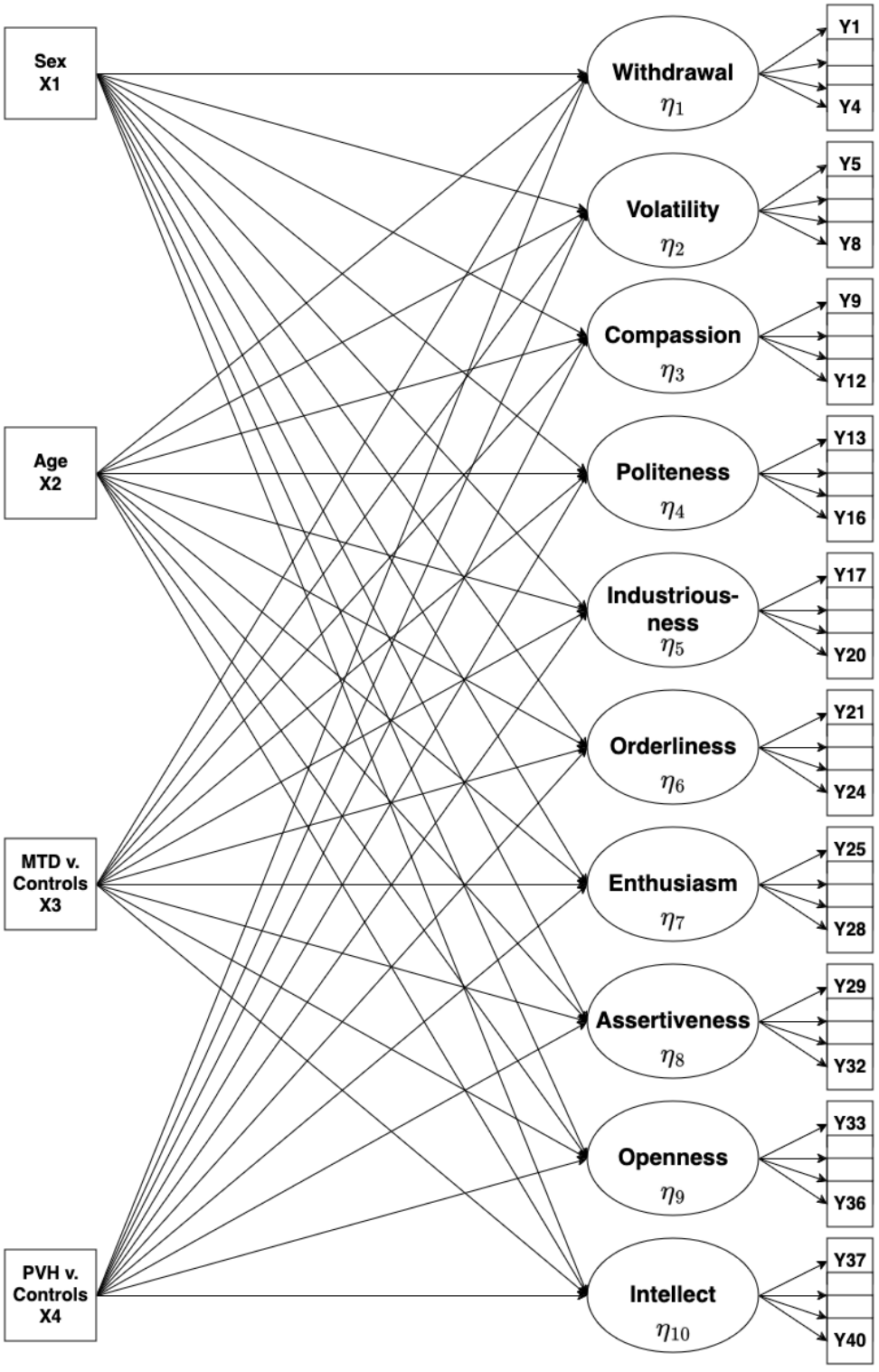


Figure 4-4 Multiple indicator multiple causes model for the aspects. Regressions, factor loadings, and endogenous manifest residuals and variances omitted. MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

4.3 Results

4.3.1 Participants

Data from the participants with voice disorders was collected from September 8th, 2023 to June 20th, 2024 (286 days). All participants voluntarily committed to providing accurate and honest information. After removing a participant who failed the traditional attention checks (*n* = 1), and a repeat entry from an individual who filled out the survey twice (*n* = 1), a total of 82 individuals with voice disorders were recruited who completed the survey through the demographic information. One participant completed the survey but indicated they were a healthy control (a clinician at one of the voice centers). Of these 83 individuals, 76 completed the entire survey. Data obtained from the six individuals who did not complete the survey will be used whenever available. Table 4-2 displays the number of individuals who participated from each clinic by diagnostic group.

The demographic and personality data from the 415 vocally healthy controls were combined with the data from the 82 individuals with voice disorders and one vocally healthy control for a total sample of 498 participants. Table 4-3 displays the demographic information of the current sample.

Table 4-2 Recruited voice disorder participants by clinic. MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

Clinic	MTD *n* (%)	PVH *n* (%)	Total *n* (%)
UPMC Voice Center	39 (47.56)	13 (15.85)	52 (63.41)
Emory Voice Center	10 (12.20)	7 (8.54)	17 (20.73)
University of Colorado	1 (1.22)	4 (4.88)	5 (6.10)
University of California San Francisco	3 (3.66)	0	3 (3.66)
UTHealth Voice Center	3 (3.66)	0	3 (3.66)
Texas Voice Center	0	1 (1.22)	1 (1.22)
University of Alabama Birmingham	0	1 (1.22)	1 (1.22)

Table 4-3 Participant demographic information.

Variable	MTD (*n* = 56)	PVH (*n* = 26)	Control (*n* = 416)	Total (*n* = 498)
Age M (SD)	39.14 (12.69)	41.96 (9.84)	37.31 (10.23)	37.76 (10.55)
Female *n* (%)	46 (82.14)	19 (73.08)	286 (68.75)	351 (70.48)
Cisgender *n* (%)	53 (94.64)	24 (92.31)	413 (99.28)	490 (98.39)
Race *n* (%)				
White	41 (69.49)	19 (70.37)	309 (78.83)	369 (74.10)
Black/African American	9 (15.25)	4 (14.81)	51 (13.01)	64 (12.85)
Asian	4 (6.78)	2 (7.41)	16 (4.08)	22 (4.42)
Prefer not to say	5 (8.47)	1 (3.70)	3 (0.77)	9 (1.81)
Other	0	0	7 (1.79)	7 (1.41)
American Indian / Alaska Native	0	1 (3.70)	5 (1.28)	6 (1.20)
Pacific Islander	0	0	1 (0.26)	1 (0.20)
Ethnicity *n* (%)				
Not Hispanic / Latino/e	52 (92.86)	25 (96.15)	391 (93.99)	468 (93.98)
Hispanic / Latino/e	2 (3.57)	0	25 (6.01)	27 (5.42)
Unknown / Not Reported	2 (3.57)	1 (3.85)	0	3 (0.60)
Highest Level of Education Attained *n* (%)				
No high school education	0	0	1 (0.24)	1 (0.20)
Some high school education	0	1 (3.85)	2 (0.48)	3 (0.60)
High school diploma	7 (12.50)	4 (15.38)	46 (11.06)	57 (11.42)
Trade or technical certificate	3 (5.36)	0	14 (3.37)	17 (3.41)
Some college	12 (21.43)	4 (15.38)	81 (19.47)	97 (19.48)
Associate degree	5 (8.93)	0	41 (9.86)	46 (9.24)
Bachelor's degree	14 (25.00)	9 (34.62)	126 (30.29)	149 (29.92)
Master's degree	7 (12.50)	7 (26.92)	88 (21.15)	102 (20.48)
Doctoral/terminal degree	7 (12.50)	1 (3.85)	16 (3.85)	24 (4.82)
Prefer not to say	1 (1.79)	0	1 (0.24)	2 (0.40)

4.3.2 Measures

Table 4-4 displays the descriptive statistics of the VHI-10 sum score and each of the personality traits' mean scores by participant group. Figure 4-5 represent the distribution of each of the personality traits across the three groups.

Table 4-4 Descriptive statistics of measures. VHI-10 = Voice Handicap Index – 10; MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

Variable	MTD	PVH	Control
VHI-10 Sum Score M (SD)	19.84 (8.66)	16.96 (9.18)	1.38 (1.14)
Personality Traits Mean Score M (SD)			
Stability	3.51 (0.41)	3.62 (0.31)	3.74 (0.42)
Neuroticism	2.92 (0.78)	2.65 (0.55)	2.50 (0.69)
Withdrawal	3.03 (0.79)	2.67 (0.62)	2.55 (0.73)
Volatility	2.81 (0.85)	2.64 (0.62)	2.46 (0.79)
Agreeableness	3.95 (0.38)	3.85 (0.40)	4.00 (0.52)
Compassion	4.07 (0.58)	4.04 (0.47)	4.01 (0.66)
Politeness	3.83 (0.34)	3.67 (0.46)	4.00 (0.55)
Conscientiousness	3.51 (0.56)	3.67 (0.44)	3.71 (0.55)
Orderliness	3.63 (0.58)	3.74 (0.48)	3.68 (0.61)
Industriousness	3.39 (0.74)	3.61 (0.55)	3.73 (0.66)
Plasticity	3.62 (0.47)	3.81 (0.37)	3.76 (0.48)
Extraversion	3.46 (0.51)	3.76 (0.46)	3.57 (0.60)
Enthusiasm	3.57 (0.55)	3.80 (0.56)	3.62 (0.70)
Assertiveness	3.36 (0.61)	3.72 (0.53)	3.52 (0.70)
Openness/Intellect	3.78 (0.52)	3.87 (0.43)	3.95 (0.51)
Openness	3.85 (0.60)	3.82 (0.59)	3.89 (0.60)
Intellect	3.70 (0.66)	3.91 (0.50)	4.00 (0.57)

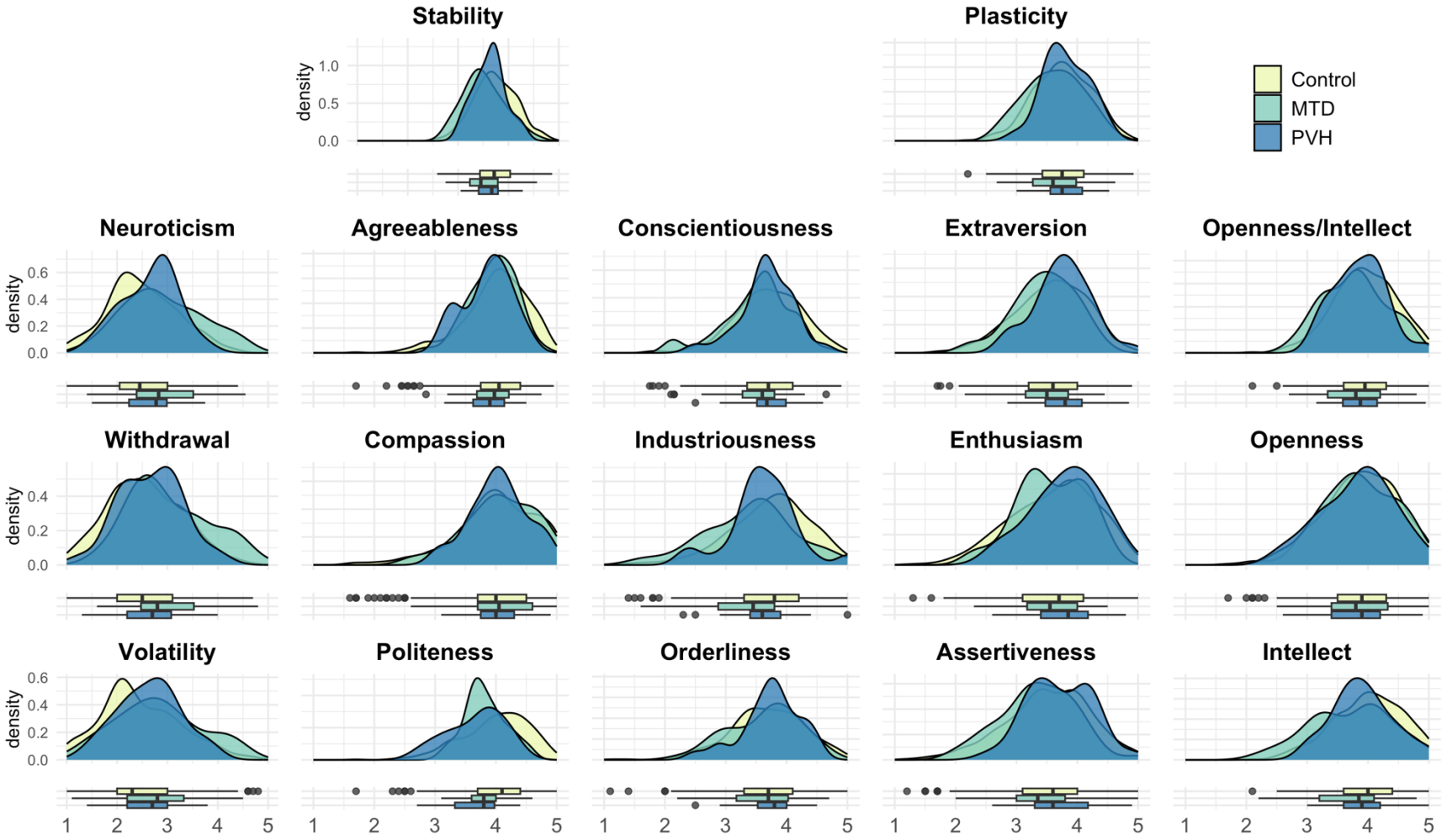


Figure 4-5 Density distributions of personality traits. Scores for each trait were calculated by taking the average of the respective items using the Big Five Aspects Scale. MTD = muscle tension dysphonia; PVH = phonotraumatic vocal hyperfunction.

4.3.3 Model Parameter Estimates

Each model measured one level of the trait hierarchy – i.e., metatraits, domains, and aspects. The parameter estimates reflect the pooled values of the 100 randomly allocated item parcels. All three models successfully converged with admissible solutions for each of the 100 estimations. Table 4-5 contains the fit indices for the three models – i.e., personality traits at the level of the metatraits, domains, and aspects. All three models demonstrated acceptable model fit. Modification indices were not examined for this MIMIC model. Although examining modification indices and making changes may yield improved model fit, this step does not align with our theoretical interest of examine group differences across the personality traits. Tables 4-6, 4-7, and 4-8 contain the pooled parameter estimates for the three metatrait-, domain-, and aspect-level MIMIC models, respectively. Table 4-9 contains a truncated table that combines only the regression estimates for the differences between the PVH and MTD groups. Figure 4-6 displays dot and whisker plots of the combined regression estimates for the effects of age and sex across the three MIMIC models. Similarly, Figure 4-7 displays dot and whisker plots of the combined regression estimates for the effects of MTD versus controls, PVH versus controls, and PVH versus MTD.

Table 4-5 Global model fit indices for each level of the trait hierarchy.

Model	χ^2	*df*	*p*-value	CFI	TLI	RMSEA	SRMR
Metatraits	1.273	93	1.000	1.000	1.258	0	.005
Domains	1.951	220	1.000	1.000	1.331	0	.008
Aspects	7.083	815	1.000	1.000	1.556	0	.008

Table 4-6 Pooled parameter estimates for the metatrait model.

Parameter	Estimate	SE	95% CI [LL, UL]	*p*-value
Factor Loadings				
Stability				
$\lambda_{1,1}$	.399	.051	[.297, .500]	< .001
$\lambda_{2,1}$	.402	.053	[.298, .507]	< .001
$\lambda_{3,1}$	.387	.048	[.291, .482]	< .001
$\lambda_{4,1}$	.394	.051	[.293, .496]	< .001
$\lambda_{5,1}$	.399	.052	[.296, .502]	< .001
$\lambda_{6,1}$	.400	.049	[.303, .496]	< .001
Plasticity				
$\lambda_{7,2}$	.440	.040	[.362, .518]	< .001
$\lambda_{8,2}$	.445	.044	[.358, .532]	< .001
$\lambda_{9,2}$	.446	.042	[.364, .529]	< .001
$\lambda_{10,2}$	.447	.042	[.364, .529]	< .001
$\lambda_{11,2}$	.439	.046	[.349, .530]	< .001
$\lambda_{12,2}$	.447	.043	[.361, .533]	< .001
Regressions				
Stability regressed on:				
$\gamma_{1,1}$: Sex	-.101	.107	[-.312, .109]	.345
$\gamma_{1,2}$: Age	.010	.005	[.001, .019]	.029
$\gamma_{1,3}$: MTD	-.525	.153	[-.826, -.225]	.001
$\gamma_{1,4}$: PVH	-.448	.227	[-.893, -.003]	.049
Plasticity regressed on:				
$\gamma_{2,1}$: Sex	-.204	.106	[-.412, .003]	.053
$\gamma_{2,2}$: Age	-.006	.005	[-.015, .003]	.157
$\gamma_{2,3}$: MTD	-.280	.152	[-.578, .018]	.066
$\gamma_{2,4}$: PVH	.097	.227	[-.347, .542]	.669
Latent Disturbance Covariances				
$\psi_{2,1}$	.490	.042	[.408, .572]	< .001
Residual indicator Variances				
Stability				
ϵ_1	.090	.030	[.030, .150]	.004
ϵ_2	.087	.023	[.042, .131]	< .001
ϵ_3	.088	.027	[.035, .141]	.001
ϵ_4	.088	.023	[.042, .134]	< .001
ϵ_5	.086	.022	[.043, .129]	< .001
ϵ_6	.085	.023	[.039, .191]	< .001
Plasticity				
ϵ_7	.116	.034	[.050, .183]	.001
ϵ_8	.115	.027	[.062, .168]	< .001
ϵ_9	.113	.029	[.057, .170]	< .001
ϵ_{10}	.114	.028	[.057, .170]	< .001
ϵ_{11}	.140	.044	[.053, .228]	.002
ϵ_{12}	.145	.033	[.079, .210]	< .001

Table 4-7 Pooled parameter estimates for the domain model.

Parameter	Estimate	SE	95% CI [LL, UL]	*p*-value
Factor Loadings				
Neuroticism				
$\lambda_{1,1}$	.650	.048	[.555, .745]	< .001
$\lambda_{2,1}$	.656	.047	[.563, .749]	< .001
$\lambda_{3,1}$	.657	.046	[.567, .747]	< .001
$\lambda_{4,1}$	.653	.046	[.562, .743]	< .001
Agreeableness				
$\lambda_{5,2}$	.442	.051	[.341, .543]	< .001
$\lambda_{6,2}$	.445	.054	[.338, .553]	< .001
$\lambda_{7,2}$	.438	.053	[.333, .543]	< .001
$\lambda_{8,2}$	.448	.056	[.336, .559]	< .001
Conscientiousness				
$\lambda_{9,3}$	.496	.072	[.354, .637]	< .001
$\lambda_{10,3}$	.512	.074	[.365, .659]	< .001
$\lambda_{11,3}$	.503	.069	[.366, .639]	< .001
$\lambda_{12,3}$	.504	.065	[.376, .632]	< .001
Extraversion				
$\lambda_{13,4}$	.541	.050	[.441, .640]	< .001
$\lambda_{14,4}$	.538	.052	[.436, .640]	< .001
$\lambda_{15,4}$	.544	.054	[.438, .651]	< .001
$\lambda_{16,4}$	.539	.055	[.431, .647]	< .001
Openness/Intellect				
$\lambda_{17,5}$	.468	.046	[.377, .560]	< .001
$\lambda_{18,5}$	.473	.048	[.378, .568]	< .001
$\lambda_{19,5}$	.470	.047	[.376, .563]	< .001
$\lambda_{20,5}$	.470	.050	[.370, .569]	< .001
Regressions				
Neuroticism regressed on:				
$\gamma_{1,1}$: Age	-.011	.005	[-.020, -.002]	.015
$\gamma_{1,2}$: Sex	-.370	.105	[-.575, -.164]	< .001
$\gamma_{1,3}$: MTD	.528	.151	[.231, .825]	< .001
$\gamma_{1,4}$: PVH	.382	.225	[-.059, .822]	.089
Agreeableness regressed on:				
$\gamma_{2,1}$: Age	.005	.005	[-.004, .015]	.258
$\gamma_{2,2}$: Sex	-.693	.111	[-.912, -.475]	< .001
$\gamma_{2,3}$: MTD	-.129	.168	[-.458, .201]	.444
$\gamma_{2,4}$: PVH	-.447	.243	[-.922, .029]	.066
Conscientiousness regressed on:				
$\gamma_{3,1}$: Age	.004	.005	[-.005, .014]	.350
$\gamma_{3,2}$: Sex	-.129	.110	[-.344, .086]	.240
$\gamma_{3,3}$: MTD	-.397	.157	[-.704, -.089]	.012
$\gamma_{3,4}$: PVH	-.139	.232	[-.595, .316]	.548

Table 4-7 (continued)

Extraversion regressed on:				
$\gamma_{4,1}$: Age	-.007	.005	[-.017, .002]	.112
$\gamma_{4,2}$: Sex	-.240	.108	[-.451, -.029]	.026
$\gamma_{4,3}$: MTD	-.162	.154	[-.464, .140]	.294
$\gamma_{4,4}$: PVH	.332	.230	[-.119, .784]	.149
Openness/Intellect regressed on:				
$\gamma_{5,1}$: Age	-.004	.005	[-.013, .006]	.448
$\gamma_{5,2}$: Sex	-.110	.109	[-.323, .103]	.311
$\gamma_{5,3}$: MTD	-.335	.157	[-.642, -.028]	.033
$\gamma_{5,4}$: PVH	-.201	.232	[-.656, .255]	.388
Latent Disturbance Covariances				
Neuroticism and:				
$\psi_{2,1}$: Agreeableness	-.176	.051	[-.277, -.076]	.001
$\psi_{3,1}$: Conscientiousness	-.466	.048	[-.560, -.371]	< .001
$\psi_{4,1}$: Extraversion	-.360	.047	[-.542, -.268]	< .001
$\psi_{5,1}$: Openness/Intellect	-.287	.050	[-.385, -.186]	< .001
Agreeableness and:				
$\psi_{3,2}$: Conscientiousness	.334	.050	[.235, .432]	< .001
$\psi_{4,2}$: Extraversion	.362	.052	[.260, .464]	< .001
$\psi_{5,2}$: Openness/Intellect	.432	.046	[.342, .522]	< .001
Conscientiousness and:				
$\psi_{4,3}$: Extraversion	.323	.050	[.225, .422]	< .001
$\psi_{5,3}$: Openness/Intellect	.196	.054	[.091, .301]	< .001
Extraversion and:				
$\psi_{5,4}$: Openness/Intellect	.552	.041	[.471, .633]	< .001
Residual Indicator Variances				
Neuroticism				
ϵ_1	.147	.045	[.057, .237]	.002
ϵ_2	.144	.039	[.067, .221]	< .001
ϵ_3	.148	.037	[.075, .220]	< .001
ϵ_4	.140	.041	[.060, .221]	.001
Agreeableness				
ϵ_5	.141	.033	[.076, .206]	< .001
ϵ_6	.140	.037	[.067, .214]	< .001
ϵ_7	.144	.034	[.076, .212]	< .001
ϵ_8	.137	.038	[.061, .213]	.001
Conscientiousness				
ϵ_9	.158	.044	[.070, .246]	.001
ϵ_{10}	.158	.052	[.054, .262]	.003
ϵ_{11}	.154	.043	[.068, .240]	.001
ϵ_{12}	.160	.050	[.062, .259]	.002
Extraversion				
ϵ_{13}	.159	.047	[.067, .252]	< .001
ϵ_{14}	.162	.049	[.064, .260]	< .001
ϵ_{15}	.155	.050	[.055, .255]	< .001

Table 4-7 (continued)

ϵ_{16}	.157	.055	[.048, .266]	< .001
Openness/Intellect				
ϵ_{17}	.147	.041	[.066, .228]	< .001
ϵ_{18}	.147	.045	[.058, .236]	< .001
ϵ_{19}	.147	.039	[.068, .225]	< .001
ϵ_{20}	.137	.036	[.066, .208]	< .001

Table 4-8 Pooled parameter estimates for the aspect model.

Parameter	Estimate	SE	95% CI [LL, UL]	*p*-value
Factor Loadings				
Withdrawal				
$\lambda_{1,1}$	.651	.063	[.527, .775]	< .001
$\lambda_{2,1}$	.659	.055	[.550, .767]	< .001
$\lambda_{3,1}$	.662	.073	[.517, .807]	< .001
$\lambda_{4,1}$	.659	.067	[.527, .791]	< .001
Volatility				
$\lambda_{5,2}$	.740	.050	[.642, .838]	< .001
$\lambda_{6,2}$	.740	.051	[.640, .841]	< .001
$\lambda_{7,2}$	.734	.059	[.618, .850]	< .001
$\lambda_{8,2}$	.732	.057	[.619, .845]	< .001
Compassion				
$\lambda_{9,3}$	.575	.043	[.490, .660]	< .001
$\lambda_{10,3}$	.577	.045	[.489, .666]	< .001
$\lambda_{11,3}$	.734	.059	[.618, .850]	< .001
$\lambda_{12,3}$	.732	.057	[.619, .845]	< .001
Politeness				
$\lambda_{13,4}$	.429	.048	[.334, .524]	< .001
$\lambda_{14,4}$	.432	.043	[.347, .518]	< .001
$\lambda_{15,4}$	.434	.055	[.324, .543]	< .001
$\lambda_{16,4}$	.421	.057	[.309, .534]	< .001
Industriousness				
$\lambda_{17,5}$	.604	.065	[.474, .733]	< .001
$\lambda_{18,5}$	.612	.062	[.491, .734]	< .001
$\lambda_{19,5}$	.609	.083	[.445, .774]	< .001
$\lambda_{20,5}$	.609	.082	[.447, .771]	< .001
Orderliness				
$\lambda_{21,6}$	.534	.077	[.381, .687]	< .001
$\lambda_{22,6}$	.515	.079	[.358, .671]	< .001
$\lambda_{23,6}$	.518	.090	[.341, .695]	< .001
$\lambda_{24,6}$	.532	.091	[.352, .712]	< .001
Enthusiasm				
$\lambda_{25,7}$	.623	.076	[.474, .773]	< .001
$\lambda_{26,7}$	.612	.081	[.451, .773]	< .001
$\lambda_{27,7}$	.616	.096	[.425, .807]	< .001
$\lambda_{28,7}$	.596	.116	[.367, .824]	< .001
Assertiveness				
$\lambda_{29,8}$	.629	.049	[.533, .725]	< .001
$\lambda_{30,8}$	.627	.050	[.529, .726]	< .001
$\lambda_{31,8}$	.630	.063	[.506, .755]	< .001
$\lambda_{32,8}$	.625	.062	[.503, .746]	< .001
Openness				
$\lambda_{33,9}$	.530	.061	[.409, .651]	< .001

Table 4-8 (continued)

$\lambda_{34,9}$	.517	.065	[.389, .644]	< .001
$\lambda_{35,9}$	.533	.080	[.375, .690]	< .001
$\lambda_{36,9}$	.538	.075	[.391, .686]	< .001
Intellect				
$\lambda_{37,10}$	.520	.046	[.431, .610]	< .001
$\lambda_{38,10}$	.525	.045	[.435, .614]	< .001
$\lambda_{39,10}$	.525	.055	[.418, .633]	< .001
$\lambda_{40,10}$	.530	.059	[.414, .647]	< .001
Regressions				
Withdrawal regressed on:				
$\gamma_{1,1}$: Age	-.021	.005	[-.030, -.011]	< .001
$\gamma_{1,2}$: Sex	-.325	.109	[-.539, -.110]	.003
$\gamma_{1,3}$: MTD	.637	.159	[.326, .947]	< .001
$\gamma_{1,4}$: PVH	.377	.234	[-.082, .835]	.108
Volatility regressed on:				
$\gamma_{2,1}$: Age	-.002	.005	[-.011, .007]	.728
$\gamma_{2,2}$: Sex	-.366	.105	[-.573, -.160]	< .001
$\gamma_{2,3}$: MTD	.377	.152	[.079, .674]	.013
$\gamma_{2,4}$: PVH	.343	.227	[-.101, .787]	.130
Compassion regressed on:				
$\gamma_{3,1}$: Age	.002	.005	[-.008, .011]	.730
$\gamma_{3,2}$: Sex	-.627	.109	[-.841, -.413]	< .001
$\gamma_{3,3}$: MTD	.055	.155	[-.249, .358]	.723
$\gamma_{3,4}$: PVH	-.060	.231	[-.512, .393]	.794
Politeness regressed on:				
$\gamma_{4,1}$: Age	.009	.005	[-.001, .019]	.090
$\gamma_{4,2}$: Sex	-.605	.124	[-.849, -.362]	< .001
$\gamma_{4,3}$: MTD	-.377	.212	[-.793, .039]	.075
$\gamma_{4,4}$: PVH	-.878	.285	[-1.438, -.319]	.002
Industriousness regressed on:				
$\gamma_{5,1}$: Age	.010	.005	[.001,] .019	.033
$\gamma_{5,2}$: Sex	.068	.108	[-.144, .279]	.532
$\gamma_{5,3}$: MTD	-.522	.158	[-.831, -.213]	.001
$\gamma_{5,4}$: PVH	-.288	.234	[-.746, .170]	.218
Orderliness regressed on:				
$\gamma_{6,1}$: Age	-.004	.005	[-.014, .006]	.428
$\gamma_{6,2}$: Sex	-.333	.116	[-.559, -.106]	.004
$\gamma_{6,3}$: MTD	-.162	.167	[-.489, .165]	.331
$\gamma_{6,4}$: PVH	.081	.245	[-.400, .561]	.742
Enthusiasm regressed on:				
$\gamma_{7,1}$: Age	-.005	.005	[-.015, .004]	.251
$\gamma_{7,2}$: Sex	-.417	.111	[-.635, -.199]	< .001
$\gamma_{7,3}$: MTD	-.082	.159	[-.394, .230]	.608
$\gamma_{7,4}$: PVH	.255	.236	[-.208, .717]	.281

Table 4-8 (continued)

Assertiveness regressed on:				
$\gamma_{8,1}$: Age	-.008	.005	[-.017, .001]	.097
$\gamma_{8,2}$: Sex	-.001	.108	[-.212, .209]	.990
$\gamma_{8,3}$: MTD	-.198	.156	[-.504, .109]	.206
$\gamma_{8,4}$: PVH	.334	.233	[-.124, .791]	.153
Openness regressed on:				
$\gamma_{9,1}$: Age	-.008	.005	[-.018, .001]	.087
$\gamma_{9,2}$: Sex	-.314	.113	[-.535, -.092]	.006
$\gamma_{9,3}$: MTD	-.083	.162	[-.400, .234]	.608
$\gamma_{9,4}$: PVH	-.143	.242	[-.617, .331]	.555
Intellect regressed on:				
$\gamma_{10,1}$: Age	.002	.005	[-.008, .011]	.724
$\gamma_{10,2}$: Sex	.109	.110	[-.106, .324]	.320
$\gamma_{10,3}$: MTD	-.520	.161	[-.836, -.205]	.001
$\gamma_{10,4}$: PVH	-.232	.237	[-.697, .234]	.330
Latent Disturbance Covariances				
Withdrawal and:				
$\psi_{2,1}$: Volatility	.770	.026	[.719, .822]	< .001
$\psi_{3,1}$: Compassion	.005	.053	[-.098, .108]	.924
$\psi_{4,1}$: Politeness	-.178	.059	[-.294, -.062]	.003
$\psi_{5,1}$: Industriousness	-.674	.035	[-.743, -.605]	< .001
$\psi_{6,1}$: Orderliness	-.176	.064	[-.301, -.050]	.006
$\psi_{7,1}$: Enthusiasm	-.425	.048	[-.518, -.331]	< .001
$\psi_{8,1}$: Assertiveness	-.445	.046	[-.535, -.354]	< .001
$\psi_{9,1}$: Openness	-.069	.062	[-.190, .052]	< .001
$\psi_{10,1}$: Intellect	-.442	.047	[-.535, -.350]	.261
Volatility and:				
$\psi_{3,2}$: Compassion	-.096	.051	[-.195, .003]	.058
$\psi_{4,2}$: Politeness	-.404	.051	[-.504, -.304]	< .001
$\psi_{5,2}$: Industriousness	-.514	.041	[-.594, -.435]	< .001
$\psi_{6,2}$: Orderliness	-.147	.062	[-.269, -.025]	.018
$\psi_{7,2}$: Enthusiasm	-.252	.050	[-.351, -.154]	< .001
$\psi_{8,2}$: Assertiveness	-.116	.052	[-.217, -.015]	.025
$\psi_{9,2}$: Openness	-.117	.057	[-.230, -.005]	< .001
$\psi_{10,2}$: Intellect	-.341	.047	[-.433, -.248]	.041
Compassion and:				
$\psi_{4,3}$: Politeness	.568	.047	[.475, .660]	< .001
$\psi_{5,3}$: Industriousness	.175	.051	[.074, .275]	.001
$\psi_{6,3}$: Orderliness	.232	.053	[.128, .336]	< .001
$\psi_{7,3}$: Enthusiasm	.612	.038	[.537, .687]	< .001
$\psi_{8,3}$: Assertiveness	.273	.049	[.176, .370]	< .001
$\psi_{9,3}$: Openness	.494	.045	[.407, .582]	< .001
$\psi_{10,3}$: Intellect	.402	.047	[.311, .493]	< .001

Table 4-8 (continued)

Politeness and:				
$\psi_{5,4}$: Industriousness	.343	.057	[.231, .455]	< .001
$\psi_{6,4}$: Orderliness	.389	.059	[.273, .505]	< .001
$\psi_{7,4}$: Enthusiasm	.249	.059	[.134, .364]	< .001
$\psi_{8,4}$: Assertiveness	-.166	.059	[-.281, -.051]	.005
$\psi_{9,4}$: Openness	.188	.062	[.067, .310]	.002
$\psi_{10,4}$: Intellect	.179	.059	[.064, .294]	.002
Industriousness and:				
$\psi_{6,5}$: Orderliness	.625	.048	[.530, .720]	< .001
$\psi_{7,5}$: Enthusiasm	.294	.052	[.193, .395]	< .001
$\psi_{8,5}$: Assertiveness	.423	.046	[.332, .514]	< .001
$\psi_{9,5}$: Openness	.026	.060	[-.092, .145]	.661
$\psi_{10,5}$: Intellect	.444	.046	[.353, .535]	< .001
Orderliness and:				
$\psi_{7,6}$: Enthusiasm	.126	.058	[.013, .239]	.029
$\psi_{8,6}$: Assertiveness	.149	.057	[.038, .261]	.009
$\psi_{9,6}$: Openness	.007	.060	[-.110, .124]	.909
$\psi_{10,6}$: Intellect	.112	.058	[-.001, .225]	.053
Enthusiasm and:				
$\psi_{8,7}$: Assertiveness	.545	.042	[.463, .627]	< .001
$\psi_{9,7}$: Openness	.366	.053	[.262, .470]	< .001
$\psi_{10,7}$: Intellect	.346	.050	[.248, .444]	< .001
Assertiveness and:				
$\psi_{9,8}$: Openness	.371	.050	[.272, .469]	< .001
$\psi_{10,8}$: Intellect	.642	.037	[.570, .714]	< .001
Openness and:				
$\psi_{10,9}$: Intellect	.613	.044	[.527, .699]	< .001
Residual Indicator Variances				
Withdrawal				
ϵ_1	.247	.062	[.124, .370]	< .001
ϵ_2	.251	.059	[.136, .367]	< .001
ϵ_3	.395	.094	[.209, .582]	< .001
ϵ_4	.375	.072	[.232, .518]	< .001
Volatility				
ϵ_5	.182	.039	[.105, .260]	< .001
ϵ_6	.185	.044	[.098, .271]	< .001
ϵ_7	.286	.062	[.164, .408]	< .001
ϵ_8	.287	.063	[.163, .410]	< .001
Compassion				
ϵ_9	.169	.035	[.099, .238]	< .001
ϵ_{10}	.174	.038	[.099, .248]	< .001
ϵ_{11}	.240	.055	[.130, .349]	< .001
ϵ_{12}	.250	.056	[.139, .360]	< .001
Politeness				
ϵ_{13}	.253	.055	[.145, .361]	< .001

Table 4-8 (continued)

ϵ_{14}	.259	.046	[.168, .350]	< .001
ϵ_{15}	.406	.085	[.237, .574]	< .001
ϵ_{16}	.406	.095	[.219, .593]	< .001
Industriousness				
ϵ_{17}	.212	.042	[.129, .295]	< .001
ϵ_{18}	.215	.047	[.122, .307]	< .001
ϵ_{19}	.333	.073	[.188, .477]	< .001
ϵ_{20}	.329	.073	[.185, .473]	< .001
Orderliness				
ϵ_{21}	.245	.074	[.098, .392]	.001
ϵ_{22}	.277	.091	[.096, .458]	.003
ϵ_{23}	.407	.145	[.120, .695]	.006
ϵ_{24}	.381	.098	[.187, .575]	< .001
Enthusiasm				
ϵ_{25}	.241	.079	[.085, .396]	.003
ϵ_{26}	.235	.068	[.099, .370]	.001
ϵ_{27}	.354	.095	[.167, .541]	< .001
ϵ_{28}	.357	.099	[.160, .553]	< .001
Assertiveness				
ϵ_{29}	.222	.058	[.107, .338]	< .001
ϵ_{30}	.223	.058	[.109, .338]	< .001
ϵ_{31}	.327	.081	[.166, .488]	< .001
ϵ_{32}	.336	.091	[.156, .516]	< .001
Openness				
ϵ_{33}	.245	.073	[.101, .388]	.001
ϵ_{34}	.248	.075	[.098, .397]	.001
ϵ_{35}	.364	.096	[.174, .554]	< .001
ϵ_{36}	.364	.094	[.179, .550]	< .001
Intellect				
ϵ_{37}	.194	.053	[.090, .299]	< .001
ϵ_{38}	.196	.045	[.107, .286]	< .001
ϵ_{39}	.304	.081	[.144, .464]	< .001
ϵ_{40}	.296	.078	[.142, .451]	< .001

Table 4-9 Abridged pooled parameter estimates of the metatrait, domain, and aspect models. To compare the differences between the phonotraumatic vocal hyperfunction (PVH) and muscle tension dysphonia groups (MTD), the same three models were estimated using the MTD group as the contrast.

Parameter	Estimate	SE	95% CI [LL, UL]	*p*-value
Metatraits				
Stability regressed on:				
Age	.010	.005	[.001, .019]	.029
Sex	-.101	.107	[-.312, .109]	.345
Control	.525	.153	[.225, .826]	.001
PVH	.077	.260	[-.433, .587]	.766
Plasticity regressed on:				
Age	-.006	.005	[-.015, .003]	.157
Sex	-.204	.106	[-.412, .003]	.053
Control	.280	.152	[-.018, .578]	.066
PVH	.377	.262	[-.136, .891]	.150
Domains				
Neuroticism regressed on:				
Age	-.011	.005	[-.020, -.002]	.015
Sex	-.370	.105	[-.575, -.164]	< .001
Control	-.528	.151	[-.825, -.231]	< .001
PVH	-.143	.259	[-.655, .363]	.574
Agreeableness regressed on:				
Age	.005	.005	[-.004, .015]	.258
Sex	-.693	.111	[-.912, -.475]	< .001
Control	.129	.168	[-.200, .458]	.444
PVH	-.318	.272	[-.851, .215]	.241
Conscientiousness regressed on:				
Age	.004	.005	[-.005, .014]	.350
Sex	-.129	.110	[-.344, .086]	.240
Control	.397	.157	[.089, .704]	.012
PVH	.257	.268	[-.267, .782]	.337
Extraversion regressed on:				
Age	-.007	.005	[-.017, .002]	.112
Sex	-.240	.108	[-.451, -.029]	.025
Control	.162	.154	[-.140, .464]	.294
PVH	.494	.266	[-.027, 1.015]	.063
Openness/Intellect regressed on:				
Age	-.004	.005	[-.013, .006]	.448
Sex	-.110	.109	[-.323, .103]	.311
Control	.335	.157	[.028, .642]	.033
PVH	.134	.269	[-.392, .660]	.618

Table 4-9 (continued)

Aspects				
Withdrawal regressed on:				
Age	-.021	.005	[-.030, -.011]	< .001
Sex	-.325	.109	[-.539, -.110]	.003
Control	-.637	.159	[-.947, -.326]	< .001
PVH	-.260	.271	[-.791, .271]	.337
Volatility regressed on:				
Age	-.002	.005	[-.011, .007]	.728
Sex	-.366	.105	[-.573, -.160]	< .001
Control	-.377	.152	[-.674, -.079]	.013
PVH	-.034	.261	[-.546, .478]	.898
Compassion regressed on:				
Age	.002	.005	[-.008, .011]	.730
Sex	-.627	.109	[-.841, -.413]	< .001
Control	-.055	.155	[-.358, .249]	.723
PVH	-.115	.268	[-.640, .409]	.667
Politeness regressed on:				
Age	.009	.005	[-.001, .019]	.090
Sex	-.605	.124	[-.849, -.362]	< .001
Control	.377	.212	[-.039, .793]	.075
PVH	-.501	.298	[-1.086, .084]	.093
Industriousness regressed on:				
Age	.010	.005	[.001, .019]	.033
Sex	.068	.108	[-.144, .279]	.531
Control	.522	.158	[.213, .831]	.001
PVH	.234	.270	[-.296, .764]	.387
Orderliness regressed on:				
Age	-.004	.005	[-.014, .006]	.428
Sex	-.333	.116	[-.559, -.106]	.004
Control	.162	.167	[-.165, .489]	.331
PVH	.243	.280	[-.306, .792]	.386
Enthusiasm regressed on:				
Age	-.005	.005	[-.015, .004]	.251
Sex	-.417	.111	[-.635, -.199]	< .001
Control	.082	.159	[-.230, .394]	.608
PVH	.336	.273	[-.198, .870]	.217
Assertiveness regressed on:				
Age	-.008	.005	[-.017, .001]	.097
Sex	-.001	.108	[-.212, .209]	.990
Control	.198	.156	[-.109, .504]	.206
PVH	.531	.269	[.003, 1.059]	.049
Openness regressed on:				
Age	-.008	.005	[-.018, .001]	.087
Sex	-.314	.113	[-.535, -.092]	.006
Control	.083	.162	[-.234, .400]	.608

Table 4-9 (continued)

PVH	-.060	.279	[-.607, .487]	.830
Intellect regressed on:				
Age	.002	.005	[-.008, .011]	.724
Sex	.109	.110	[-.106, .324]	.320
Control	.520	.161	[.205, .836]	.001
PVH	.289	.274	[-.249, .826]	.292

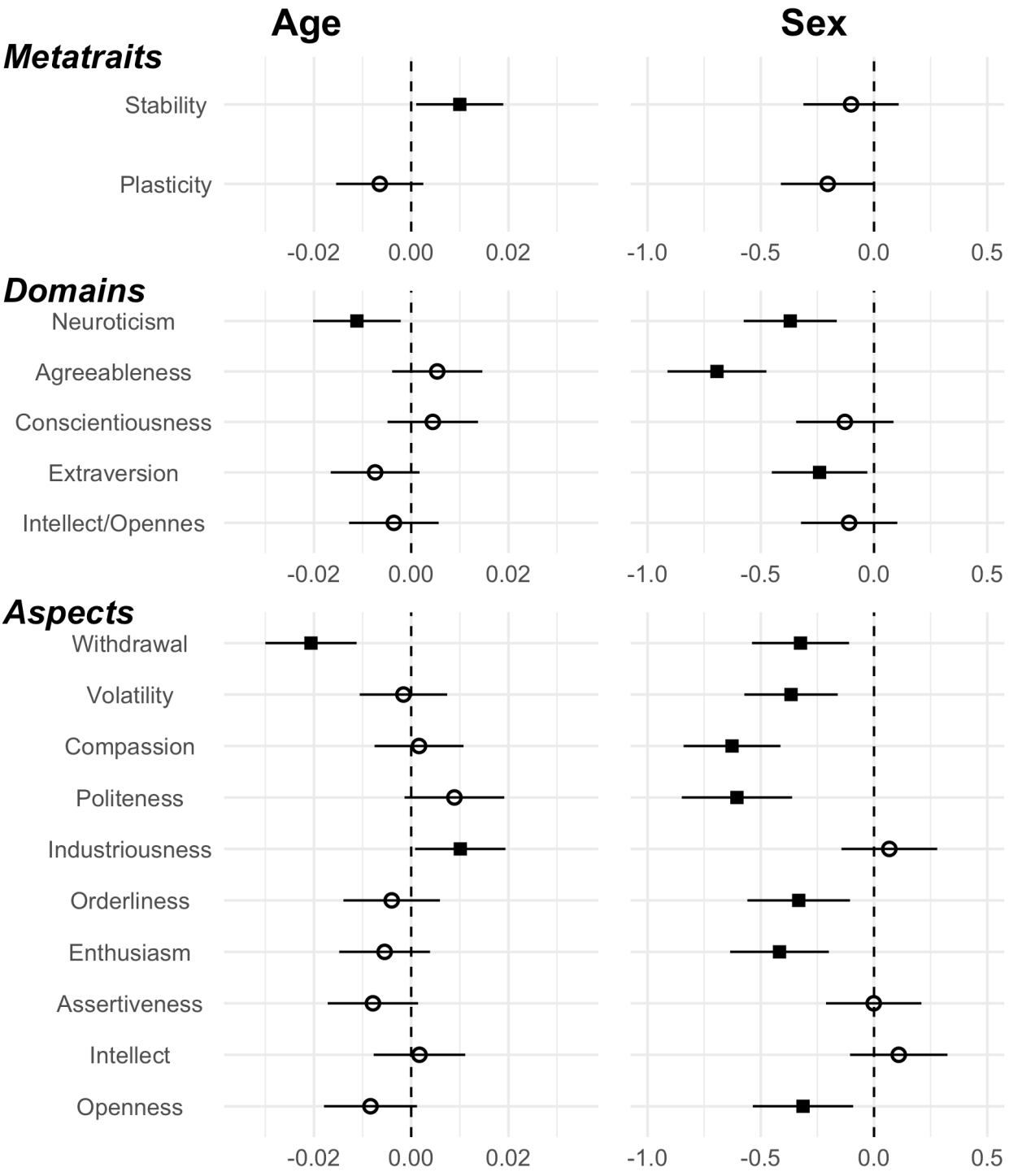


Figure 4-6 Dot and whisker plots for age and sex parameter estimates. Dots correspond to the regression coefficient across each of the metatrait, domain, and aspect models. Circles = NS; squares = $p < .05$; solid lines = 95% confidence intervals.

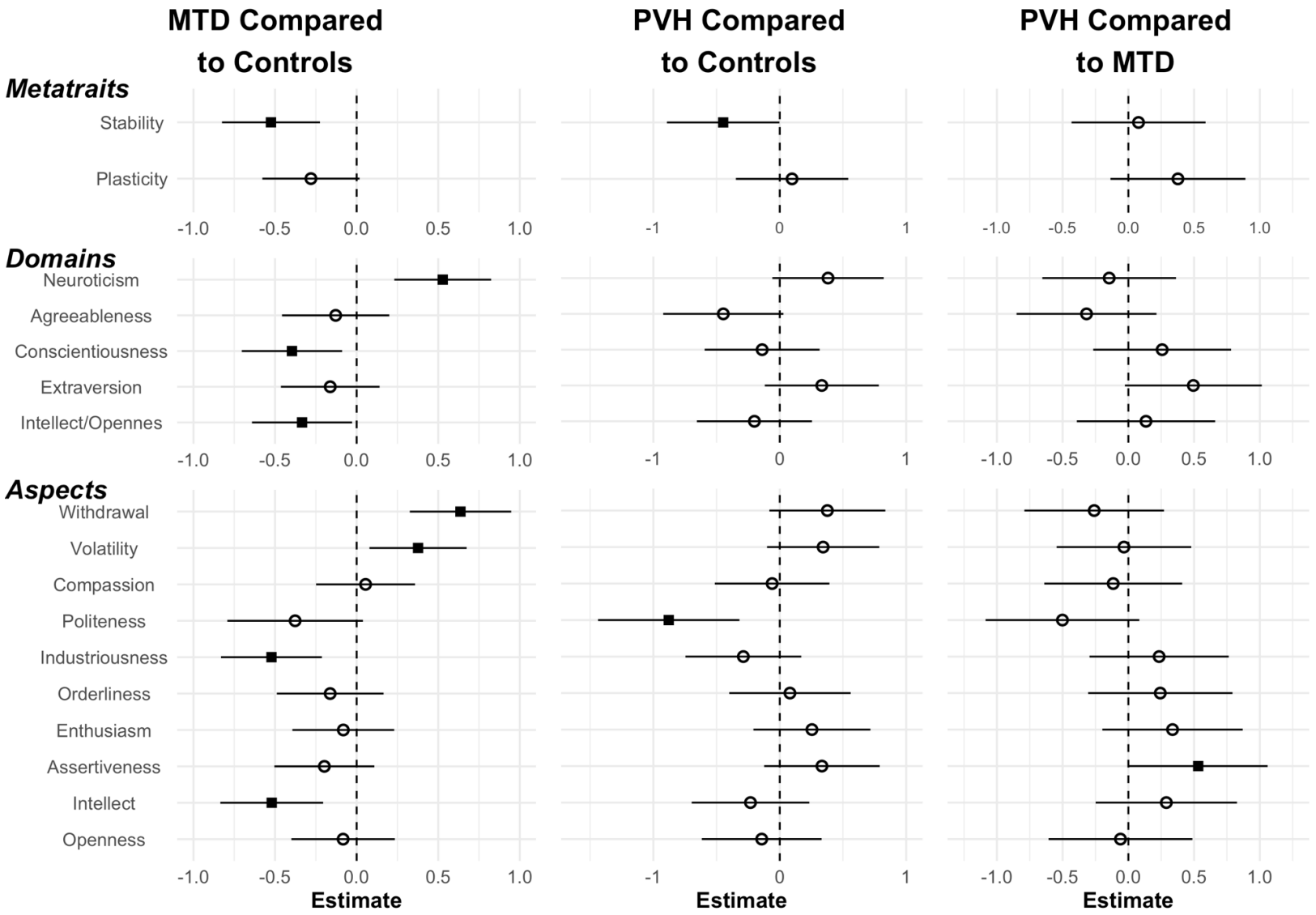


Figure 4-7 Dot and whisker plots for cohort parameter estimates. Dots correspond to the regression coefficient across each of the metatrait, domain, and aspect models. Circles = NS; squares = $p < .05$; solid lines = 95% confidence intervals.

4.3.4 Hypothesized Group Differences

These results support our first hypothesis that the MTD group would score higher on Neuroticism and its aspects compared to controls. The MTD group reported significantly higher levels of Neuroticism (γ = .526, 95% CI [.229, .823], p = .001), Withdrawal (γ = .625, 95% CI [.313, .938], p < .001) and Volatility (γ = .374, 95% CI [.076, .672], p = .014). Our results do not support our second hypothesis that the MTD group would score lower on Extraversion and its aspects compared to controls. The MTD did not differ significantly on Extraversion (γ = -.162, 95% CI [-.464, .140], p = .294), Enthusiasm (γ = -.082, 95% CI [-.394, .230], p = .608), or Assertiveness (γ = -.198, 95% CI [-.504, .109], p = .206).

Similarly, these results did not support our third hypothesis that the PVH group would score higher on Volatility compared to the controls. The PVH group had a higher, but not significantly different score on Volatility (γ = .343, 95% CI [-.101, .787], p = .130). These data also do not support the fourth hypothesis that the PVH group would report higher levels of Extraversion and its aspects compared to the controls. The PVH group reported higher, but not significantly different scores on Extraversion (γ = .332, 95% CI [-.119, .784], p = .149), Assertiveness (γ = .334, 95% CI [-.124, .791], p = .153), and Enthusiasm (γ = .255, 95% CI [-.208, .717], p = .281).

The current results also did not support our fifth hypothesis that the PVH group would report lower scores on Conscientiousness and its two aspects. Compared to the controls, the PVH group did not report significantly different scores on Conscientiousness (γ = -.139, 95% CI [-.595, .316], p = .548), Industriousness (γ = -.288, 95% CI [-.746, .170], p = .218), or Orderliness (γ = .081, 95% CI [-.400, .561], p = .742). These results partially supported our final hypothesis, that the PVH group would report higher scores on Extraversion and its aspects compared to the MTD group. The PVH group did not score significantly higher on Extraversion (γ = .494, 95% CI [-.027, .1.015], p = .063) or Enthusiasm (γ = .336, 95% CI [-.198, .870], p = .217) compared to the MTD participants. However, the PVH group reported significantly higher scores on Assertiveness (γ = .531, 95% CI [.003, .1.059], p = .049).

4.4 Discussion

The current study re-investigated the TTVD by examining personality trait differences in adults with MTD and PVH. In addition to replicating the TTVD, this study provides a unique contribution to the literature by integrating contemporary theories, perspectives, and evidence in voice and personality science. Specifically, we adopted Hillman et al.'s (2020) *Updated Framework of Vocal Hyperfunction* to investigate both non-phonotraumatic and phonotraumatic vocal hyperfunction. Additionally, we leveraged the CB5T and its corresponding personality battery to examine a hierarchically arranged FFM of personality.

Although other studies have examined a FFM in adults with voice disorders, relatively few exist (e.g., Amir et al., 2023). Likewise, Verduckt et al. (2019) examined one level of the FFM in a cohort of children with VFNs. Notably, Lee et al. (2021) examined multiple levels of the FFM in children with VFNs but did not use a measure based in a larger theory of personality. We note these points not to discredit previous work, but to highlight the careful, deliberate attempt to advance our understanding of these relationships by integrating current theories and evidence in voice and personality science.

Finally, the analytic approach in the current study departed from the stepwise regression methods used in many of the previous studies. To our knowledge, this study is one of the first to use SEM to investigate personality differences in voice disorders. With this method, we used three MIMIC models to examine each level of the personality trait hierarchy while controlling for age and sex. The following paragraphs interpret these results and their partial support for the hypothesized group differences.

4.4.1 Age and Sex Differences

For the current study, we sought to examine personality differences while controlling for age and sex. Both age and sex are known to meaningfully relate to a variety of the personality traits. Because these results are not central to the main purpose of the paper and most of the participants were vocally healthy controls (n = 416), we will briefly review

these results and contextualize them within previous studies investigating age and sex differences.

Personality traits are relatively stable over time, but continually change across the lifespan (see Roberts & Nickel, 2021 for review). Roberts et al. (2006) conducted a meta-analysis and demonstrated the following general trends. Extraversion increases the most during young adulthood and declines as we age (specifically the facet of Social Vitality). Similarly, Neuroticism also declines (i.e., more emotional stability) as people get older. Both Agreeableness and Conscientiousness generally increase with age, and Openness to Experience increases as we age, but then begins to decline after our 60's.

The findings in our sample generally support these previously published trends, though not all the relationships are statistically significant. Industriousness was positively associated with age, while Withdrawal and Neuroticism were inversely associated with age. Stability, the shared covariance between Neuroticism (reversed), Agreeableness, and Conscientiousness, also demonstrated a positive association with age.

Similarly, we also found several trait differences across the sexes. Weisberg et al. (2011) studied sex differences on personality traits with the BFAS in 2,643 people (892 men, 1751 women). Remarkably, our findings are almost identical to the sex differences reported in their study. In the current sample, men scored significantly lower in Withdrawal, Volatility, Compassion, Politeness, Orderliness, Enthusiasm, and Openness. Likewise, at the domain level, men scored lower in Neuroticism, Agreeableness, and Extraversion. No differences existed for Industriousness, Conscientiousness, or Intellect/Openness in either study. Only two results from their study differ from our findings. Weisberg et al. (2011) reported that men were significantly higher on Assertiveness and Intellect; however, our results do not indicate any differences on these two variables. The authors did not report sex differences for the metatraits; our results do not reveal any differences on these traits.

Many previous investigations into voice disorders and personality traits have recruited only (presumably cisgender) women. The authors of these studies generally justify this decision as voice disorders are more common in women, with a preponderance of 3:1 for MTD and 1.8:1 for PVH (Aronson & Bless, 2009; Herrington-Hall et al., 1988). However,

examining these relationships in men and women and controlling for known personality trait sex differences may prove more useful to understand the veridical relationships between personality traits and voice disorders. While some recent studies control for both age and sex (e.g., Amir et al., 2023), not all studies control for these variables (e.g., Josep et al., 2024) despite recruiting men and women. Age and sex are two important confounding personality variables that need to be considered when designing and consuming future research in this area.

4.4.2 Group Personality Differences

4.4.2.1 Muscle Tension Dysphonia

The TTVD proposed that the people with MTD have high Neuroticism and low Extraversion. While Roy et al.'s (2000a, 2000b) results supported this claim, our results only partially match their findings. We found that the MTD group reported significantly higher scores for Neuroticism and its two aspects, Withdrawal and Volatility, but not Extraversion or its aspects, Enthusiasm and Assertiveness. Our findings are similar to Josep et al. (2024), who reported that individuals with voice disorders reported significantly higher Neuroticism but not significantly lower Extraversion. These authors also reported that a significant interaction existed between Neuroticism and Extraversion for the voice disorder group, and they concluded that their findings support Roy et al. (2000a, 2000b). However, we interpret their conclusions with caution, as insufficient information is provided to assess the validity of their methods.

Across several studies, individuals with MTD report significantly higher levels of Neuroticism and its lower order aspect- and facet-level traits. This pattern of findings is consistent with extant literature that implicates, in part, stress as a contributing factor to the pathogenesis and maintenance of MTD. Individuals higher in Neuroticism are more likely to experience negative emotions; higher levels of Withdrawal are associated with anxiety and depression, and higher levels of Volatility relate to increased emotional lability (DeYoung et al., 2016). The Psychobiological Framework of Stress and Voice (Dietrich & Abbott, 2008)

describes how prolonged stress and/or inadequate stress recovery leads to a cascade of physiological effects that may result in more laryngeal tension. Previous laboratory stress paradigms demonstrate that vocally healthy women exhibit increased extrinsic and intrinsic laryngeal muscle activity during acute physical, cognitive, and psychosocial stressors (Dietrich & Abbott, 2014; Dietrich & Verdolini Abbott, 2012; Helou et al., 2013, 2018, 2020).

Likewise, Dahl & Stepp (2023) reported that both vocally healthy participants and participants with vocal hyperfunction exhibited increased acoustic measures of laryngeal tension during a cognitive stressor. Unexpectedly, the two groups did not display any differences on these measures to the stressor. If both vocally healthy individuals and people with vocal hyperfunction display the same phonatory changes due to a stressor, it stands to reason that individuals who experience more frequent and/or more severe stress and negative emotions may exhibit this increased laryngeal tension more often. This increased frequency may become habituated over time and result in MTD.

Although the relationship between MTD and Neuroticism-related traits is quite robust across studies, our results contribute to the mixed evidence about the relationship between MTD and Extraversion. Our results do not find significant differences on Extraversion, Enthusiasm, or Assertiveness for the MTD group compared to the controls. Likewise, Josep et al. did not find meaningful difference on Extraversion (Table 1 in Josep et al., 2024). These results are inconsistent with Roy et al. (2000a, 2000b) that found the MTD group was lower on the EPQ's Extraversion and the MPQ's Well-being, Social Potency, and Social Closeness (three of the four facets of Positive Emotionality). Notably, the MTD group did not show a significant difference on the domain of Positive Emotionality (Roy et al., 2000b).

Together, these findings demonstrate robust evidence for a relationship between Neuroticism (and its lower-order traits) and MTD. However, the relationships between MTD and low Extraversion appear to be less robust. Speculatively, age might be a factor that could explain this discrepancy in the current study and Roy et al. (2000a, 2000b). In their studies, Roy et al. recruited a sample of 45 women with an average age of 49 years (*SD* = 13.3, range 22-79). In the current sample, we recruited men and women with an average age

of 39.17 (*SD* = 12.69, *Med* = 37, range 19-60). We controlled for age (and sex) in our analyses, whereas Roy et al. (2000a, 2000b) did not find that age was a significant covariate and thus did not control for it in their analyses. Importantly, our sample average is almost a decade younger with an upper range of 60 compared to Roy et al.'s (2000a, 2000b) upper range of 79. As mentioned previously, Extraversion tends to decline with age (Roberts et al., 2006; Roberts & Nickel, 2021). The lower levels of Extraversion in Roy et al. (2000a, 2000b) may, in part, be due to sampling variability and the sample's age.

4.4.2.2 Phonotraumatic Vocal Hyperfunction

The TTVD asserts that individuals with PVH will report higher levels of Neuroticism and Extraversion. This theory also proposed that the combination of high Neuroticism and high Extraversion would lead to "the impulsive behavior of neurotic extraverts," and that these individuals would also score lower on Constraint (Roy & Bless, 2000b, p. 476). The notion that adults with PVH report elevated Neuroticism has received relatively less empirical support. Toles et al. (2021) did not find a significant relationship between Negative Emotionality and PVH in a cohort of singers, though singers tend to have higher levels of Neuroticism (Heller et al., 2015). Yano et al. (1982) also did not find a difference in Neuroticism between the PVH and control groups.

In the current study, we did not find a significant difference between the PVH and control groups for Neuroticism or its aspects. The PVH group reported higher levels of Neuroticism, Withdrawal, and Volatility, but none of these differences were statistically significant, mirroring the results presented by Roy et al. (2000a, 2000b). Roy et al. (2000b) found that the PVH group reported higher levels of Stress Reaction (after being rank transformed) and Aggression.

Translating these findings to a FFM framework, the MPQ's Stress Reaction and Aggression facets are most closely related to high Neuroticism and low Agreeableness, respectively (Church, 1994; Gaughan et al., 2009). As already mentioned, the current study did not find any significant differences on Neuroticism or its facets. However, our results indicate that the PVH group scored significantly lower on Politeness compared to the

controls, an aspect of Agreeableness. This finding is consistent with Roy et al.'s (2000b) results that the PVH group demonstrated higher Aggression on the MPQ.

Across the current study and Roy et al. (2000a, 2000b), the results demonstrate a pattern of elevated, but not-quite-significant levels of Neuroticism and its lower-order traits for the PVH group compared to controls. It may be that the aspect of Politeness better captures these group differences, which is negatively correlated with Neuroticism and its aspects (DeYoung et al., 2007). Alternatively, this pattern of findings may indicate that a meaningful relationship between PVH and Neuroticism exists, but that the effect size of this difference is relatively small and would require a larger sample to be adequately powered to detect this difference. Future work is necessary to better understand the extent to which Neuroticism meaningfully relates to PVH.

The TTVD also states that people with PVH would also have higher levels of Extraversion. Again, the empirical evidence supporting this claim is mixed. Yano et al. (1982) found that the PVH group demonstrated significantly higher levels of Extraversion. Similarly, Mattei et al. (2017)[14] reported that their PVH group demonstrated higher levels of Novelty Seeking, which they argue is related to Extraversion.

Unlike these studies, the current PVH group reported elevated, but not statistically different, levels of Extraversion and its aspects compared to the controls. This finding may, again, be an issue relating to statistical power due to the relatively small sample of participants with PVH (n = 26). Alternatively, these results are consistent with Roy et al. (2000a, 2000b) that did not find any significant differences between the PVH group on domain-level Extraversion or Positive Emotionality. They did find that their PVH group was significantly higher on Social Potency, a facet of Positive Emotionality. Toles et al. (2021) also found that singers with PVH scored higher on Social Potency and not the broader domain of Positive Emotionality. These findings suggest that Social Potency may more readily differentiate people with PVH from controls.

[14] Mattei et al. (2017) used a personality battery that measured a seven-factor structure of personality, which will not be discussed in the current manuscript.

Viewing these previous findings through a FFM, Social Potency has a strong positive association with Assertiveness and a moderate negative association with the domain Agreeableness, particularly the facets of Straightforwardness, Modesty, and Tendermindedness (Church, 1994; Gaughan et al., 2009). These three facets of Agreeableness load strongly onto the BFAS' Politeness (DeYoung et al., 2007). We found that the PVH group scored significantly lower compared to the controls on Politeness.

Although the TTVD proposed that, people with PVH would score higher on Neuroticism and Extraversion, the MPQ's corresponding lower-order facets of Aggression and Social Potency appear to better distinguish these groups. Both Aggression and Social Potency exhibit negative correlation with Politeness (Church, 1994; DeYoung et al., 2007; Gaughan et al., 2009). Our current results demonstrate that the PVH group reports almost an entire standard deviation lower on Politeness compared to the controls. This finding moves away from the so-called "neurotic extravert" hypothesis and provides novel insight into personality features that may be associated with developing PVH.

Additionally, the MPQ's Positive Emotionality facet Social Potency demonstrates a strong positive relationship with Assertiveness (Gaughan et al., 2009). In the current study, the aspect Assertiveness did not distinguish the PVH group from the controls. However, the PVH group scored significantly higher on Assertiveness compared to the MTD cohort. This finding replicates Roy et al. (2000b), which found that the PVH group scored higher on the Social Potency compared to the MTD group. These findings appear to suggest that Assertiveness itself might not be a risk factor, but in the context of chronic vocal hyperfunction, individuals higher in Assertiveness may experience PVH rather than MTD.

Finally, the TTVD also proposed that individuals with PVH would score lower on Constraint / higher on Psychoticism compared to controls. Roy et al (2000a, 2000b) found evidence to support these relationships and that the PVH group reported lower levels of Control compared to the controls. Toles et al. (2021) also reported that singers with PVH demonstrated significantly lower levels of Control compared to controls but not on the higher-order Constraint.

Our results do not replicate these findings. Constraint and its facet of Control are both strongly positively associated with Conscientiousness (Church, 1994; Gaughan et al., 2009). In the current sample, we did not find any differences between the PVH group and the healthy control on Conscientiousness or its corresponding aspects, Industriousness and Orderliness. Although Gaughan et al. (2009) report that Constraint has weak positive associations with Agreeableness and the facet of Politeness, the strengths of these associations are considerably smaller than the relationship between Constraint and Conscientiousness. While it is possible that the original differences found between the PVH and control groups on Constraint might load onto the Politeness aspect, the current study is not equipped to test this association.

So far, we have discussed our findings as they relate to the six proposed hypotheses. These hypotheses were developed to both test the original personality differences described in the TTVD, as well as re-examine the results of Roy et al. (2000a, 2000b) through a five-factor personality framework. These results demonstrate partial support for the relationships outlined by the TTVD, and generally align with the results of Roy et al. (2000a, 2000b) when examined through a different factor structure.

Our study found that individuals with MTD scored significantly higher on Neuroticism and its aspects, Withdrawal and Volatility, consistent with the TTVD and Roy et al. (2000a, 2000b). In contrast to the TTVD and Roy et al. (2000a, 2000b), we do not find evidence to suggest that individuals with MTD report lower levels of Extraversion or its aspects, Enthusiasm and Assertiveness. The TTVD predicted that individuals with PVH would report higher levels of Neuroticism and Extraversion. Roy et al. (2000a, 2000b) did not find evidence to support this claim; however, they did find that individuals with PVH scored higher on Aggression and Social Potency. In the current study, although the PVH group scored higher than controls on Neuroticism, Extraversion, and the corresponding aspects, none of these traits were significantly higher. Of particular interest, the PVH group scored significantly lower on Politeness compared to controls, a trait that maps onto Aggression and Social Potency. The trait of Aggression also maps onto Assertiveness; while Assertiveness did not differentiate the PVH from controls, the PVH group reported significantly higher scores than

the MTD group. Finally, our results do not find any differences on Conscientiousness or its aspects, Industriousness and Orderliness, for the PVH group, as suggested by the TTVD and Roy et al. (2000a, 2000b). In addition to these results, this study found additional, unexpected group differences between the cohorts. The following section reviews these results and provides potential explanations for these findings.

4.4.3 Additional Group Differences

The previous section described the results of the hypothesized group differences. In addition to these hypotheses, the results of our models also identified significant differences that were not anticipated. Compared to the controls, both the MTD and PVH groups demonstrated significantly lower Plasticity. To our knowledge, this finding represents the first time these highest-order traits of the FFM hierarchy have been examined in individuals with a voice disorder.

While a full review of the CB5T is beyond the scope of the current paper (see DeYoung, 2015), we briefly review some of its basic tenants to help interpret these findings. Within the CB5T, the metatraits relate to self-regulation and an individual's characteristic adaptations (i.e., interpretations, strategies, and goals). Colloquially, characteristic adaptations can be loosely thought of as one's "identity," or sense of self. The CB5T describes Stability as the trait that helps to maintain one's characteristic adaptations from disruption, while Plasticity is the trait that allows an individual to alter or develop new characteristic adaptations. Stability is defined as the shared variance of Neuroticism (reversed), Agreeableness, and Conscientiousness, and it is theoretically associated with global levels of serotonin. Conversely, Plasticity is defined as the shared variance of Extraversion and Openness/Intellect, and it is theoretically associated with global levels of dopamine (Allen & DeYoung, 2016; DeYoung, 2010, 2013; DeYoung et al., 2021).

Higher levels of Stability are associated with higher levels of behavioral restraint and maintaining goal-directed psychological functioning (DeYoung, 2015; Hirsh et al., 2009). Conversely, low Stability is "associated with impulsivity and lack of self-control, with various

forms of distress, and, perhaps most relevantly, with a shaky sense of identity, direction, and social role" (Wilmot et al., 2016, p. 345). The lower levels of Stability across the two groups provides a novel insight that previous studies on personality and voice disorders have not investigated.

Understanding these higher order metatraits and their potential associations with voice disorders has important theoretical implications. First, these two metatraits relate to an individual's characteristic adaptations/identity. The field of Communication Science and Disorders is beginning to pay increasing attention to the role of identity as it relates to communication and well-being (Welch & Helou, 2022), successful voice therapy outcomes (Helou, 2017, 2019; Helou et al., 2021), fluency disorders (Daniels et al., 2023; Gore & Margulis, 2023), and augmentative and alternative communication (Wofford et al., 2022). People with voice disorders often describe a disrupted sense of self/identity. Understanding how these traits relate to patients with voice disorders has the potential to improve therapeutic targets and provide additional prognostic insight for patient outcomes (e.g., a person who more easily adapts their identity may more readily change their phonatory habits, resolving their voice disorder and preventing reoccurrence).

One possible interpretation of the lower Stability result in the voice disorder groups is that lower levels of Stability may predispose an individual to develop MTD or PVH. Previous studies have associated MTD with anxiety and depression (Dietrich et al., 2008; Marmor et al., 2016). It stands to reason that low Stability with various forms of distress (e.g., anxiety) and/or a shaky sense of identity may serve as a risk factor for developing MTD. Additionally, Wilmot et al. (2016) suggests that low Stability relates to low levels of self-monitoring. Some investigations into MTD and PVH find that these individuals display nontypical responses to sensorimotor tasks, possibly suggesting aberrant sensorimotor control might contribute to maladaptive phonatory behaviors that cause these disorders (Stepp et al., 2017; Ziethe et al., 2019).

Alternatively, this finding of lower Stability could also be explained as a result of the experience of having a voice disorder. As previously mentioned, many patients describe a disrupted sense of self due to their voice disorder. This disruption may be exacerbated by

long wait times to be seen in a specialty voice disorder clinic. Many patients must wait weeks or months before they are seen for an evaluation and/or voice therapy. This prolonged period of persistent dysphonia (and any resulting anxiety or distress) may disrupt a person's sense of self and lead to a lower score of Stability on a personality battery.

Ultimately, we cannot conclude any causality with these results. Yet, these findings highlight the importance and demonstrate the utility of investigating personality traits at different levels of the trait hierarchy. We did not propose any hypotheses around traits at this level, as we were unaware of any studies investigating these higher-order traits in voice disorders. Future work would benefit from continuing to study these higher order metatraits as they relate to voice disorders and voice therapy outcomes.

In addition to the unexpected differences at the level of the metatraits, these results also demonstrated group differences at the domain and aspect levels. In the current study, the MTD group reported significantly lower scores on the domains Conscientiousness and Openness/Intellect, and their corresponding aspects Industriousness and Intellect. While we hypothesized that the PVH group would report lower levels of Conscientiousness, we did not expect to see any differences in these traits for individuals with MTD.

A full review of the biological mechanisms associated with personality traits is beyond the scope of the current paper. However, the mechanisms associated with these traits may prove useful for future research. Conscientiousness is associated with the *goal priority network* in the brain and lower gray matter volume of the insula (Allen & DeYoung, 2016; DeYoung, 2010; DeYoung et al., 2021; Rueter et al., 2018). The current proposed theory is that the insula generates potentially distracting impulses, which is why lower volume of this structure is associated with higher levels of Conscientiousness. Kryshtopava et al. (2017) studied women with and without MTD using functional magnetic resonance imaging. They found that the MTD cohort displayed significantly higher levels of activation in the insula during phonation. They also reported that the MTD group displayed significantly lower levels of activation in the superior temporal gyrus and the medial temporal gyrus, two regions involved with self-monitoring vocalizations.

Together, these findings implicate interacting brain systems that may contribute to the pathogenesis of MTD. One of the key benefits of adopting the CB5T is its explicit aim of providing a mechanistic understanding of personality that is consistent with empirical personality neuroscience. By integrating this mechanistic understanding of personality traits, future research can generate testable hypotheses to advance our understanding of the pathogenesis and maintenance of vocal hyperfunction.

Additionally, we did not expect to see any differences on the Intellect or Openness/Intellect traits. Comparing the MPQ's three-factor structure with a FFM, the MPQ's Absorption scale most closely approximates the Openness/Intellect domain (Church, 1994; Gaughan et al., 2009). The Absorption scale was developed to assess hypnotic susceptibility (Tellegen & Atkinson, 1974), and was not discussed in the TTVD or Roy et al. (2000a, 2000b). When the Absorption scale has been reported, no differences have been found in voice disorders (Toles et al., 2021; van Mersbergen et al., 2008). Only Amir et al. (2023) has reported that their voice disorder cohort scored significantly lower on the domain Openness to Experience compared to their non-dysphonic sample; however, directly comparing this trait across different batteries can pose challenges.[15] Additionally, their participant sample included a wide range of voice disorders, many of which have not been previously associated with personality traits (e.g., sulcus, paresis, hyperemia). This heterogenous sample poses a challenge to comparing their results. From a mechanistic perspective, these traits have been associated with dopamine, the dorsolateral prefrontal cortex, and the frontoparietal control network (Allen & DeYoung, 2016; DeYoung et al., 2005, 2021). However, we are unaware of any investigations into MTD demonstrating that these mechanisms influence phonatory muscle pattern activation.

It is also worth noting that the current study is one of the first to report that the MTD group reported lower scores on Industriousness, Conscientiousness, Intellect, and/or

[15] Of the "Big Five" domains, much debate surrounds this personality trait, which limits our ability to directly compare these findings. Some personality batteries describe this fifth domain as Intellect, while other batteries label it Openness to Experience. When developing the BFAS, DeYoung (2007) specifically chose items that measured both Intellect *and* Openness, arguing that disagreements about this domain trait were due to researchers prioritizing different sub-traits within this domain – hence the label Intellect/Openness in the CB5T and BFAS.

Openness/Intellect. These findings may reflect natural sampling variability, and these results need to be replicated in multiple separate, larger samples before determining if these traits meaningfully vary for people with MTD. Without more rigorous work and/or sufficient theoretical rationale, we strongly caution against any interpretation or insinuation that individuals with MTD are somehow less industrious and/or intelligent.

4.4.4 Limitations and Recommendations for Future Research

We designed the current study to leverage contemporary personality science to re-examine our understanding of the relationships between voice disorders and personality traits. Although we used rigorous analytic methods to investigate these differences, the current study is not without its limitations. We will highlight some of the most important limitations of the current study and provide context and recommendations for future research to better understand these relationships.

4.4.4.1 Biases

As with any study, several types of bias likely exist that are worth noting. First, our sample likely contains a self-selection bias. Individuals who choose to participate in psychological studies may be more likely to report symptoms associated with personality disorders (Kaźmierczak et al., 2023). Although the recruitment flyer did not indicate that the study was focused on psychological processes, participants were informed that the study focused on psychological components during the informed consent. Second, we relied entirely on self-report measures, and participants might consciously or unconsciously respond in a manner that is more socially desirable (Bäckström & Björklund, 2013). Although participants were instructed that no "right" or "wrong" answer existed and to "go with [their] gut" when responding, social desirability bias may still be present. A key strength of the current study is its use of SEM, which accounts for measurement error. But we acknowledge that social desirability may still influence participants' responses.

Additionally, the participants with voice disorders were recruited after going through a voice evaluation and receiving a diagnosis. This process (which included laryngoscopy) may be very stressful and/or anxiety-provoking for some individuals. Likewise, we did not provide clinicians with a script or standardized procedure to avoid them being "engaged" in research (which would require a multi-site IRB). We instructed clinicians to perform their routine clinical procedures and to provide recruitment materials to individuals that met the inclusion/exclusion criteria. This approach has high external validity but allows for different practices that may inadvertently influence how participants responded to the survey (e.g., a clinician who calms down an anxious patient after receiving a diagnosis).

Furthermore, patients are generally poor historians; 25.30% reported not knowing their diagnosis. We relied heavily on clinicians to give people the correct flyer which directed participants to separate but identical surveys for each group. When discrepancies did arise, we reached out to participants to seek clarification. But without access to a participant's medical records, we are unable to independently confirm they were directed to the correct diagnostic grouping. We accepted this risk as we have high confidence in the clinicians at the voice centers we partnered with.

4.4.4.2 Sample Size, Statistical Power, and Replicability

Personality studies often have hundreds to thousands of participants. The current study sought to recruit a relatively large sample to examine personality trait differences between controls and patients diagnosed with MTD or PVH. Based on our *a priori* power analysis, we attempted to recruit at least 100 people per group by partnering with multiple voice disorder clinics around the country. However, despite our best efforts, the number of participants recruited was much smaller than desired. This small sample has some important implications for the results of this study, and we strongly advise that these results are interpreted with caution.

First, random samples inherently have variability between them. Generalizing this random sampling variation and concluding that these differences hold true in the broader population is problematic, especially when the samples used to inform these conclusions

are small and/or unrepresentative of the population. Second, the specific benefit of having large random samples is that the random variation reduces the effects of uncontrolled confounding variables. Although we attempted to recruit a geographically diverse sample of participants, most of the participants were recruited from a single voice disorder clinic. As a result, it is possible that uncontrolled confounding variables are contributing to these findings. For instance, a growing body of research shows meaningful personality differences between geographical location (Allik & McCrae, 2004; Ebert et al., 2022; Ren et al., 2020). Without large, diverse samples, researchers are unable to control for these confounding variables and risk drawing inaccurate or misleading conclusions.

Third, small participant samples are more likely to be underpowered to detect meaningful differences, especially if the effect size of these differences are small. Our results found that the PVH group reported elevated, but not significantly higher levels of Extraversion and its aspects. This finding contrasts Yano et al. (1982), who reported that the PVH group reported significantly higher levels of Extraversion. It is likely that their study was adequately powered to detect this effect with a sample of 97 participants compared to the 26 participants with PVH in the current study.

In addition to these important implications, we hope that this small sample size can serve as a learning opportunity for clinicians and researchers alike. Without recruiting larger samples to study the psychological processes relevant to voice disorders, we do our science a disservice when we make bold claims about these psychological processes from small samples. We encourage future clinicians and researchers to critically appraise results from small samples and be thoughtful about how findings from small samples may or may not generalize to the broader population. Likewise, we strongly encourage future psychological research into voice disorders to carefully consider sample size planning to ensure adequate power.

Similarly, the results of the current study underscore the importance of replication in the scientific process. Much of the research into personality traits and voice disorders since the TTVD was published has focused on different populations (e.g., singers, children). Undoubtedly, it is important to understand how these psychological processes may differ

across populations. Yet, replication remains an important, often overlooked step in the scientific process.

We concede that the current study is not an exact replication of the TTVD; we have integrated advances in personality theory (the Big Five), measures (BFAS), and analytic methods (SEM), as well as adopted Hillman et al.'s updated framework on vocal hyperfunction (2020). However, we neither intend nor wish for the current study to be the final verdict on the relationships between personality traits and voice disorders. We hope that future research will replicate this study, address the limitations described herein, provide better insight into the veridical nature of these relationships, and integrate advances in personality and voice science as appropriate.

4.4.4.3 Considerations for Future Research

Integrating recent theories and methods is only the first step in a larger programmatic line of research to study the relationships between personality traits and voice disorders. In the current study, we used a MIMIC modeling approach. This is an appropriate method to examine group differences that can generate similar findings to a multi-group SEM method (Thompson et al., 2023). However, using a MIMIC model assumes scalar invariance (i.e., factor loadings and intercepts are equal across groups). Future work would benefit from recruiting a larger sample size and using a multi-group SEM to test and account for measurement non-invariance. This issue may not be salient for personality items; but if psychopathologies (e.g., anxiety) are relevant to voice disorders, it is important to establish that we are measuring the same constructs in the same way across groups.

Future investigations that are unable to recruit a large sample size may benefit from a Bayesian framework instead of a frequentist approach. Bayesian methods are better suited for smaller sample sizes when using appropriate priors (McNeish, 2016). The current study did not use a Bayesian framework due to the relatively limited information about personality trait differences in these populations using a FFM and/or SEM. The results of the current study could be used to inform the prior distributions of future studies using a Bayesian framework, providing a viable route forward for small sample sizes.

Finally, longitudinal data are necessary to model psychological processes. While personality traits are relatively stable, current perspectives view personality traits as density distributions of states that exhibit meaningful variability across time and situations (DeYoung, 2015; Fleeson, 2001; Jayawickreme et al., 2019). This variation has important implications for our understanding of personality and its relationship to voice disorders. It remains possible that people with PVH are not necessarily higher in Neuroticism on average, but that they display a wider range of states over time (i.e., more variability). Longitudinal data are necessary to test these possibilities; without longitudinal data, researchers risk conflating intra-individual and inter-individual variability.

Despite our best attempts, this project highlights many of the challenges associated with recruiting a large, diverse sample of participants diagnosed with a voice disorder. We hope that these documented challenges encourage continued collaboration and facilitate new cooperation amongst clinicians and researchers in the field. Many voice clinicians readily accept the widespread clinical wisdom that psychological factors influence voice production. Yet, our ability to empirically study these interactions will continue to be impeded without large-scale, multi-site collaborations and a concerted effort to address the limitations outlined above.

Despite its limitations, the current study and its findings represent a meaningful contribution to our understanding of the relationships between personality traits and MTD and PVH. By adopting a contemporary, modern, and mechanistic theory of personality, we re-investigated the TTVD using a FFM of personality traits with more rigorous analytic methods. Our results are generally consistent with Roy et al. (2000a, 2000b) using a five-factor lens. Having replicated these previous findings, future work will be better suited to integrate additional recent personality research to generate and test novel hypotheses about these relationships.

While this study sought to address some of the discrepancies between the TTVD and recent personality literature, much more work is necessary to understand personality processes. In addition to the recommendations outlined above, we provide the following additional recommendations for researchers who may wish to help advance our

understanding of these relationships. First, our field must adopt contemporary theories in Personality Psychology. In addition to a comprehensive theory of personality like the CB5T, future investigations would benefit from carefully considering other theories relevant to personality and health outcomes, e.g., dynamic lifespan approaches instead of outdated health-behavior models (Friedman & Hampson, 2021).

Second, and related to the first, our field should adopt current, empirical, evidence-based perspectives on personality traits. Adopting these perspectives would help move the field away from discrete categories of personality (e.g., "Type A" or "Type D"). Likewise, it would behoove future research to move away from dichotomizing variables into "high"/"low" categories. Similarly, we should shift our focus away from the idea that people with MTD are "neurotic introverts" and that people with PVH are "neurotic extraverts." Not only is this labeling reductive and perpetuates a false notion of discrete personality boundaries, but evidence from multiple studies call into question this conceptualization.

Third, our field would benefit from careful consideration of personality batteries and analytic methods used to measure traits. Has the personality battery kept up with current trends in Psychology? What are the mathematical advantages and disadvantages of using a scale with a binary response versus a 5- or 7-point Likert response? Does empirical evidence support the purported factor structure of the chosen scale? For instance, although the Ten Item Personality Inventory provides a measure of the Big Five, its brevity results in "some serious limitations" (Gosling et al., 2003, p. 524). While administering a 100-item personality battery might not be feasible for clinical research, shorter measures of the FFM exist, including the 20-item Mini-IPIP (Donnellan et al., 2006) and two 40-item versions of the BFAS (Chou, 2023; Gallagher et al., 2022). These shorter, validated measures of the FFM of personality can be completed in a few minutes, administered to many patients with voice concerns, and help advance our understanding of personality's potential role in the pathogenesis and maintenance of MTD and PVH.

4.5 Conclusion

The current study expands upon prior literature by examining personality traits in individuals diagnosed with MTD or PVH. Previous literature has found meaningful personality trait differences across groups but has often examined personality traits through a three-factor trait model. With the current study, we largely replicated the findings of Roy et al. (2000a, 2000b) using a hierarchically arranged five-factor trait structure rooted in the CB5T, a comprehensive and mechanistic personality theory. The current study also differs from previous investigations through its use of SEM, a gold standard analytic framework regularly used in contemporary Personality Psychology research.

The current results demonstrate that, compared to controls, individuals with MTD report significantly higher levels of Neuroticism and its aspects, Withdrawal and Volatility. We did not find evidence that this group reported lower levels of Extraversion or its aspects, Enthusiasm and Assertiveness. Unexpectedly, we found that this group reported lower levels of Industriousness and Intellect, and their higher-order domains, Conscientiousness and Openness/Intellect, respectively.

Our results also found that individuals with PVH exhibited elevated levels of Neuroticism, Extraversion, and their corresponding aspects, but none of them were significantly higher compared to controls. However, the PVH group reported significantly lower levels of Politeness when compared to controls. Additionally, when compared to MTD, the PVH group reported significantly higher levels of Assertiveness. This constellation of findings corroborates many of the previous findings reported by Roy et al. (2000a, 2000b).

Finally, this study is among one of the first to examine personality trait differences in these groups at the highest level of the trait hierarchy. Both voice disorder groups reported significantly lower Stability compared to the controls. We discuss these findings, their implications, and provide several tangible next steps for future research. More work is necessary to better understand personality as a precipitating factor for developing vocal hyperfunction. Integrating contemporary personality science to study these relationships is an essential first step.

5.0 General Discussion

Many voice clinicians readily accept the widespread clinical belief that a bidirectional relationship exists between one's psyche and their voice. For instance, patients who develop a voice disorder often describe losing a sense of their identity. Conversely, a crack in one's voice while talking reveals the emotional state of a speaker. For centuries, philosophers and scientists from various cultures have speculated on the exact nature of the voice (Stemple et al., 2020). Despite the seemingly ubiquitous opportunities to observe the voice-psyche relationships, relatively little empirical evidence exists to understand the veridical nature of these relationships.

The previous chapters have focused on two components of the voice-psyche relationships, specifically communicative congruence and the relationships between personality and voice disorders. While other studies have investigated these relationships, the current body of work provides a novel, meaningful contribution to these lines of research by integrating modern theories, measures, and methods from Personality Psychology. As a result, these studies provide a solid foundation for future, more rigorous investigations into the voice-psyche relationships.

Chapters Two and Three examined communicative congruence and its relationship with depression. To our knowledge, Chapter Two represents one of the first investigations into the notion of CC. In a sample of 196 primarily cisgender adults, we found that CC was inversely related to depression, i.e., people who reported a sense of alignment between their sense of self and their voice and speech also reported less depression. Likewise, people who reported a sense of congruence reported less communicative dysphoria, or sense of emotional, motivational, cognitive, and behavioral dysregulation due to a perceived incongruence. We also found that these individuals scored higher on Plasticity, a personality trait that theoretically relates to how easily a person can update or adapt their sense of self. These results are consistent with our predictions based on the Cybernetic Big Five Theory of Personality (CB5T).

Chapter Three sought to replicate these initial findings in a separate, larger, more gender diverse sample of adults. However, we improved the rigor of this study by using structural equation modeling (SEM), which allowed us to measure latent variables and to model the hypothesized relationships between them. This study replicated many of our previous results and provided more nuanced understanding of these constructs and their relations to each other. As with the first study, people who reported more CC reported less communicative dysphoria and Plasticity significantly related to CC. Unlike the first study, CC did not directly relate to depression. Rather, this relationship was mediated by the severity of communicative dysphoria they reported, suggesting that experiencing a sense of incongruence may only relate to depression if they also experience a higher sense of dysphoria from the incongruence. These meaningful relationships existed for both the cisgender and transgender participants. This finding is consistent with the idea that these constructs reflect a more basic human desire to experience congruence, rather than an experience that is specifically unique to transgender/non-binary individuals.

We also found that the transgender/non-binary individuals reported significantly lower CC, which is consistent with anecdotal evidence that some (though not all) transgender/non-binary individuals experience less congruence with their voice and speech. Additionally, this group reported significantly lower levels of Stability. This was an unexpected finding that requires further investigation before forming any conclusions. Finally, Stability displayed a significant inverse relationship with Depression. This relationship was not included in the initial model but was added to improve the overall fit of the model. This finding is consistent with previous research demonstrating that Neuroticism (which inversely relates to Stability) is highly correlated with depression.

Together, Chapters Two and Three represent the most in-depth investigation into these constructs in vocally healthy adults. Future work is needed to examine the experience of CC and dysphoria in individuals with voice disorders. Additionally, future research is warranted to see how these constructs change over time because of behavioral voice intervention in individuals with voice disorders and transgender/non-binary people seeking

voice training. Future research would also benefit from further development and validation of items to probe CC and dysphoria.

Chapter Four re-investigated the Trait Theory of Voice Disorders with a five-factor personality trait structure based on a comprehensive and mechanistic theory of personality, the CB5T. We recruited 56 people with muscle tension dysphonia (MTD) and 26 people with benign lesions of the lamina propria, or phonotraumatic vocal hyperfunction (PVH), and compared their personality traits to a control group of 416 individuals. Unlike previous studies into personality traits and voice disorders, we again used SEM to compare group differences while controlling for age and sex.

Overall, our findings are relatively similar to Roy et al.'s (2000a, 2000b) results. Consistent with our hypothesis, the MTD group scored significantly higher on Neuroticism and its aspects, Withdrawal and Volatility. We did not find support for our hypothesis that the MTD group would be significantly lower on Extraversion or its aspects. The PVH group was not significantly higher on Neuroticism, Extraversion, or any of their respective aspects. While the PVH group displayed elevated levels on each of these traits, none of these differences were statistically significant. Roy et al. (2000a, 2000b) also found that this group demonstrated elevated, but not significantly higher levels of Neuroticism and Extraversion.

We also found that the PVH group reported significantly lower Politeness compared to controls. This result corroborates Roy et al. (2000b), who found the PVH group had higher levels of Social Potency and Aggression, two traits that are inversely correlated with Politeness. Social Potency also correlates with Assertiveness, and the PVH group in our study was significantly higher on Assertiveness compared to the MTD group, but not the controls. Unlike Roy et al.'s previous work, we did not find that the PVH group scored lower on Conscientiousness or its aspects, which are related to the Constraint and Control traits used in their study.

In addition to replicating many of Roy et al.'s previous findings using a five-factor model of personality, our study found unexpected group differences. Both the MTD and PVH groups scored significantly lower on the metatrait Stability. Our study is among one of the first to investigate differences in these voice disorders with these highest-order traits and

highlights the importance of investigating personality at different levels of the trait hierarchy. More work is necessary before it is clear if lower levels of Stability somehow serve as a risk factor for developing MTD or PVH, or if the lower levels of Stability are more reflective of a disrupted sense of identity due to the voice disorder.

Our results also demonstrated that the PVH group scored significantly lower in Conscientiousness, Industriousness, Openness/Intellect, and Intellect. Prior research has not documented meaningful relationships between these traits and MTD. It is unclear if these differences are due to sampling variability, or if these traits meaningfully differ in individuals with MTD. More work is necessary before a conclusion can be reached.

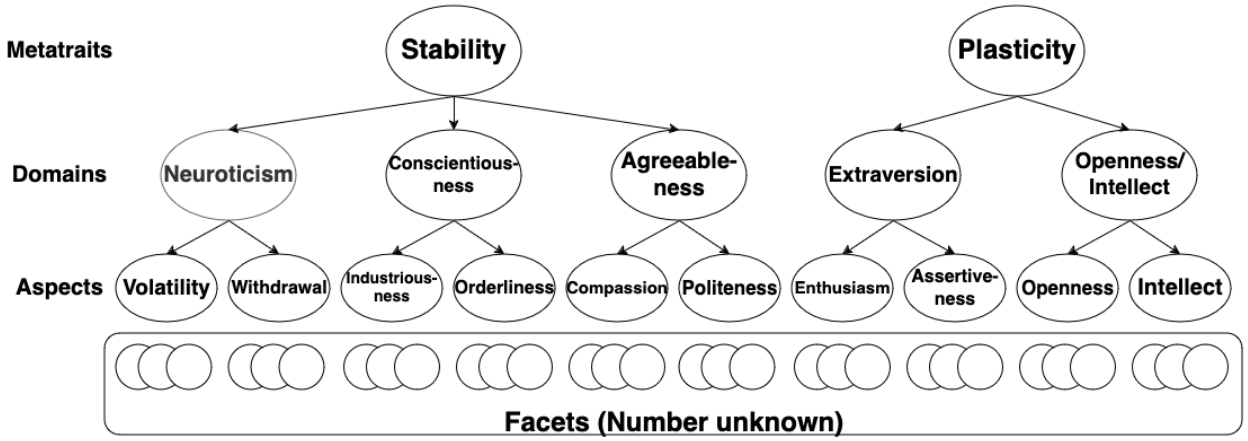
Across all three studies we adopted the CB5T, a modern, mechanistic, and comprehensive theory of personality to generate testable hypotheses regarding individual differences relevant to communication. We used the Big Five Aspect Scales, a personality battery rooted in the CB5T, to measure personality traits at different levels of the trait hierarchy. In the second and third study we used structural equation modeling to test our hypotheses, a powerful analytic technique routinely used to model and study psychological processes. Adopting this multivariate analytic framework provided an unprecedented examination of CC and a rigorous investigation into personality traits and voice disorders.

Together, these three studies sought to leverage contemporary personality science to examine the psychological aspects of voice and communication. While the results of these studies are promising, more work is necessary to fully understand these psychological processes. In addition to needing larger sample sizes, longitudinal data are necessary to model these processes and intra-individual variability. Without longitudinal data, our understanding of the psycho-social-vocal relationships will be limited.

Having integrated current theories, measures, and methods to examine both CC and the Trait Theory of Voice Disorders, we hope these studies will support future, more rigorous investigations into these relationships. By adopting best practices from Psychology, we will be better poised to investigate the psychological phenomena relevant to voice, communication, and their disorders. With this improved understanding, clinicians and

scientists will be able to improve our ability to assess, treat, and prevent certain disorders, while also improving outcomes and patients' psychosocial well-being.

Appendix A Personality Trait Definitions



Appendix Figure 1 Personality Trait Hierarchy in the Cybernetic Big Five Theory of Personality

Below are quotes from DeYoung (2015) that provide more information about each of the personality traits in the Cybernetic Big 5 Theory. More detailed information about each trait's role in the cybernetic mechanism of personality is also available in the same article. Additional information relating to the Big Five Aspects Scales can be found in DeYoung et al. (2007).

Stability – "reflects variation in the control mechanisms that prevent the cybernetic system from being disrupted by emotional impulses." (p. 47)

> **Neuroticism** – "individual differences in the tendency to experience negative emotions — anxiety, depression, irritability, anger, shame, etc." (p. 43)
>
> > **Withdrawal** – "the tendency toward both anxiety and depression. ''Withdrawal'' is a potentially misleading label because it does not refer to social withdrawal specifically, but rather to the automatic withdrawal of

motivation, either partially or completely, from particular strategies or goals, in response to uncertainty." (p. 44)

Volatility – "the tendency to be emotionally labile and to get upset, irritated, or angry easily and, thus, appears to reflect individual differences in the tendency toward active defense." (p. 44)

Agreeableness – "the general tendency toward cooperation and altruism, as opposed to exploitation and lack of concern for others." (p. 46)

Compassion – "relatively automatic emotional processes, including empathy, caring, and concern for others." (p. 46)

Politeness – "restraint of aggression and other rude behavior and seems likely to involve more voluntary top-down control than does Compassion." (p. 46)

Conscientiousness – "reflects variation in the mechanisms that allow people to follow rules and prioritize non-immediate goals." (p. 45)

Industriousness – "self-discipline and the tendency to work hard and effectively without being distracted before tasks are completed." (p. 45)

Orderliness – "neatness, perfectionism, and attention to rules." (p. 45)

Plasticity – "the general tendency toward exploration, with exploration defined as the creation of new goals, interpretations, and strategies." (p. 47)

Extraversion – “will predict who is more motivated by the possibility of attaining a given reward and who gets more enjoyment out of a reward when attained. The theory that Extraversion reflects reward sensitivity is reasonably well supported.” (p. 42)

> **Enthusiasm** – “the tendency toward gregarious social interaction and positive emotions, reflects wanting to some extent but is primarily a reflection of liking, the enjoyment experienced on receiving or imagining a reward.” (p. 42)
>
> **Assertiveness** – “the tendency toward drive, social status, and leadership, is a reflection of wanting — that is, motivation to attain desired goals.” (p. 42)

Openness/Intellect – “individual differences in cognitive exploration, the tendency to seek, detect, appreciate, understand, and utilize both sensory and abstract information.” (p. 44)

> **Openness** – “linked to implicit learning, automatic detection of patterns in sensory experience.” (p. 45)
>
> **Intellect** – “the aspect that encompasses IQ, and it has also been associated with working memory — manipulation of information in conscious attention — which appears to be the cognitive process that most contributes to intelligence.” (p. 45)

Appendix B Additional Information for Chapter 2

Appendix B.1 Instructions to Online Participants

While creating their account on cannonicalvoice.com, participants filled out an electronic consent form. In this consent form they were given the following instructions:

1. You will be asked to create a profile and enter a code to join the study.
2. You will begin by filling out questionnaires that ask questions about you, your demographic information, your personality, moods, depression and self-harm, and preferences. These can typically be completed in 20-40 minutes.
3. You will use your personal device (e.g., personal computer, phone) to audio record your speech during various tasks, such as reading short sentences, describing a picture, and producing brief vowel sounds.
4. You will be asked to play back your speech sample and will be asked a short series of questions about it.
5. Because we will ask questions about your mental health, you will receive a link to a list of mental health resources in the event that you have concerns about your well-being.

Appendix B.2 Instructions for Speech Sample

During the speech recording tasks, each task was displayed one at a time. Participants were provided the following instructions:

- Sustained vowel:
    - Please ensure you are in a quiet environment.
    - Say “ah” for 3-5 seconds at a comfortable volume and pitch.
- CAPE-V:
    - Please ensure you are in a quiet environment.
    - In your natural speaking voice, read the following sentences:
        - [CAPE-V sentences]
- Months of the year:
    - Please ensure you are in a quiet environment.
    - Recite the months of the year.
- Rainbow passage:
    - Please ensure you are in a quiet environment.
    - Read the following paragraph at a comfortable volume and pitch:
        - [Rainbow passage]
- How to make a peanut butter and jelly sandwich:
    - Please ensure you are in a quiet environment.
    - Describe how to make a peanut butter and jelly sandwich.
- Picture description:
    - Please ensure you are in a quiet environment.
    - Describe what is going on in this picture.
        - [Cookie Theft picture (Miro Inc. in Berube et al., 2019)]

Appendix B.3 Model Results for Fixed Effect of Online Participation

All models were run with a fixed effect of whether the data were collected in-person or online. Because the mode of data collection was not significant in any of the models, the data presented in the paper treated the data collected in-person versus online in the same cohort. Statistics for the fixed effect of online data collection are shown below. The following formula is used as a shorthand for the models: Y ~ X. CC = communicative congruence.

Appendix Table 1 Fixed effect regression parameter estimates.

Predictor Variable	In-person v. Online Coefficient Estimate	*t*-value	*p* value
CC ~ Communicative Euphoria	.12	.88	.38
Depression ~ CC	.05	.27	.79
CC ~ Stability	.15	.88	.38
CC ~ Plasticity	.10	.62	.54
CC ~ Neuroticism	.15	.87	.39
CC ~ Withdrawal	.13	.76	.45
CC ~ Volatility	.13	.73	.47
CC ~ Agreeableness	.09	.53	.60
CC ~ Compassion	.08	.43	.67
CC ~ Politeness	.09	.52	.60
CC ~ Conscientiousness	.13	.74	.46
CC ~ Industriousness	.14	.81	.42
CC ~ Orderliness	.10	.61	.54
CC ~ Extraversion	.10	.17	.57
CC ~ Enthusiasm	.10	.56	.57
CC ~ Assertiveness	.09	.56	.58
CC ~ Intellect/Openness	.10	.57	.57
CC ~ Intellect	.12	.69	.49
CC ~ Openness	.09	.52	.60

Appendix C Equation for Hypothesized Model in Chapter 3

The path diagram in Figure 3-5 represents the final hypothesized model after including the suggested modifications. This figure can also be expressed mathematically.

The equation representing the exogenous variable (a binary variable for whether a person identifies as transgender/non-binary or cisgender) is expressed as:

$$x_1 = 1 * x_1 + 0$$

The expanded notation for the endogenous variables is:

$$\begin{bmatrix} y_1 \\ \vdots \\ y_7 \\ \vdots \\ y_{13} \\ \vdots \\ y_{16} \\ \vdots \\ y_{20} \end{bmatrix} = \begin{bmatrix} \gamma_{1,1} & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \gamma_{7,2} & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \gamma_{13,3} & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 1 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \gamma_{20,4} \end{bmatrix} [\eta_1 \quad \eta_2 \quad \eta_3 \quad y_{16} \quad \eta_4] + \begin{bmatrix} \epsilon_1 \\ \vdots \\ \epsilon_7 \\ \vdots \\ \epsilon_{13} \\ \vdots \\ 0 \\ \vdots \\ \epsilon_{20} \end{bmatrix}$$

The expanded notation for the structural model is:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ y_{16} \end{bmatrix} = \begin{bmatrix} \gamma_{1,1} \\ \gamma_{2,1} \\ \gamma_{3,1} \\ \gamma_{4,1} \\ \gamma_{5,1} \end{bmatrix} x_1 + \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \beta_{3,1} & \beta_{3,2} & 0 & 0 & 0 \\ 0 & \beta_{4,2} & \beta_{4,3} & 0 & \beta_{4,5} \\ 0 & 0 & \beta_{5,3} & 0 & 0 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ y_{16} \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \epsilon_4 \\ 0 \end{bmatrix}$$

Appendix D Equations for MIMC Models in Chapter 4

The path diagrams of the MIMIC models used to examine group difference of the metatraits, domains, and aspects in Figures 4-2, 4-3, and 4-4 can also be expressed mathematically.

For all three models, the condensed versions of the equations are the same, where the measurement model of the exogenous variables can be expressed as:

$$X = \Lambda_x \xi + \delta$$

The measurement model of the endogenous variables can be expressed as:

$$Y = \Lambda_y \eta + \epsilon$$

And the structural model can be expressed as:

$$\eta = \Gamma \xi + B\eta + \zeta$$

Since the exogenous predictor variables are all the same across the three models, the expand exogenous measurement model for all three MIMIC models is:

$$\begin{bmatrix} x_{1_{sex}} \\ x_{2_{age}} \\ x_{3_{MTD}} \\ x_{4_{PVH}} \end{bmatrix} = I_4 \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

where I_4 is a 4x4 identity matrix with 1s on the diagonal and 0s on the off diagonals.

Appendix D.1 Equations for the Metatrait Model

The measurement model for the endogenous variables for the metatrait model can be expressed as:

$$\begin{bmatrix} y_1 \\ \vdots \\ y_7 \\ \vdots \\ y_{12} \end{bmatrix} = \begin{bmatrix} \lambda_{1,1} & 0 \\ \vdots & \vdots \\ 0 & \lambda_{7,2} \\ \vdots & \vdots \\ 0 & \lambda_{12,2} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \vdots \\ \epsilon_7 \\ \vdots \\ \epsilon_{12} \end{bmatrix}$$

The structural model for the metatrait model can be expressed as:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} \gamma_{1,1} & \gamma_{1,2} & \gamma_{1,3} & \gamma_{1,4} \\ \gamma_{2,1} & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix}$$

Appendix D.2 Equations for the Domain Model

The measurement model for the endogenous variables for the domain model can be expressed as:

$$\begin{bmatrix} y_1 \\ \vdots \\ y_5 \\ \vdots \\ y_{20} \end{bmatrix} = \begin{bmatrix} \lambda_{1,1} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \lambda_{5,2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_{20,5} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \vdots \\ \eta_5 \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \vdots \\ \epsilon_5 \\ \vdots \\ \epsilon_{20} \end{bmatrix}$$

The structural model for the domain model can be expressed as:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \eta_4 \\ \eta_5 \end{bmatrix} = \begin{bmatrix} \gamma_{1,1} & \gamma_{1,2} & \gamma_{1,3} & \gamma_{1,4} \\ \gamma_{2,1} & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} \\ \gamma_{3,1} & \gamma_{3,2} & \gamma_{3,3} & \gamma_{3,4} \\ \gamma_{4,1} & \gamma_{4,2} & \gamma_{4,3} & \gamma_{4,4} \\ \gamma_{5,1} & \gamma_{5,2} & \gamma_{5,3} & \gamma_{5,4} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \end{bmatrix}$$

Appendix D.3 Equations for the Aspect Model

The measurement model for the endogenous variables for the aspect model can be expressed as:

$$\begin{bmatrix} y_1 \\ \vdots \\ y_5 \\ \vdots \\ y_{40} \end{bmatrix} = \begin{bmatrix} \lambda_{1,1} & 0 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \lambda_{5,2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \lambda_{40,10} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \vdots \\ \eta_{10} \end{bmatrix} + \begin{bmatrix} \epsilon_1 \\ \vdots \\ \epsilon_5 \\ \vdots \\ \epsilon_{40} \end{bmatrix}$$

The structural model for the aspect model can be expressed as:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \\ \vdots \\ \eta_{10} \end{bmatrix} = \begin{bmatrix} \gamma_{1,1} & \gamma_{1,2} & \gamma_{1,3} & \gamma_{1,4} \\ \gamma_{2,1} & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} \\ \gamma_{3,1} & \gamma_{3,2} & \gamma_{3,3} & \gamma_{3,4} \\ \vdots & \vdots & \vdots & \vdots \\ \gamma_{10,1} & \gamma_{10,2} & \gamma_{10,3} & \gamma_{10,4} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \vdots \\ \zeta_{10} \end{bmatrix}$$

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